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INTRODUCTION:

CURRENT AND FUTURE CHELLENGES TO ENERGY SECURITY

- the just transition -

The Italian Association of Energy Economists - AIEE (Italian affiliate of the IAEE - The International Association for Energy Economics) has organized this international conference in cooperation with the *LUMSA University* to bring together energy experts engaged in academic, business, government, international organizations for an exchange of ideas and experiences on the present and future landscape of energy security.

The first three editions of the *AIEE Symposium on Energy Security* - Milan 2016 (Bicocca University), Rome 2017 (LUMSA University), Milan 2018 (Bocconi University), were an opportunity to explore new energy trends, challenges and creative solutions for the energy security, the availability of new technologies, the emergence of new market conditions and of new market operators.
Following up on the success of the past editions this fourth AIEE Energy Symposium to provided a fresh look on the major forthcoming issues offering an excellent occasion to continue the dialogue and to share best practice and experience with delegates from all over the world.

The energy situation is evolving in Europe as well as in the rest of the world, where new actors, the emerging economies, are taking the leading role. Political developments in several areas of the globe (North Africa and Middle East, the Caspian region, ASEAN countries) are reshaping the geopolitical situation, generating some worries about the security of supply in the EU countries. The concept of energy security is undergoing a rapid transformation. In the past, geopolitics and the supply of oil and gas were the dominant factors determining energy security. Today, a broader and more complex spectrum of elements are interacting to both stabilize and threaten energy security.

The IEA defines energy security as "t*he uninterrupted availability of energy sources at an affordable price. Energy security has many aspects: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance*".

Energy security concerns relate to the robustness (sufficiency of resources, reliability of infrastructure, and stable and affordable prices); sovereignty (protection from potential threats from external agents); and resilience (the ability to withstand diverse disruptions) of energy systems.
The absolute majority of the countries of the world are vulnerable from at least one of these three perspectives. For most industrial countries, energy insecurity means import dependency and aging infrastructure, while many emerging economies have additional vulnerabilities such as insufficient capacity, high energy intensity, and rapid demand growth. In many low-income countries, multiple vulnerabilities overlap, making them especially insecure.

Oil and its products lack easily available substitutes in the transport sector, where they provide at least 90% of energy in almost all countries. Furthermore, the global demand for transport fuels is steadily rising, especially rapidly in Asian emerging economies. Disruptions of oil

supplies may thus result in catastrophic effects on such vital functions of modern states as food production, medical care, and internal security. At the same time, the global production capacity of conventional oil is widely perceived as limited. These factors result in rising and volatile prices of oil affecting all economies, especially low-income countries.
Vulnerabilities of electricity systems are not limited to power plants relying on imported fossil fuels.

Many countries using nuclear power are experiencing an aging of the reactor fleet and workforce, as well as difficulties in accessing capital and technologies to renew, expand, or launch new nuclear programs. If nuclear energy can address energy security challenges, it will only happen in a few larger and more prosperous economies.

The reliability of electricity supply is also a serious concern, especially in developing countries. Almost all countries associate enhanced energy security with higher diversity of energy sources (especially in the transport sector), lower energy intensity of national economies, and reduced import dependency by relying on domestic energy sources. International regimes fostering cooperation between exporters and importers of energy and interacting with global governance arrangements for climate change and energy access are important for achieving these energy security goals. Energy security under sustainable energy transitions will be determined by the dynamics of phasing out fossil fuels and their substitution by new energy sources, as well as by new technologies.

One of the EU's key tools for ensuring energy security is its regulatory framework.
While in the past the supply side was the dominant factor in energy security, with the critical element being the possibility of sourcing the products to produce electricity and provide mobility, now the energy security balance is changing.
Energy has come to be a vital part of Europe's economy and of modern lifestyles. We now expect secure energy supplies: uninterrupted availability of energy sources at affordable prices. We expect to find oil at the pumps, gas for heating and, in this computerized era, non–stop electricity, as the effects of blackouts have become too disruptive.

The EU has made great strides on regulations and infrastructure, but key energy security challenges remain for optimizing competitiveness and interconnections in the European energy market. The biggest barriers to an integrated and liberalized energy market in Europe are the uneven implementation of the Third Energy Package and the Energy Union Strategy across EU members states and infrastructure gaps in electricity and gas interconnectors.

The development of priority infrastructure projects, support for consistent implementation of EU rules, increased education for energy consumers, resolution of energy-related conflicts, and joint collaboration on funding mechanisms for European and global energy infrastructure are critical to European energy security and present the greatest opportunities for transatlantic cooperation.

Another aspect is the new challenges of the digital revolution that on one hand offers opportunities to improve efficiency, to have lower costs but on the other hand raises a whole new set of challenges and creates vulnerabilities we have never seen before so that energy is being viewed as a key part of national security.

While in the past the supply side was the dominant factor in energy security, with the critical element being the possibility of sourcing the products to produce electricity and provide mobility, now the energy security balance is changing.

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Elena Donnari, Coordinator Customers & Retail Markets – Market Integrity &Transparency Council of European Energy Regulators (CEER)
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Abstracts

Daniel R. Hill

DETERMINANTS OF HOUSEHOLD ENERGY EXPENDITURES IN AUSTRIA: A CASE USING EU SILC MICRODATA

Daniel R. Hill, Vienna University of Economics and Business

Overview

This paper examines the determinants of residential energy expenditures in Austra. The aim is two-fold: first, to identify the determinant factors of household energy expenditures, explore the regional differences therein, and further investigate differences in those factors between owner- and renter-occupied households; and second, to demonstrate the viability of microdata from the EU Statistics on Income and Living Conditions (SILC) to study energy-related policy issues in the residential sector. EU SILC microdata for Austria is presented as a case study, on which a conditional-demand mondel is regressed whereby annual energy expenditure per square meter is estimated as a function of occupancy type, housing characteristics, regional and socio-economic variables. Results imply that a number of socio-economic criteria have a significant influence on energy expenditure, independent of the fuel used for space heating, water heating, or cooking. Understanding the impact of different factors on energy expenditures and differences between types of household is necessary in designing target-oriented policy measures. Given the significance of the socio-economic variables provided by the SILC micro-data, this paper also successfully demonstrates the viability of EU SILC as an instrument to drive energy-related policy, although not without some caveats.

Methods

The EU SILC is an instrument that collects comparable, cross-sectional and longitudinal micro-data on income, poverty, social exclusion and living conditions in EU Member States. The dataset was selected because it provides descriptive variables on housing, demographics, socio-economic and financial characteristics on individuals and households in Member States. Around 6,000 households participate annually in the Austrian EU SILC survey; making is a nationally representative dataset. In 2012, Eurostat included a specialized module which collected data concerning housing conditions and, of particular interest, the types of fuel and heating systems of each household, as well as the annual energy costs. The study, therefore, is restricted to that survey year.

The model specifies the annual household energy expenditures per square meter as a function of the occupancy type, characteristics of the building in question, type of fuel, as well as socio-economic and regional characteristics. A multiple-linear regression model is estimated using ordinary least squares (OLS) with a logarithmic function form. Regression results were obtained from seven log-linear models corresponding to sample designs that differ in terms of their geographical coverage or occupancy type. The first model included all households that met the criteria (4,164 households); the second is restricted to Vienna only; the third, forth and fifth were restricted to regional areas corresponding to NUTS Level 1 regions in Austra (e.g. Eastern, Western and Southern Austria, respectively); and the sixth and seventh models examine owners and renters, separately. Furthermore, interaction analyses were conducted and reported.

Results[1]

Most housing characteristic variables have their expected impact of the dependent variables and are consistent across regional models. For example, detached and semi-detached dwellings are found to be 29 and 27% more costly than a multi-family building with 20 or more flats, respectively. The vintage (construction period) also has its expected impact: buildings built before 1919, for example, are 14% more expensive per square meter compared to those built between 2006-2010. In the Vienna-only model, however, building vintage is less significant – and interesting outcome, since nearly 40% of renters in Vienna live in a building built before 1919. Income elasticity ranges from 0.01-0.04, but is not statistically significant for households in Vienna. Contrary to expectations, however, the net effect of being an owner in Austria actually increases annual energy expenditures per square meter by 4%, significant at the 5% confidence level. There is an even greater 9% increase in energy outlays per square meter in the Vienna-excluded model, significance at the 1% confidence level. In the Vienna-only model, the effect is negative but statistically insignificant. As certain subgroups of owners may consume less energy than their renter counterparts due to non- investment in energy efficiency, a log-linear specification that adds interaction effects between the household variables and the binary Owner variable was regressed. The analysis shows that building type (especially detached and semi- detached) and disposable income exhibit interaction effects to a greater extent for owners than renters.

Conclusions

The aim of this paper was to examine the determinants of household energy expenditures and to explore regional differences and differences between owners and renters in the Austrian residential sector using EU SILC micro-data. Estimates derived from the regressions suggest that restricting the sample according to occupancy type indicates that building and socio-economic characteristics do not affect energy expenditure for owners to the same extent as renters. Interaction effects between occupancy type and the explanatory variables provide significant evidence of an interaction between the type of building and ownership. Furthermore, these results indicate that socio-economic criteria have a significant influence on energy outlays, especially income elasticities and household size, in addition to building characteristics and tenure.

Lastly, the study demonstrates the viability of the EU SILC in analysing household energy-related questions, particularly relating to the socio-economic characteristics of households. The instrument, however, is not without limitations. For example, the current study was restricted to survey year 2012 since Eurostat collected the necessary data within a specialized module, which was not repeated in subsequent years. This limitation prevents us from taking full advantage of the longitudinal design features of the SILC dataset. Furthermore, the dataset does not indicate for which energy usage the fuel is being used (i.e. space heating, water heating or cooking). On the other hand, the socio- economic data collected in the SILC survey could also allow for further research into areas such as fuel poverty, financial capacity to invest in energy efficiency measures, renewable energy usage, as well as fuel switching capability. Moreover, the national statistical offices of several Member States may have continued to collect energy- specific data; if this is the case, cross-national longitudinal analysis would be possible, providing an avenue for EU SILC micro-data analysis to inform residential energy policy.

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[1] Due to limited space, tables of the regression outout were not included; they will be provided upon request and in the full paper.

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Phuong M. Khuong

BOOSTING SOLAR ROOFTOP IN HOUSEHOLD BY FINANCIAL INCENTIVES – A COMPARISON ANALYSIS. A CASE STUDY IN VIETNAM

Phuong M. Khuong, Chair of Energy Economics, Karlsruhe Institute of Technology, Germany

Abstract

Finance policy plays an important role in establishing and promoting decentralized solar rooftop power market, where the payback time is calculated as around ten years. This paper focuses on analyzing the relationship between finance decision-making and the market benefit by examining the market's reaction to different financial changes. The paper considered the newborn market in Vietnam with four system models, four business models in the traditional financial supports including self-financed and debt finance and new financial supports including leasing and crowdfunding. The results show the favor financial decision of all parties in all cases are the 70% support of total investment, where the total market benefit would increase by 10%, customer benefit increases an average of 20% and investor benefit increases average 7%.

Index Terms—Solar rooftop market, Developing country, Promotion policy, Vietnam, Financing policy

Introduction

Solar energy is one of the key elements of sustainable development all over the world. The emerging countries have a chance to shorten the way to sustainable development by enhancing the contribution of solar energy in their energy supply. However, after ten to twenty years of effort, the government and the public are struggling to encourage more solar energy use (Fernando and Siani 2016). The main and tautology problem is lacking capital, policy support and awareness that is very often mentioned in other developing countries (Gaëtan Masson, Jose Ignacio Briano, Maria Jesus Baez 2016). The promising potential of decentralized solar power is more and more obvious since the accelerating development of renewable energy technologies (RETs) recently (International Renewable Energy Agency (IRENA) 2019, 2019) reduces investment for solar power to be even cheaper than fossil fuel. Therefore, a new window for developing solar power and create a potential for a competitive market for rooftop solar as well as the market become a profitable product in public views is opening.
As one of the emerging countries, the Vietnamese government sets out an ambitious plan with bold targets for solar by pushing household solar energy usage increasing 26% by 2030. To actualize the target, the government has proposed new Feed-in-Tariffs (FiTs) and detailed guidelines and requirement for rooftop solar projects in Vietnam in early 2019. In which, the government replaced the net metering payment mechanism for rooftop solar projects with a direct trading scheme under the regulation code 02/2019/QD-TTG. Thus, the State utility Vietnam Electricity Corporation (EVN) is now eligible to pay directly for the electricity getting from rooftop solar power sellers. The new scheme opens the way for buyers to directly purchase rooftop solar power and pay separately for the electricity they consume from the grid.

Under the Draft Decision, they defined four models for solar rooftop project, which have an installed capacity of 1MWp or less. “Whole power selling business” model is an on-grid system with generated electricity trading between the business owner and the state utility. “Consumption household” model is a bi-directional metering system or prosumer system, which produces and consumes solar power directly from the solar system and sells the excess electricity to the state utility.

"Direct power sale and purchase" model is an off-grid model, in which the generated power is traded between the owner and consumer without using state utility and facility. "Intermediary power sale and purchase" model is an on-grid business model, where the owners sell their solar electricity to the customer through the state utility.

To provide a suggestion for the government in encouraging household solar power, the paper will assess the financial aspect of the four types of the solar system, which are an off-grid system with battery backup, an on-grid system without battery, and self- owners and third party owners. Based on the current offer of providers, the new solar rooftop tariff and the prediction for solar technology by 2030, the paper attempts to calculate the change of payback period and internal rate of return (IRR) for all the
systems when the government's financial subsidies change. Moreover, since rooftop PV is a newborn market in Vietnam, the government need to improve their support incentives to encourage investment in various means. Learning from other pioneering countries in developing rooftop solar, this paper aims to exams the benefit changes of each market's entity with different financing option such as traditional financing instruments such as equity, debt financing and new financing instruments including leasing and crowdfunding

1. Determine business models

Method
Figure 1 illustrates the cash and power flows for all types of solar power model in Vietnam. There are three entities including consumers, state utility and investors in the market. Investors represent for the business company, which invests in installing a solar power system to generate electricity for trading without consuming. Consumers are residential customers, who are purchasing electricity for private use. Besides, state utility is the organization that provides and maintains the infrastructure for electricity use.

The responsibility for each party in the residential market is presented in table 1. In any business model, there are two parties negotiate a solar contract and earn financially benefit from the contract. In the WPSB model, the contract is signed between the investors and the utility. While in the CH model, the contract is between the customers and the utility. Customers in the CH model play both investor and consumer roles. PV system generates power can be easily directly consumed and the surplus power will be sold to the grid.

In the DPSP and IPSP model, the investors sign the electricity contract directly with their customers. However, in the DPSP model, the investors are responsible for all installation, operation, and transmission their PV system, while in the IPSP model, the Utility will take over the transmission responsible for them.

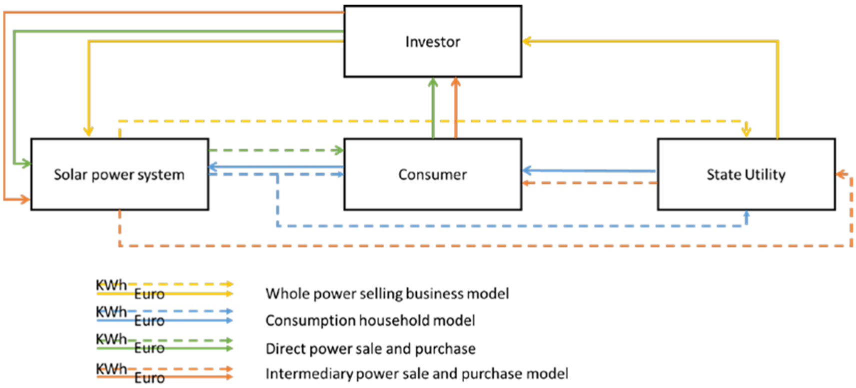

Figure 1. ***Solar Power Models with actual electricity flows in dotted line and cash flows in bold lines***

Table 1. ***Responsibilities of stakeholders in residential PV system model***

Model	Consumer	Investor	Utility
Whole power selling business (WPSB)		Owner	Transmission & Payment
Consumption household (CH)	Consume + Owner		Transmission & Payment
Direct power sale and purchase (DPSP)	Consume	Owner + Transmission + Payment	
Intermediary power sale and purchase (IPSP)	Consume	Owner + Payment	Transmission

2. Determine the system model

To calculate the correlation between each party's benefit with the government financial support changes, the paper investigates two typical PV systems are an off-grid and on-grid system at the residential scale. The off-grid system consists of PV generators, battery, converter, load regulator and switchboards, while the on-grid system includes PV generators, inverter, and meter (figure 2).

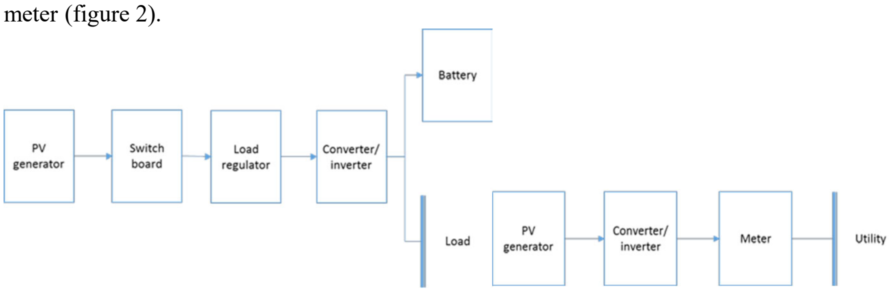

Figure 2. ***On-grid solar system*** *(on the left)* ***and off-grid solar system*** *(on the right)*

Because the average household area in Vietnam is around 60m^2 (Vietnam Government Statistical Office – GSO, 2018), the available rooftop area is suitable for installing PV panel in such houses is around 1 to 5 kWp with total PV panel area from 6-32 m^2 (Appendix 1).

Table 2 shows the technical parameters and the estimated investment and annual cost for the sample PV systems (further information in appendix 3). The current investment and cost are calculated based on the current technology and market price and charge provided by the whole sales and retailed sales in the market. The system cost includes investment cost or capital expenditure and the annual operation and maintenance costs (O&M), which are cleaning, electrical checks, inverter replacement cost, the insurance cost. The price for the system is the initial cost or the investment cost includes equipment cost and labor cost. Since solar radiation in Vietnam is differed significantly along with the country from North to South, the capacity utilization factors are estimated based on the radiation characteristic of four zones. The solar rooftop price is also distinguished by four zones (see table 2).

Table 2. ***Technical parameters and cost of the sample PV systems***

	System 1-a	**System 1-b**	**System 2-a**	**System 2-b**
Technical parameters				
Type	Off-grid	Off-grid	On-grid	On-grid
System size (kWp)	1	5	1	5
Plantlife (year)	25	25	25	25
Degradation factor %/year	0.5	0.5	0.5	0.5
Performance ratio (%)	80	80	80	80
Required space (m^2)	6	32	6	32
Capacity Utilization factor (%)				
Zone 1	14.5	14.5	14.5	14.5
Zone 2	17	17	17	17
Zone 3	18.5	18.5	18.5	18.5
Zone 4	20	20	20	20
Cost and expenses				
Investment cost (Euro/kWp)	1200	1000	1000	600
O&M first year (%)	3	3	3	3
Annual O&M (%)	0.65	0.65	0.65	0.65

3. Determine the financial model

The paper considers traditional financial models are self-financing and debt financing, which is common in any investing project and compares them with the new financial models including leasing and crowdfunding models to investigate the specific advantage and disadvantage of each model. The consumers, in any case, will be benefited by saving electricity bill when replacing partly the electricity drawn from the utility and they are partly prevented from the increasing electricity cost over the years by using solar electricity. While the investors receive benefit from selling their generated solar power. The utility or state will benefit from reducing financial effort investing in building a new power plant.

The paper analyzes different cases of the debt-financing model including 30% and 70 % loans at 8% and 10% interest. The cases are built based on the government-financing program for the solar power project. This program has been prepared to approve for solar rooftop project at the end of 2019.

To be convenient for reading results, the paper coded the different experimental models as shown in *Table 3*.

Table 3. ***Code of different considered models***

Business model code		Financial case code	
Code	**Explanation**	**Code**	**Explanation**
C	Consumption household (CH)	D30_10	30% loan at 10% interest
D	Direct power sale and purchase (DPSP)	D30_8	30% loan at 8% interest
I	Intermediary power sale and purchase (IPSP)	D70_10	70% loan at 10% interest
W	Whole power selling business (WPSB)	D70_8	70% loan at 8% interest
		S	Self-financing

To financially compare between different solar models and financial models, the paper uses the financial indicators including net present value (NPV), Internal rate of return (IRR), payback period. The savings and expenses of each PV system for each parties participating into the market are calculated by saving electricity cost based on solar rooftop Feed-in-tariff (FiT) and grid tariff for the household customer (*Table 4 and 5*). The escalation rate of the grid tariff is estimated at around 5% per year in the base case of Vietnam Master Plan VII for the electricity sector.

Table 4. ***Solar rooftop power Feed-in-tariff by zone in Vietnam***
(Decision No. 02/2019/QD-TTG of the Prime Minister dated 8 January 2019)

Zone I		**Zone II**		**Zone III**		**Zone Vùng IV**	
Northern Vietnam (28 provinces)		Central (6 provinces)		Southern East Vietnam (23 provinces)		Southern West Vietnam (6 provinces)	
VNĐ/kWh	Euro cent/kWh	VNĐ/kWh	Euro cent/kWh	VNĐ/kWh	Euro cent/kWh	VNĐ/kWh	Euro cent/kWh
2.7346	10.31925	2.3529	8.878868	2.1076	7.953208	1.9833	7.484151

Table 5. ***Retail electricity grid tariff for a household in Vietnam***
(Decision No. 4495/QĐ-BCT of the Prime Minister dated 30 November 2017)

	Grid tariff		**Consumed Capacity**	**Total pay**	**Cumulative consume**	**Cumulative bill**	**Average tariff**
	1000 Vnd/kWh	**cent/kWh**	**kWh**	**cent**	**kWh**	**cent**	**cent/kWh**
Step 1: 0 - 50 kWh	1.55	5.85	50.00	292.26	50.00	292.26	5.85
Step 2: 51 - 100 kWh	1.60	6.04	50.00	301.89	100.00	594.15	5.94
Step 3: 101 - 200 kWh	1.86	7.01	100.00	701.13	200.00	1295.28	6.48
Step 4: 201 - 300 kWh	2.34	8.83	100.00	883.02	300.00	2178.30	7.26
Step 5: 301 - 400 kWh	2.62	9.87	100.00	986.79	400.00	3165.09	7.91
Step 6: >401 kWh	2.70	10.19	100.00	1019.25	500.00	4184.34	8.37

The saving is calculated as shown in equation 1.

$$\sum_n B_s = \sum_n B_i = \sum_n E_i \times T_i \quad \text{eq.1}$$

where:

- B_s is the benefit of the system in one year
- B_i is the benefit of party i in one year
- E_i is the consumed electricity of a party in one year
- T_i is electricity tariff by the party i in the year
- n is the lifetime of the solar PV system

The net benefit is calculated by

$$NPV = \sum_n \frac{B_n - C_n}{(1+r)^n} \quad \text{eq.2}$$

where:

- B_n is the total benefit of the system ($B_n = \sum_n B_s$
- C_n is the cost of the system
- r is the discounted rate

Internal rate of return (IRR) is the discount rate that forces NPV to equal zero is calculated by

$$NPV = \sum_n \frac{CF}{(1+IRR)^n} \quad \text{eq.3}$$

where:

- CF is the cash flow in one year

Payback period indicated to the time when the investment is paid off

$$Payback\ period = \frac{Initial\ Investment}{CF_n} \quad \text{eq.4}$$

where:

CF_n is the cash flow per period of n year

Results and discussion

3.1 The traditional financing models

In the traditional financial models, the investors own the PV system, sell the generated electricity for the state utility and gain the benefit from solar electricity in WPSB model. While in IPSP and DPSP, the investors have to bargain the price with their customers. They can offer their electricity to the consumer at a lower price than the utility charges the consumer, thus the consumers will benefit by saving on the electricity bill, while their benefit will be the difference between their bargained price and the grid price. In the case of the CH model, the PV system generates power during the daytime while the consumer is working outside the house, this electricity can be easily exported to the grid. The consumer would draw electricity from the grid during the nighttime for their using purposes. Thereby, the customers will gain benefit from consuming their own generated electricity and from selling surplus electricity to the grid.

3.1.1 Total market benefit and government scheme

The paper compares the market benefit from different system models, business models, and financial models. The market benefit is the total market of every entity including the investors, the customers, and the utility. In general, the results show that market benefit reaches a maximum level in the CH model at around 10000 euro per kWh after 25 years, or 4000 euro/kWh/year (figure 3). However, it decreases significantly in the WPSB model, DPSP model and IPSP model by 31%, 36% and 42% respectively (Table 6). Comparing system case 1b and 2a shows, the on-grid model provides around 8% for the total market benefit than the off-grid model. By investing in a bigger PV, the whole market would increase its benefit to 0.23% per capacity increase for off- grid system and 0.2% per capacity increase for the on-grid system.
In case of financial support, if the government does not give any financial support to the market, the market could work at the favored benefit of around 6650 Euro/kWh after 25 years, or 266 Euro/kWh/year. However, if the government could provide a loan scheme of at least 30% capital support at 10% interest the benefit of the whole market will increase by 10%. The increase in the loan from 30% to 70% at maximum as applied for the solar project would slightly benefit the whole market with 2%
However, of the government would tend to decrease the loan interest from 10% to 8%, which is the current lowest loan rate of the government support scheme for energy investment, the benefit would only be increased if the investors choose the package of 70% capacity support.

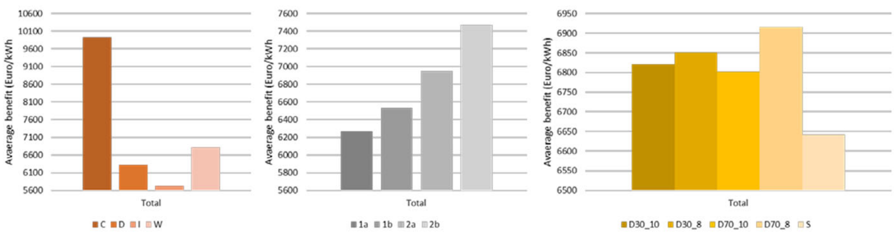

Figure 4. ***Average market benefit by (a) business model, (b) system model and (c) financial cases after 25 years***

Table 6. ***Comparing between different models by relative comparisons index***

Business model	Relative comparisons Index	System model	Relative comparisons Index	Financial cases	Relative comparisons Index
C	1.00	1a	1.00	S	1.00
D	0.64	1b	1.04	D30_10	1.09
I	0.58	2a	1.11	D30_8	1.09
W	0.69	2b	1.19	D70_10	1.08
				D70_8	1.11

3.1.2 Consumers and Investors choices

Figure 5 compares the benefit of each entity in the market with different considerations. First, in case of CH model, since the customers are the investors, their total benefit is estimated around 300 Euro/kWh/year after 25 years at 7% inflation rate and 5% electricity price escalation. The customers' benefit decreases while the investors' benefit increases in the CH model, DPSP model, IPSP model, and WPSB model respectively. It shows that the most favorite business model for the customer in investing in solar PV is the CH model, while the most favorite model for the investor is the WPSB model. However, they would both prefer the on-grid system and the 70% loan support scheme (figure 5)

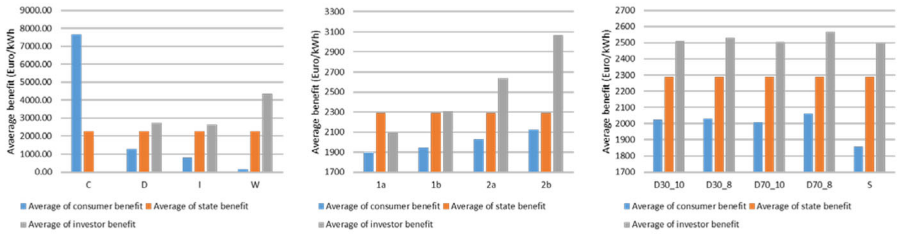

Figure 5. ***Comparing the average benefit of each entity by (a) business model, (b) system model and (c) financial cases after 25 years***

Since the solar capacity performance and solar price are differentiated by four regions, the paper compares the benefit between them to assess the attraction of each market with the investors and the customers. The results show that the investors would slightly earn more at zone 1 market or northern part of Vietnam than the other part, while the customers gain much more benefit in the other zones than zone 1 (figure 6)

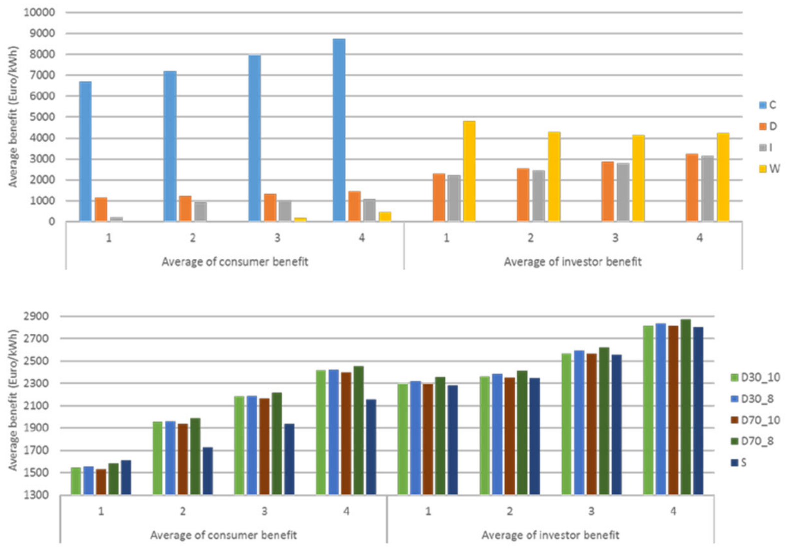

Figure 6. ***Comparing customers and investors benefit from different zones after 25 years***

3.1.3 Bargain price in DPSP and IPSP models

In the case of DPSP and IPSP, the investors have to bargain price with the customers. Therefore, the paper compares the benefit of the two parties at a different level of bargain price to find out the reasonable range, which brings benefit for both parties. Since the bargain price should be lower than the grid price to convince the customers to buy solar power instead of grid power, the paper examines the level of bargain price ranging from 30% to 90% of the average grid price. Figure 7 shows that at the end of the 25-year-period, the benefit of the investor increases from around 32 Euro/kWh/year to about 200 Euro/kWh/year by increasing the bargain rate from 30% to 90% of the average grid price. However, at the 30% rate, the investors would rather choose to save money in the bank rather than decide to invest in a solar project. Because the IRR at 30% is around 1%, which is lower than the bank interest at 7%. From the customers' perspective, their benefit from using solar power decreases from average 120 euro/kWh/year at 30% bargain rate to around 10 euro/kWh/year in average at 70% bargain rate. That would keep them still be interested in choosing power solar for consumption. However, at the higher rates, the customers will not choose to buy solar power instead of grid power. However, the bargain rate is different between different zones. In zone 1, the investors could negotiate from around 45% to a maximum of 76% of the grid price. While in zone 2, zone 3 and zone 4 the range covers from around 50% to 80% of the grid price.

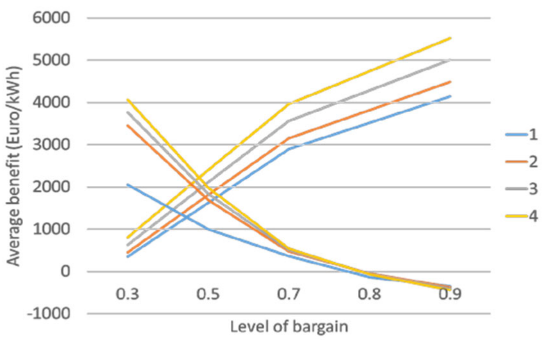

Figure 7. ***The changes in each party's benefit when changing the level of bargain price after 25 years***

3.2 The new financing models

In the new financial models, the role of the entities in the market will be changed. There is a new role called the third party will appear in the market (Table 7). The third-party owns the PV system and pay onetime for the capital investment and the annual O&M charges. The third-party has the option of selling the electricity to the consumer at a lower price than the grid price or leases its PV system to the customer. The first case can be called double sell and purchase contract (row 1 table 7), in which the customers save their electricity bill according to the arrangement between them and the third party, while the third party earn benefit from price difference of the contract with customer (S&PC 1) and the contract with the utility (S&PC 2). In the second case or leasing contract case (row 2 table 7), the consumers benefit from the electricity bill to the utility based on net consumption (export-import) of electricity and the leasing fee but avoid large upfront capital investment and are free from maintaining the system.

Solar crowding funding is another new financial model. It works as a platform investment for small investors to join and receive interests by investing in a common solar system. This mechanism covers the financing gap of projects, which have difficulties to get bank credit. The crowdfunding contract can be combined easily with other types of financial model (table 7). The crowding funding model is suitable for the installation of PV systems in residential customers, especially in the scale of multi-family.

New financial model	Consumer	Third-party	Utility
Double sell and purchase contract	S&PC 1	S&PC 1 S&PC 2 (Crowdfunding contract)	S&PC 2
Leasing contract	Leasing contract, S&PC (Crowdfunding contract)	Leasing contract	S&PC
Crowdfunding contract	Crowdfunding contract, S&PC		S&PC

Acronyms: S&PC is selling and purchase contract

The leasing and crowdfunding models can be simple or complicated depends on the government procedure. Since Vietnam has not introduced these models to the market, the paper tends to test the simple case of the two markets. In which, the leasing and crowdfunding are considered separately. A leasing contract is established between the third party and the consumers or the system's owners. The third-party will supply electricity at 90% of the grid price. The consumer in this case still gains benefit at around 30 euro/kWh/year. It is higher than in the case of DPSP and IPSP, in which the investors could not bargain at 90% rate. However, the IRR results show that the third party would not be favored by investing in off-grid (table 8).
By using crowdfunding with three investors, the IRR would slightly decrease compared with the CH model. However, since the investors do not take the whole risk of investment and operation cost, they will gain less benefit. The PV rooftop seems still very attractive since the IRR results shown at the high interest of nearly 17% to 25.5% depending on the system (table 8).

Table 8. ***Financial calculation in case of simple leasing and crowdfunding models***

Row Labels	Average of consumer benefit	Average of third party benefit	Average of IRR	Average of Payback
Leasing	29.96	130.00	13.53%	10.02
1a	29.87	109.24	4.91%	13.21
1b	29.92	119.63	9.60%	11.05
2a	29.98	135.40	11.95%	10.00
2b	30.09	155.72	27.65%	5.81
Crowding	156.08	87.37	27.87%	7.33
1a	144.00	77.43	16.95%	10.25
1b	149.67	82.42	18.82%	7.41
2a	159.67	89.82	18.18%	7.41
2b	170.99	99.81	25.53%	4.25

Conclusion and outlook

Because of the limited land for building centralized solar, the decentralized market could be a solution for a developing country like Vietnam. Moreover, the development of decentralized solar PV would help to diversify the national economy in the ongoing transition process by avoiding additional cost for investing in utility for solar plants. Following the pioneering countries in developing solar power, Vietnam should put more effort in designing financial attractions for solar energy development to attract more investment that is public. Financial attractions involve the transfer of funds in investing in rooftop solar and promises of future return. Specifically, the policymakers should make up financial schemes for rooftop solar funds individually instead of combining with other renewables and transforming risk schemes to increase the public will.

The paper assesses the financial analysis and comparison to different system models, business models in different financial cases to find a suggestion for the government in encouraging household solar power aspect of the four types of the solar system. Based on the current market status and the government plan by 2030, the paper calculated the change of payback period and internal rate of return (IRR) and benefit of each participant in the market when the government's financial subsidies change.

The results show that if the government would support solar rooftop project in a household with a loan program of 30% to 70% total capacity investment, the total market benefit would increase by at least 10%. If the government would consider applying new financial models such as leasing or crowdfunding it would help to scale up the residential solar market. Because the solar leasing would offer financing for customers to own or have access to solar systems requiring monthly installments and no upfront cost. The third-party in this case would benefit at IRR of nearly 17% to 25.5% depending on the system. It also allows providers to benefit from customers through a combination of access to financing, operations, and maintenance (O&M) service, and performance guarantee.

Apendix

Appendix 1. **Summary of solar PV system packages for a household customer in Vietnam**

On-grid

Capacity (kWp)	area (m^2)	Price (1000 Vnd)	Price (euro)	price (euro/kWp)
1	6	25000	943.39	943.39
2	12	37000	1396.22	698.11
3	20	50000	1886.79	628.93
5	32	75000	2830.18	566.03
10	56	162000	6113.20	611.32

Off-grid

Capacity (kWp)	area (m^2)	Price (1000 Vnd)	Price (euro)	price (euro/kWp)
1	6	28000	1056.60	1056.60
2	12	55000	2075.47	1037.73
3	20	75000	2830.18	943.39
5	32	127000	4792.45	958.49
10	56	240000	9056.60	905.66

Source*: in the links below. Last accessed 19 March 2019*
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Mattia Luca and Tiziana Torelli

ENERGY EFFICIENCY IN ITALIAN BUILDINGS: DISRUPTIVE NZEB VERSUS TRADITIONAL CONSTRUCTIONS FOR DECARBONIZATION

Mattia Luca, Professional Registry of Engineers at the province of Rome
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Overview

Together with the Kyoto Protocol, the United Nations Framework Convention on Climate Change provided the main impetus for the 2007 launch of the Climate-Energy Package with challenging goals for 2020. In this context, the role of NZEB (nearly zero-energy buildings) and their proliferation is fundamental for the achievement of an increase in energy efficiency of at least 32,5% by 2030 and for the purposes of the climate agreement reached at COP 21 in Paris for decarbonisation by 2050.
Buildings are key to a secure and sustainable energy system because their design, construction, operation, and the activities in buildings are significant contributors to energy-related challenges, their construction and operations accounted for 36% global final use and nearly 40% of energy-related dioxide (CO_2) emissions in 2017[1]; in the EU buildings use 40% of total energy consumptions[2]. An analysis[3] of data for 16 countries/regions, covering 66% of the European total floor area, shows that over 97% of the building stock must be upgraded to comply with the 2050 decarbonisation vision. France and Denmark have the biggest share of highly efficient buildings to Energy Performance Data (7% and 8% respectively). EU building stock observatory finds that less than 3% of the building stock in the EU has an A-label. Improving the energy efficiency of buildings can help to effectively combat Europe's energy security concerns and limit the environmental degradation associated with the consumption of fossil fuels. More specifically in national framework, an analysis of Eurostat data, which looks at the end uses of energy by sector, shows that similar as the EU data, in Italy in 2017 the transport and residential sectors (34,60 and 32,90 TOE respectively) are those with the highest consumption, respectively 30,4% and 29,0%. For this reason, the increase in energy efficiency in buildings and the transition to almost zero energy buildings are therefore priority objectives to be pursued through the activation of a wide range of regulatory and incentive policies.

Method

Over the last decade there has been a significant change in the energy policy sector with particular reference to the application of new regulatory instruments and new methodologies for the adoption of technical-regulatory measures aimed at improving the energy performance of buildings. To design an NZEB building in Italy, it is necessary to apply a methodology for calculating the energy performance with reference to the UNI 11300 standards and the compliance with the energy performance indexes calculated in accordance with the values of the minimum requirements established by the Ministerial Decree of June 26, 2015 and also the fulfilment of the obligations to integrate renewable sources in compliance with the principles of Legislative Decree 28 of 2011.

Thanks to these measures, in the 2010/31/UE Energy performance of buildings directive or EPBD an NZEB building is defined as: "a building that has a very high energy performance,

[1] These data cover buildings and construction, including the manufacture of materials and products for buildings construction, such as steel, cement and glass. 2018 Global Status Report, Derived from IEA (2018a), World Energy Statistics and Balances 2018, www.iea.org/statistics and IEA Energy Technology Perspectives buildings model, www.iea.org/buildings.
[2] European Energy Security Strategy Data
[3] Buildings Performance Institute Europe, 2017, last update December 2019

as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby."
A significant example of NZEB applicability is a Casaclima R in Bellano, a building of historical interest converted into a nearly zero-energy buildings, preserving its artistic and architectural peculiarities: Energy requirement from 230 kWh/m^2 per year to 15 kWh/m^2 per year, 87% savings on global consumptions. High energy performance can be achieved especially in the creation of new buildings, adopting new design methods and using plant solutions with sustainable and high-performance technologies. By way of example, the Aurum building (BZ), certified by the seal "Casaclima A nature" has an energy requirement for heating of 14 kWh/m^2 per year, which is covered entirely by renewable sources.

Results

Given that Legislative Decree No. 63 of 2013 defines the obligation of new or existing buildings, subject to significant restructuring, to possess the energy characteristics of nearly zero-energy buildings from January 2019 for the public sector and from January 2021 for all other sectors, there are only a tiny number of NZEB buildings in Italy. That the number derives from the obligation is proven by the results of the ENEA NZEB Observatory, which estimates a total of 1.400 NZEB in Italy as of the 30th of June, 2018. The percentage of NZEB compared to existing buildings varies between 0,005% and 0,02% by region, an indicator influenced in some cases by the early introduction of the obligation in northern Italy: in Lombardy, the NZEB obligation was brought forward to January 2016, in Emilia Romagna to 2017 for the public and to 2019 for others, and new buildings in the province of Bolzano have been obliged to possess minimum Class A ClimateHouse energy efficiency certification since the 1st of January, 2015.

Conclusions

New measures need to be put in place to increase the number of buildings that not only meet the minimum requirements but have even higher energy performance, thus reducing both energy consumption and CO_2 emissions. To this end, the diffusion of almost zero energy residential buildings in the regions of Italy where there is currently no obligation should start immediately without waiting for 2021, for example through the promotion of a volume discount or other national incentives which can be combined with other types of financing. In other words, the improvements in energy efficiency that were seen in recent years are now slowing down as fewer new standards and policies were introduced in the past two years. Support tools should be introduced to allow citizen to develop individual renovation plans, individual building renovation passport, regular checks and updates of the technical building system. It lacks a transparent and comprehensive national database of individual building data.

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Gracia M. Brückmann

PROMOTING ENERGY EFFICIENCY IN CAR TRANSPORTATION THROUGH USER EXPERIENCE OR INFORMATION?

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Overview

Decarbonizing the transportation sector is crucial to limiting global warming but faces severe feasibility challenges due to the fact that individuals place a high value on the advantages of individual motorized transport. It is very difficult to change away from the fossil-fuel car as the main mode of individual motorized transport. The conventional car is perceived as convenient, fast, ideally for long-distance driving, while it offers privacy and luggage space and is regarded as a status symbol (Gärling and Schuitema 2007). Decarbonizing transportation poses enormous challenges (Rockström et al. 2017; Rogelj et al. 2015; Schellnhuber, Rahmstorf, and Winkelmann 2016): cars with internal combustion engine need to be replaced with vehicles that do not rely on fossil fuel, such as battery electric vehicles (BEVs) in conjunction with energy from renewable sources (Ajanovic and Haas 2016). A suitable country for using many BEVs is Switzerland: It has enormous decarbonization potential as it currently is year-after-year the fleet of newly registered cars has the worst emission record (ACEA 2019; auto suisse 2019) in Europe. On the other hand a high share of the country's electricity is already from renewables (mostly hydropower) and the government is planning to replace all remaining non-renewable energy sources, including nuclear energy, with renewables by 2050 (SFOE 2018). For the transition to decarbonized transportation, many states enact policies to promote electric vehicles (Hardman 2019; Hardman et al. 2017; Rietmann and Lieven 2019; Zhang et al. 2014). However, so far the effectiveness of two particular incentives have not been studied so far: first, a 48 hours test drive with a fully-electric car (BEV) and a detailed, comprehensive information package on these cars. Following established findings in the literature (Graham-Rowe et al. 2012; Schneider, Dütschke, and Peters 2014) experience matters for stated interest in EVs. In this paper, I used a randomized-control trial among Swiss car holders to assess whether any of these measures will lead to more purchase interest in electric vehicles.

Methods

Using a random sample of Swiss car holders (from the Swiss cantons of Aargau, Schwyz, Zug, and Zurich) we administered a baseline survey (Brückmann and Bernauer 2019; Brückmann, Willibald, and Blanco 2019). We received answers from 4,148 owners of conventional cars, that had no BEV registered yet. Survey participants were then randomly assigned to one of three experimental treatment groups: (1) information on BEVs, relating to car attributes that buyers typically pay attention to; (2) the same information on BEVs, plus test-driving of such a car; (3) a control group with neither (1) nor (2). This design is a two-by-two design (information yes/no, test drive yes/no, leaving out a group that would receive no information and a test drive, which would either confuse test drivers or them searching the information (at least partially) themselves).

A follow-up survey took place around three weeks after the test-drive treatments, and assess whether these interventions (treatments) have had a positive effects on desirable attributes respondents associate with BEVs as well as on their intentions to switch to more fuel-efficient cars.

Results

We were able to collect results of 200 test-drivers, 1,097 people who received purely the information treatment as well as 1196 responses from the control group. However, we were only able to collect full information on the next drivetrain choice for 1408 respondents.

The linear estimate of choosing a BEV as the next car increase by around 9% when the test-drive was done, while it remains unchanged when only information is provided. However, due to the low n, these are hardly significant (same for logistic regressions or looking at all types of electric vehicles, not only BEVs). Controlling for previously stated drivetrain preferences in a logit model for stating to buy a BEV as the next car the marginal effect increases. As the interaction between previously stated purchase interest in electric cars with receiving the test drive is insignificant, the effect seems not to be depending on prior decisions. In a later stage of the research project, results will include also moderation effects, intention-to-treatment effects as well as treatment heterogeneity.

Conclusions

This work shows the importance of experiencing a test-drive, while detailed information is hardly altering the stated car purchase. The test-drive could be encouraged by policy and industry to decrease transport's dependency on fossil fuels and increase energy efficiency.

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Mari Ito, Naoya Kihara, Ryuta Takashima, Noriaki Sakai, Natsuki Nagata, Yumiko Kawasaki and Takeshi Iimoto

QUANTIFICATION OF SOCIAL COSTS CONSIDERING THE REDUCTION IN THE RISK PERCEPTION WITH PUBLIC OPINION ON JAPANESE NUCLEAR POWER GENERATIONS

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Overview
On March 11, 2011, an accident occurred in the Fukushima Dai-ichi nuclear power plant in Japan. This accident increased the risk perception such as danger and worry. The Japanese government spends on policies to reduce excessive risk perception. However, the social costs incurred to reduce risk perceptions are not quantified. In this study, we quantify the social costs toward Japanese nuclear power generations in the framework of Huhtala and Remes (2017). We examine the changes in social costs over the past 3 years (Japan Atomic Energy Relations Organization, 2018).

Methods
To determine the social costs considering the reduction in the risk perception with public opinion, we define social welfare and the net benefit of energy production. The social welfare function is expressed in terms of utility in both favor and disfavor of nuclear power generations and the disutility. The net benefit of energy production function is expressed in terms of the marginal price of electricity and the objective external cost estimation of nuclear power plant accident, among others. The social costs considering the reduction in the risk perception with public opinion are shown in terms of the probability of favoring restart of nuclear power plants. Cumulative logistic regression is used to estimate the probability of favor. The study analyzes data obtained from the results of a nationwide public opinion survey on the nuclear energy utilization in October 2018. This survey sample included 1,200 men and women aged between 15 and 79 years. The analysis of changes in social costs over the past 3 years uses the same survey data and the same attribute from 2016 to 2018.

Results
The results of cumulative logistic regression show that the probability of disfavor increases among the highly educated and the aged. The social costs incurred per generated energy 1 kWh is about 1.10 yen. An earlier study shows that the social costs in Japan are higher than in Finland of Huhtala and Remes(2017).
We also found that social costs decreased over the past 3 years

Conclusion
In this study, we calculated social costs on nuclear power using the quantification model of social costs considering the reduction in the risk perception with public opinion and the data on the nuclear energy utilization in Japan. We also confirm that social costs have changed over the past 3 years. As a result, we can quantify the social costs per generated energy of 1 kWh.

We also found that social costs decreased over the past 3 years. We believe that the Japanese social background has largely affected the decreased in social costs.

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WHAT MOTIVATES US TO SEEK INFORMATION ABOUT ENERGY POLICIES?: SWISS CITIZENS' INFORMATION SEEKING BEHAVIOR ON DEEP GEOTHERMAL ENERGY

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Overview

A wealth of research shows that we, the public, are largely misinformed or under-informed regarding important energy policy issues on which we are expected to vote or to act. In order to enact fact-based, effective public policy, we need to be able and willing to update our beliefs and knowledge. However, there are multiple barriers to our willingness to update our knowledge including the following three that are the focus of this paper: (1) our interest in energy topics or their relevance to us (2) our current level of understanding (3) our current belief of our current understanding, and (4) powerful emotional and political mental associations. In this paper, we ask to what extent our subjective knowledge (how much we think we know), our objective knowledge (how much we do know), our interest, and some political and value-based judgments influence our willingness to seek information about deep geothermal energy (DGE).

Methods

In order to understand citizens' information seeking on DGE, we launched an original survey of the German-speaking region of Switzerland[1]. we implemented the survey between May 24th and June 6th 2018 using the professional survey-panel service Intervista[2] to ensure the sample that approximates the demographic distribution of the Swiss population, Intervista recruited participants of voting age (18+) using quotas of age, sex, education level, political party preferences, and WEMF region. In the survey, we measured both respondents' stated interest in getting additional information (attitudinal) but also their actual behavior in seeking of additional information (behavioral). We also measured important control variables such as knowledge (subjective, objective, and experiential) (e.g., Brucks, 1985); political ideology; general attitudes related to climate and energy issues; and demographic characteristics. We analyzed the results of the survey empirically using regression methods to calculate conditional correlations among the dependent variables (attitudinal and behavioral information seeking) and the independent variables.

Result

We find evidence that the variables indicative of respondents' "informational needs to make a decision" (i.e., objective knowledge; risk and benefit perception; trust in government and science) are less important in predicting attitudinal and revealed information seeking than the variables describing respondents' interest in the topic and how much they think they know (subjective knowledge).

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[1] We chose to conduct the study in this region because it accounts for the largest share both geographically and by the size of population (63%) (Swiss Federal Statistics Office, 2017)

[2] https://www.intervista.ch/

Even though the respondents are not confident in their knowledge about DGE, their lack of confidence in their knowledge does not motivate them to seek additional information. Indeed, we find that interest in energy topics, rather than objective knowledge, is an important predictor of attitudinal information seeking. Furthermore, we see evidence of a non-linear relationship between information seeking (both attitudinal and revealed) and subjective knowledge. That is, as subjective knowledge increases, information seeking forms an inverted-U shape. We explain this pattern as follows: at low levels of subjective knowledge, one believes seeking information will be difficult for them - a cognitive hurdle to seeking information (e.g., lack of vocabulary or familiarity with the topic). At a middle level of subjective knowledge, onebelieves they possess enough knowledge to understand new information quickly. Respondents at the highest knowledge assessment do not tend to seek more information because they believe they have enough (e.g., Bettman and Park, 1980). The mismatch between objective and subjective knowledge, however, makes this inverted-U shape problematic. If the factor shown to be related to the desire to seek informa- tion (i.e., subjective knowledge) is not an accurate signal, then we will not seek information when we need it.

In terms of actually seeking information - revealed information seeking - we find that approximately half of those respondents who indicate an interest in more information actually seek it. This result exemplifies the theory in Lupia and McCubbins (1998) - people have limited time and resources that they must allot to the issues they find most interesting and important. Interestingly, we see that those who actually seek more information tend to have higher objective knowledge scores, reinforcing the cognitive hurdle hypothesis.
In trying to disseminate information about energy and climate policies, scientists and policymakers alike face a huge challenge in capturing individuals' attention and motivating people to update their beliefs accurately. Misinformation (and outdated information) is reinforced not only through the selection of belief-confirming sources but also when individuals fail to seek any new information at all. Scientific endeavors are designed to be self-correcting undertakings through regular knowledge and belief updates in light of new evidence. Our findings are the important foundation of a larger effort to identify interventions that can support the public's willingness to self-correct by seeking additional information. Ultimately, we believe such interventions could enliven public discourse on energy topics.

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FUNDAMENTAL ANALYSIS OF CONSUMER PREFERENCE FOR RENEWABLE AND NUCLEAR ENERGY AND FORMATION OF PUBLIC OPINION

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Overview

The retail electricity market in Japan became fully open to competition in April 2016. The purpose of this study is to clarify how consumers' choice of electricity supplier and rate plan is affected by the fuel mix and monthly electricity bill in Japan, limiting our study to the period since electricity market liberalization. To achieve that, we build a consumer preference model of the choice of electricity supplier and rate plan by using conjoint analysis. We then apply the model to estimate the formation of public opinion.

Methods

Conjoint analysis is a survey-based statistical technique often used in market research. It can help determine how strongly people value the different components that make up an individual product or service. We apply that to the Japanese retail market for electricity since liberalization. Approximately 18 months after liberalization, in October 2017, we surveyed 1,086 households randomly sampled from all prefectures of Japan. In our choice experiment, three attributes and three levels of electricity service were considered. Next, nine virtual electricity rate plans (one for each pairing of attribute and level) were created and presented to the surveyed consumers. Respondents assigned a degree of desirability to the rate plan, with a possible maximum of five points.

Results

It was found from the partial utilities of each attribute that respondents desired a large (resp., small) proportion of the energy come from renewable (resp., nuclear) sources. The ratio of nuclear energy showed positive utility only at 0%. This indicates a persistent resistance to the use of nuclear energy. It was found from the relative importance of each attribute that the amount of the monthly electricity bill was the most important attribute; with respect to the proportion of renewable energy, the relative importance was low, with no major impact on consumer decision-making.

Conclusions

Consumers' preference for the ratio between renewable energy and nuclear energy and its effects on the amount of monthly electricity bill when choosing an electricity supplier and rate plan were estimated by conjoint analysis of survey data from Japan soon after electricity market liberalization. These analysis results enable us to estimate the formation of public opinion by means of a mathematical diffusion model and/or agent-based simulations.

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MODELLING THE VOLATILITY OF ELECTRICITY SPOT PRICE IN BRAZIL

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keywords: Electricity spot price, Volatility, GARCH

Overview

The Brazilian Electricity Sector faced two reforms in the last decade, in 1996 and 2004. These reforms introduced market mechanisms in the sector, among them a short-term Market. However, they also provoked an incrase in the complexity of princing behaviour. In particular, the volatility of the electricity spot price is the feature that best describes the current Brazilian market. the price of electricity in this market has experienced significant volatility. The Electricity spot price in Brazil is determined by a computacional model that takes into consideration the amout of water (current and future) present on reservoir. Therefore, it is very volatile. So, the main goal of this paper is to present a model of the volatitlity of the electricity spot price in Brazil. Firstly, we discuss the characteristics of the spot price in Brazil, which are different from other countries. Then, we present the GARCH model to estimate the volatility. The data is the weekly spot price from January 2003 until july 201. We show that the spot price in week A is highly correlated with the price in week A-1. In the end, we discuss the causes of the volatility onf the spot price in Brazil.

The Brazilian Electricity Industry (BEI) is a large-scale hydro-thermal system characterized by the presence of large reservoirs, high capital intensity, large interconnections (Leite, 2012). The main institutional feature of the BEI is the predominance of hierarchy as a governance structure. Until the 1990's, in Brazil, Eletrobras, the State owned holding, was on the top of the hierarchy. Eletrobras controled nearly 90% of supply and was responsible for planning and operating the whole system. This governance structure was created in the 1950's, based on state monopoly. From March 2004, generators sell energy to distributors only at the regulated contract environment (ACR). But, they can compete with distributors and retailers to sell electricity to free consumers. This is the free contract environment (ACL). The system is operated and coordinated by the National System Operator (ONS), which is a private institution. The shareholders are the generator, transmission, distribution and retail firms. ONS has five directors, and three of them are nominated by MME. Unlike other countries, in Brazil there is no electricity market. The short-term electricity price in Brazil is known as Settlement Differences Prices (PLD) and it reflects the difference between what was contracted and what was really consumed . The PLD reflects, in instance, the opportunity costs for short-term electricity

For generator, that can sell non-contracted electricity.

For consumers, that can buy or sell the differences between what was contracted and what was effectively consumed.

The PLD is determined by a computational program that takes into account the availability of water, for immediate use and for future use.. A balanced operation of the system involves a compromise between depleting (using water) and not depleting (using thermal plants) the reservoirs. The decision variable is the volume of water stored at the end of the operational period (Ferreira et al. 2015). This decision is associated with the Immediate Cost Function (ICF) and the Future Cost Function (FCF), in this case, the cost to use or to stock water in reservoirs. The PLD is calculated ex-ante on a weekly-basis and it is based on the marginal price model system (PMS), as described in Silva (2001). To reduce computational overhead and to represent their hydrological interdependence, they are aggregated in reservoirs. Four subsystems are then represented by their corresponding shells equivalent, in which the main features are the generating capacity and the flow of energy. The whole market is divided in four submarkets: Southeast and Mid-West; South; Northeast and North.

The National Electric System Operator (ONS) uses two optimization models (Newave, for long run term and Decomp, for the short run term) to determine the minimum cost of operation dispatch (Mendes and Santana, 2003), as shown in figure 3. Also, a stochastic dual dynamic programming models is used to define the profile of generation units for each planning horizon to calculate the marginal cost of short-term operation (CMO) for the four sub-market. The information that are essential for optimal operation are: the prediction of water flows, load profile, network configuration, availability of resources and the generation and transmission planning.

Methods

To model the volatility of the PLD, we developed a GARCH model (General Autoregressive conditional heteroscedasticity model). A Garch Model is a useful generalization of the ARCH model developed by Engel (1982) and it was first introduced by Bollerslev (1986). This model is also a weighted average of past squared residuals, but it has declining weights that never go completely to zero. It gives parsimonious models that are easy to estimate and, even in its simplest form, has proven surprisingly successful in predicting conditional variances. It describes volatility clustering and excess kurtosis. The most widely used GARCH specification asserts that the best predictor of the variance in the next period is a weighted average of the long-run average variance, the variance predicted for this period, and the new information in this period that is captured by the most recent squared residual. Such an updating rule is a simple description of adaptive or learning behavior and can be thought of as Bayesian updating (Engel, 2001).

The data used is the PLD, of the four submarkets (North, Northeast, Southeast and South), from January 2003 until july 2018, and is available at www.ccee.org.br.

Results

In the case of the Brazilian electricity sector, the price of electricity is a function of the characteristics of theindustry, i.e., the availability of water in reservoirs and rain level, thermal transmission constraints, availability and cost of the deficit. In most systems, the hydroelectric energy prices tend to be somewhat volatile in the short term and more volatile in the medium term. This is because, in the short term, there's a transfer energy from low-load hours to the cutting edge by modulating the supply and reducing price volatility. While, in the medium term, the price of energy is more volatile because the hydraulic systems were designed to ensure the supply of electricity in adverse hydrological conditions.

The high volatility is related mainly with the dynamics of inflows. Another problem of the PLD is the fact that it does not take into account the reaction of demand, being just the hydrology-present and future-predicting the price forming.
In short, it is a consensus among the various agents in the industry that there is significant volatility of PLD (Rodrigues, 2007; Leite and Santana, 2006).
The GARCH models showed some interesting results. For the Southeast sub-market the, model that fits the best is Garch (-1,-6). For the other three sub-markets, the best result was Garch (-1), These results are statistically significant and are shown in the appendix. What they mean is that the PLD in week t is highly correlated with PLD in week t-1, that means that the only way to forecast the PLD is to do so by taking into account the previous week.
Essentially, there are three causes of such volatility. First, there was, in the period immediately after the energy rationing in 2001, a significant reduction of investments in the expansion of the system.
Another cause is related to the promulgation of the Federal Constitution in 1988, which brought to the fore a greater concern with environmental issues. These issues deal specifically with the consequences of flooding caused by the construction of large reservoirs, which entailed reducing the construction of new reservoirs of hydroelectric plants.
In fact, the hydropower plants built in the last two decades are of the run of the river type. The large reservoirs were used mainly to maintain the security of the system, and provide better control of the production of electricity in dry seasons. With the reduction of the volume of water stored in relation to demand, the volume of electricity generated from water source became more volatile, since it depends on more rainfall. And, this made the operator include more thermal plants in the calculation.

Conclusions and further research

Approximately, 90% of the energy generated in Brazil comes from hydro plants. The PLD is calculated in an ex-ante weekly basis through stochastic dynamic programming dual models that analyze the current flow and the flow rates in the short, medium and long term. Thus, the PLD is the result of computer models, and by failing to take into account the demand side, the PLD is inadequate and inconsistent signal to signal future investments and provide long-term contracts. In relation to the volatility of the PLD, examined mainly three factors: a shortage of investment in the period after crisis, the end of the construction of new reservoirs and the order of the system operator. It was noted that these elements are interdependent, which implies that there is a trend increasingly explicit, the PLD will become an even more volatile variable, contributing to instability in the Brazilian electricity market.

Roland Menges, Dominic Jung and Stefan Traub

ENERGY EFFICIENCY AND GAMIFICATION: STORYTELLING AND INDIVIDUAL BEHAVIOUR IN SOCIAL DILEMMA SITUATIONS

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Overview

When energy efficiency technologies are developed to achieve more flexible and smart solutions or to balance supply and demand on electricity markets, energy consumers also have to adopt the perspective of producers and investors. Individual production and investment decisions of market actors create spillover effects which are either to the benefit or to the worse for other parts of the system. Economic theory highlights two questions for the social design of this transformation process which are closely related: First, as the whole society has to bear the cost of transforming the energy system, the question has to be answered, how to distribute these costs among all individual members of society such as market participants and other parties. Secondly, as individual decisions to act on energy markets create economic, technological or environmental spillovers for the rest of society, one has to deal with the problem of how to internalize external effects. If behavioural effects are ignored, experimental studies of consumer behaviour show that bare and abstract theoretical positions how to internalize external effects cannot be translated directly to recommendations for political action (Beyer et al. 2018). However, as such kind of economic experiments concentrate primarily on the theoretical accuracy of the underlying behavioural model and its application in a public good environment, one might critizise that these methods lack real world interrelations and do not account for experiences and feedbacks individuals face when they act. Alternative approaches such as serious games focus more on creating innovative adventures and stories which enable players to gather more realistic hands-on experiences in an interactive environment with other players. These approaches are primarily directed to enable players to get in touch with real world phenomena and learn about the consequences of individual and collective decisions, but they do not deliver a methodological basis for measuring individual preferences. In this paper, we present an innovative approach which integrates the theoretical accuracy of behavioural and experimental economics into a professional serious game. This approach is based on preliminary work as presented in Müller et al. (2018). Gamification is used to highlight the dilemma of co-operative investments in energy-related infrastructure such as energy efficiency which gives rise to positive externalities in a well-designed regional vicinity.

Methods

The theoretical framework is based on an incentivized, non-linear public good experiment. The underlying model is a derivative of the impure public good model as used in previous studies (Paetzel & Traub 2017, Menges & Beyer 2014). It features three core attributes of investments into energy efficiency which are expressed in a payoff function: opportunity costs in terms of reduced private consumption (1), private benefits of efficiency investments such as local quality improvements or reduced energy expenditures (2) and public benefits reflecting the positive spillovers of efficiency investments such as improvements of environmental quality (3).

When modelling energy efficiency in this multiplicative payoff function, we follow Chan et al. (1999), who state that in the energy efficiency case all involved parties have different sizes, different interests, and different abatement cost structures.

This leads to non- linear payoff structures of individual decisions. Heterogeneity of parties is modelled by assuming that three subjects with different endowments form a community. The investment problem is non-linear in the sense that each optimal individual investment almost certainly is greater than zero and lies in the interior of the choice set of each agent. Note, that the incentive structure of such kind of model is characterized by the motivation of free-riding. Even in the absence of regulation, it is in the private interest of all individuals to invest at least certain quantities of their endowments, given the expected investments of all other individuals (Nash equilibrium). However, all individuals would benefit if they were cooperating and investing in a way which maximizes the sum of all individual payoffs (welfare maximization). Hence, the gap between the optimal investment in the Nash equilibrium and the welfare maximizing investment can be interpreted as energy efficiency gap. The model also predicts that subsidies for energy efficiency investments can be used to internalize external effects. The implementaion of this model within a professional full-computerized gamification approach is based on the concept of Müller et al. (2018). Our approach emphasizes on game principles to generate an immersive setting, it allows for translating abstract decisions into a visible outcome related to the idea of good life. Moreover, we utililize the design of simulation games whilerecording user data. By implementing game analytics routines we are able to track the decisions of the users for empirical research on user behavior.

The design is subject of the following story: Three players adopt the role of mayors in neighbouring cities and attempt to increase the number of their citizens by investing in an environmentally friendly infrastructure. The game is guided through three stages:

1. Lobby: The players create the identity of their cities in several steps. For instance, they choose an energy-related city arm and decide on a city name.
2. Main part: Each player has to decide how much of his budget he wants to invest in energy and environmental projects within his city. To support this decision, players are asked to estimate the decisions of the others. Due to externalities of the projects, not only the own investment decision, but also the unknown decisions of the other two players affect the attractiveness as well as the influx of the population into every city. Ten rounds are played and feedback about investments and growth of all cities is given after every round. The game experience is implemented in two ways: On the one hand, after each round, new buildings are being built and the cities grow visually with the number of new residents . While good spending decisions result in attractive buildings, bad decisions end up in simple buildings or empty construction sites. On the other hand, various visual and audible stories, e.g. bans on motor vehicles or the opening ceremony of a new bus station, are added in each round to underline the quality of the decision.
3. Questionaire: The experiment concludes with a questionnaire concerning sociodemografic variables and certain attitudes of each player towards environmental and energy policy.

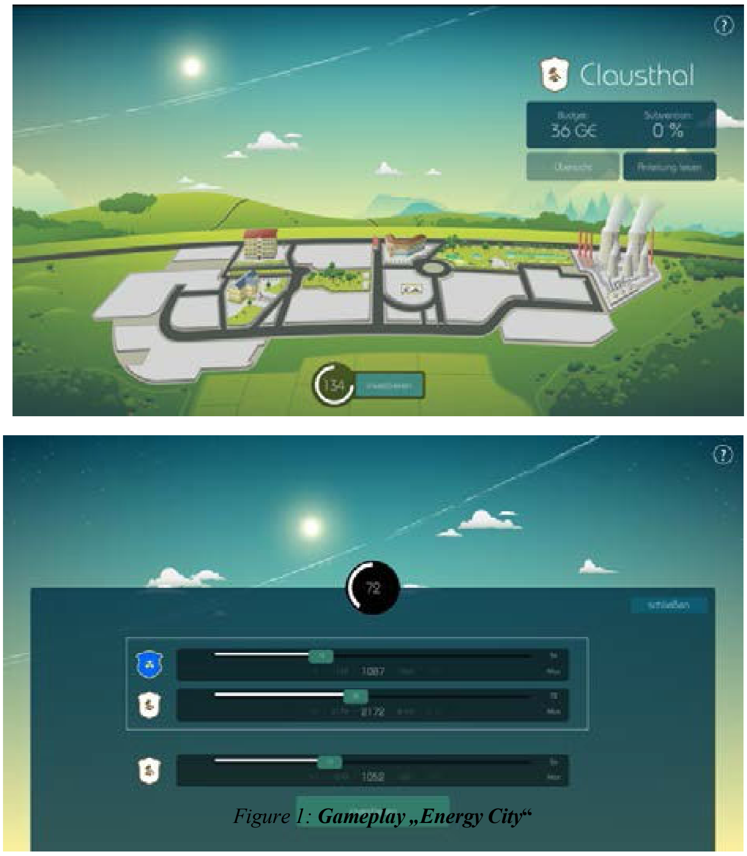

Figure 1: ***Gameplay „Energy City“***

Results and Conclusions

A pilot version of this experimental game will be conducted with upperclassmen of a German high school in September 2019. To our knowledge this will be the first economic experiment which combines experimental game theory and professional gamification. We will ask, wheter gamification which lays greater emphasis on an immersive framing of tasks in order to stimulate motivation and immersion of players tends to influence the results of standard experiments conducted in this field of research. Moreover, based on a well-defined treatment structure, the experiment will deliver answers how the skewness of endowments and the design of subsidies in order to compensate for positive externalities affect co-operative behavior of individuals.

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Francesco Benedetto, Loretta Mastroeni and Pierluigi Vellucci

IS FINANCIALIZATION OF ENERGY COMMODITIES STILL GOING ON? EVIDENCE FROM AN ENTROPY-BASED APPROACH

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Overview

Financialization is a recent phenomenon involving an unprecedented inflow of institutional funds into commodity futures markets. Started in the early 2000s, after the equity market collapsed in 2000, it revealed a rising in commodity investments from $ 15 billion in 2003 to $ 250 billion in 2009. These vast inflows are mainly attributable to financial institutions, insurance companies, pension funds – among others – and had important implications for commodity markets. For instance, over the years, because of the financialization process, commodity prices became more correlated with prices of financial assets. Meanwhile, the surges in crude oil prices has brought substantial impact to social economic development around the world. As a result, there can be found close interaction among these markets.

Method

To dig further on this analysis, we investigate whether the crude oil and natural gas market prices are influenced by the stock market risk aversion or investor sentiment as captured by the VIX and VSTOXX indexes, or whether these variables move all together. We model the information content exchanged between these financial time-series by adopting an entropy-based approach. Our approach has the advantage that it does not require a parametric model describing the transmission of information between the time series under investigation; it is also able to detect non- linear relationships and is robust with respect to non-stationarity. Modeling the flows of information between the analyzed data allows us to understand the capability of each of these series to predict the others.

Results

In this paper, we consider: CBOEVIX is the CBOE SPX VOLATILITY VIX (NEW) - PRICE INDEX (briefly denoted as VIX); VSTOXX is the EURO STOXX 50 Volatility (briefly denoted as VSTOXX); OILBREN is the Crude Oil-Brent Cur. Month FOB US$/BBL (briefly denoted as BRENT); CRUDWTC is the Crude Oil WTI FOB Cushing US$/BBL (briefly denoted as WTI); NATGHEN is the Natural Gas, Henry Hub US$/MMBTU (briefly denoted as HH); TRGBNBD is the TR Natural Gas NBP UK 1st Fut. Day – Settlement price (briefly denoted as NBP). With respect to the 2008 financial crisis we found the following findings:

- Before the crisis.
  - The relationships between oils and volatility series are relatively poor. It shows, however, an increasing trend along the entire time span.

- There is an important presence of mutual relationships in energy pairs. In particular, the European NBP shows high similarities with the two oil series with peaks in September 2006. A possible interpretation of this result may be found in the events concerning the Russia-Ukraine gas crisis of 2006.

- After the crisis. Oil and equity markets being more and more integrated, a piece of news impacting one of these markets can affect the other one.

Conclusions

The empirical results indicate that there is evidence of contagion: the information conveyed by a source (oil or natural gas markets) is shared with the other one (equity markets) and the amount of information increases with time, experiencing also a further expansion in the aftermath of the financial collapse of 2008 (news information impacting one of these markets can affect the other ones). In other words, there is no evidence of de-financialization for crude oil and natural gas markets after 2008.

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Dina Azhgaliyeva

RENEWABLE ENERGY DEPLOYMENT AND ENERGY STORAGE: EMPIRICAL EVIDENCE

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Overview

Renewable energy can reduce pollution in cities by providing renewable electricity, heating, cooling and transportation. The main disadvantage of renewable energy deployment, is that once it reached a high share in electricity generation, the intermittency caused by renewable energy sources makes balancing of the energy system challenging. This study answers the question "What is the impact of renewable energy on energy storage?" Empirical literature studying deployment of renewable energy is abundant, however empirical literature studying the energy storage deployment is highly limited due to data availability. Using panel data from 28 OECD countries over the period 1990-2014 this paper provides an empirical evidence on the role of renewable energy deployment and low carbon technologies policy on energy storage investment. The results of fixed effects estimation provide an empirical evidence that countries with greater share of renewable energy promote energy storage. Drawing from the empirical results and experience from Singapore, this paper provides evidence-based policy recommendations on integration of energy storage with renewable energy. The results will be useful for policy-makers from countries with a growing share of renewable energy in total electricity, by providing lessons from countries which experienced problems with high share of renewable energy and started to promote energy storage alongside with renewable energy.

Methods

Data on storage and intermittent energy are collected from four sources, i.e. International Energy Agency Energy Technology RD&D Statistics, International Energy Agency Renewables Information Statistics, International Energy Agency World Energy Statistics and Balances, International Energy Agency / International Renewable Energy Agency Global Renewable Energy Policies and Measures Database. All variables are across 28 countries over the period 1990-2014.

Several tests are performed to identify the suitable model for estimation. Fixed effects are identified using the Hausman test. The null-hypothesis of difference in coefficients is not systematic (random effects) in the Hausman test is rejected ($\chi^2(3) = 10.19^{***}$), in a favour of fixed effects model (Error! Reference source not found.). We failed to reject the null that the coefficients for all years are jointly equal to zero, therefore no time fixed effects are needed in this case ($F(24, 557) = 0.88$) with ($Prob > F = 0.6276$). The presence of heteroscedasticity is identified using Modified Wald test which tests for group wise heteroscedasticity in fixed effect regression model.

The null hypothesis of homoscedasticity is rejected ($\chi^2(29) = 2.1e + 05^{***}$) in favour of alternative hypothesis of heteroscedasticity. The presence of heteroscedasticity is corrected using robust standard errors. The absence of serial correlation is identified using Wooldridge test for autocorrelation in panel data. The null hypothesis of no first- order autocorrelation cannot be rejected ($F(1,28) = 1.02$ with $Prob > F = 0.32$).

Using the results of the above tests, fixed effects with robust standard errors is used as the most suitable model.

$$storage = \beta_0 + \beta_1 capacity_{it-1} + \beta_2 production_{it-1} + \beta_3 policy_{it} + u_i + \varepsilon_{it},$$

where storage is a share of expenditure on RD&D of energy storage technologies in total expenditure on RD&D of energy, capacity is a share of energy capacity of intermittent energy sources in total capacity of renewable energy, production is a share of electricity generation from intermittent energy sources in total electricity generation from all energy sources, including renewable and non-renewable and policy is a binary variable, which equals one from the year when policy to promote energy storage was introduced and zero zero before.

Results
Using data from 28 countries over the period 1990-2014 this paper provides an empirical evidence on the role of energy storage in renewable energy deployment. The impact of renewable energy generation on energy storage is presented in Table 1 column 2 "Fixed effect with robust standard errors". The results of estimation using other methods fixed effect, random effect and OLS are also presented for comparison. The preliminary results of panel data estimation provide an empirical evidence renewable energy generation promoted energy storage. This could be explained by the challenges caused by intermitted energy sources. Countries with greater renewable energy share will deploy more energy storage in order to overcome challenges associated with intermittent energy sources.

Table 1 Results

Variables	Fixed effect robust s.e.	Fixed effect	Random effect	OLS
Production	0.26*	0.26*	0.14	0.11
	(0.14)	(0.15)	(0.12)	(0.12)
Capacity	-0.02	-0.02	0.04*	0.04*
	(0.05)	(0.04)	(0.02)	(0.02)
Policy	0.01	0.01	-0.01	-0.01**
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.04***	0.04***	0.04***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)
Observations	613	613	613	613
R-squared within	0.01	0.01	0.00	
R-squared between	0.14	0.14	0.19	
R-squared overall	0.00	0.00	0.02	0.02
F-test (Wald χ^2)	2.16*	2.16*	9.25**	5.67***
Number of panels	29	29	29	

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Conclusions
We provide an empirical evidence that a greater share of renewable energy generation associated with a greater investment in RD&D of energy storage technologies.

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Diyun Huang

DYNAMICS TOWARDS THE NEW WORLD – ENERGY SECURITY AS SHAPING FORCE FOR REGIONAL COOPERATION IN EUROPE

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Overview

There is no consensus about what the concept energy security entails in the academic literature. Extended from the IRENA conceptualization, the main contribution of this paper is to provide a framework to analyse what energy security entails towards the new world with high renewable energy share. By examining the role of gas under climate policies, this paper directs additional attention to the transitional phase with the discussion of divergent consideration for switching fuel. Furthermore, a narrative is constructed with case studies to show energy security implication on the regional cooperation.

Method

The Institutional Analysis and Development Framework is employed to dig into the factors that affect the energy security perceptions for cross-border energy cooperation in Europe. This research analyses the elements from energy security concept from the two major international energy agencies. In its energy supply security 2014 report, IEA gives a definition: uninterrupted availability of energy sources at an affordable price. In the report, IRENA has mapped two main aspects in the power shift of renewable energy transition: 1) change of flow in fossil fuel trade; 2) the commercial race to be renewable technology leader. Taking the IEA definition of ‘affordable price’, energy affordability is added as the third dimension to complement the IRENA energy security concept. Germany and Poland are chosen to illustrate the to illustrate the divergence in pace and preference of European energy transition.

Result

Three energy security variables in the transition towards decarbonised energy future are investigated in German and Polish case studies: 1) desired change of fossil fuel flow; 2) affordability; 3) relative position in the race of renewable technology. Coincided with the absence of national player, the competitive market is at the centre to ensure security of supply for energy transition in Germany. Fast deployment of renewables provides alternative to import energy by domestic production and is perceived as an effective long term means to improve energy security. At the same time, sector coupling, in particular the potential for hydrogen, provides an opportunity to decarbonise heating and transport from renewable electricity. In the Polish narrative, the main policy objective is on changing direction of gas import in short term. The high affordability index suggests that the burden for vulnerable consumers will need to be addressed carefully in the energy transition process. The focus on different aspects of energy security has major implication for a country to position itself in the energy transition, its preferred technology paths and timing.

Conclusion

The asymmetry of the geopolitical weight, energy market development and the social economic factors of the countries that are interconnected shapes the dynamics of cross-border cooperation. Sector coupling between electricity and gas means that different preferences in gas import may create the momentum to identify which players are likely to move towards deeper intra-regional energy cooperation.

The desired flow change for gas import is influenced by the geopolitical perceptions of the countries that are interconnected. Social economic factors matter to provide affordable energy and determine relative position in the technology race. This research calculates the affordability index to represent the social differences and renewable energy technology patent as proxy to represent industry policy in clean technology. The combined effect of the three factors is an organic regionalization process different in pace and technology preference in the energy transition.

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SPATIAL OPTIMIZATION OF RENEWABLE ENERGY INTEGRATION FOR DECARBONIZING POWER SECTOR IN JAPAN

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Overview

Extensive penetration of variable renewable energy (VRE) such as solar PV and wind power has been observed in Japan ,which struggles with integrating them into the power grid. By developing an optimal power generation mix model with 383 buses and 472 power transmission lines in an hourly temporal resolution through 8,760 hours, this paper aims to analyze the optimal integration of VRE into a power grid in Japan under carbon regulation and to identify the best location of VRE to be installed in the grid so as to minimize power system cost and to decarbonize the power sector. Simulated results recommend the deployment of solar PV and wind power in the area with higher solar insolation and better wind speed as well as enough grid capacity, because higher solar radiation or wind speed contributes to reduce each required capacity and the associated investment cost, and VRE integration in area with sufficient grid capacity enhances the cost-effectiveness of VRE investment.

Methods

This paper performs an assessment of optimal VRE deployment including solar PV, onshore and offshore winds in power grid by developing an optimal power generation mix model. The model can uniquely specify an optimal VRE deployment together with power system operation through cost minimization of the power system. This paper enhances the authors' previously developed model [1][2], which, for example, deals with a grid topology at 352 buses and 441 power lines, to consider the country's power system including substations integrating offshore wind, 383 buses and 472 bulk power transmission lines, with an hourly representation through 8,760 hours. This paper assumes reference scenario and carbon regulation scenario which regurates the emissions at 60 g-CO_2/kWh achieving 80% reduction from the current level. Through the latter scenario, optimal VRE integration is analysed.

Results

In the author's previous study analysing optimal solar PV integration in the power grid [1], computational results reveal that optimal PV deployment shifts to the area with larger grid capacity and higher PV capacity factor, compared with the result in reference scenario. The authors extend the previous study to optimize onshore and offshore wind powers as well as solar PV. The simulated results imply that the optimization of the model promotes wind power integration in the area with favourable wind speed and near the area with intensive electricity demand. Although Hokkaido, the northerm part of Japan, has the largest wind potential in Japan, the scale of installation there is smaller than Tohoku which has the second largest wind potential in Japan and is located near demand-intensive Kanto (Tokyo) area. Because Hokkaido is located far from demand-intensive Kanto (Tokyo) area and large-scale deployment of wind in Hokkaido is not economically optimal. The results imply that spatial consideration is important for optimal wind power integration as well.

Conclusions
For evaluating the optimal VRE integration into power system, this paper develops an optimal power generation mix model characterized by 383 nodes with 472 bulk power transmission lines with hourly temporal resolution through 8,760 hours. The results suggest that spatial consideration is significant for optimal integration of solar PV, onshore and offshore winds to economically achieve deep cecarbonization of power system in Japan.

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Kristina Govorukha, Christopher Ball and Stefan Vögele

HOW REALISTIC ARE ENERGY INVESTMENT MODELS? REFLECTING ON GERMAN POWER PLANT INVESTMENT DECISIONS BETWEEN 2005 AND 2014

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Overview

A central challenge within electricity markets is to incentivize long-term investments on the part of market actors in low carbon generation technologies, renewables and capacity [1]. These long-term investments are essential to an efficient and sustainable power system, yet there is often patchy understanding about what drives investment decisions in particular technologies under “restructured markets” [2]. This relates to markets which have undergone liberalization, resulting in prices being set, to a far greater extent, on competitive wholesale markets as opposed to through regulated tariffs [3]. Under the liberalized power market model, common in the European Union, there has been a shift from centralized planning of generation investments to decentralized investment decisions, involving many profit maximizing actors [4], with long-term planning complex [5]. The future role of and investment in conventional plants is an important question [6]. In this paper, using two models that aid power market investment decisions, we aim to judge how accurately these models reflect actual investment decisions and their completeness in predicting real investor behavior.

Methods

Our paper uses two investment models: (i) the Electricity Market Model for Europe and (ii) a model based on Levelized Cost of Electricity (LCOE) optimization only. Under the EMME model, investment in generation and dispatch is optimized according to a set of endogenous parameters, whereas, under the LCOE model, the relative LCOEs of generation technologies within a technology bundle, designed to provide a certain level of constant generation, are calculated by using generalized data (e.g. on utiltization rates).
We perform the sensitivity runs with respect to changes in the investment and fuel costs, to analyze the effect on the full load hours of the newly installed capacities. Assumption about the full load hours is the most critical point in LCOE calculation when comparing attractiveness of the investment between technologies. The amount of the newly installed capacities and full load hours, resulting from the EMME model, would then be entered into the LCOE model to calculate the LCOEs of coal-fired plants vs. gas-fired plants in a technology bundle (consisting only of gas- fired and coal-fired power plants). The results from both of these models would then be compared with the generation capacity that was actually built between 2005 and 2014 in Germany to evaluate how accurately they predict investment decisions. This period is specifically interesting for its volatile prices on energy carriers, and policies that shaped the electricity market.

Results

Both the EMME and the LCOE model arrive at similar results based on full load hours and investment capacities:
i.e. on average, lignite coal is most competitive followed by hard coal and natural gas. Results in Figure 1 show that the full load hours for gas are highly sensitive to fuel costs and the investment in gas plants is also far more sensitive
to fuel costs than capital costs. Investment in hard coal-fired plants is not particularly sensitive to changes in capital cost. For gas-fired plants, there is an interaction effect between changes in fuel costs and changes in investment costs; increases in investment costs compound the effect of rising fuel costs on gas plant investment.

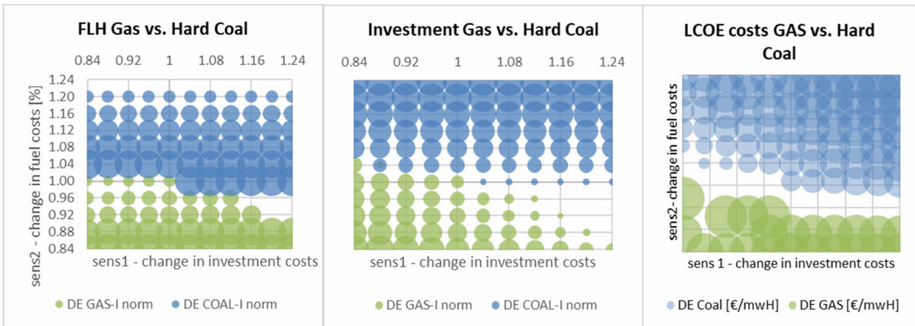
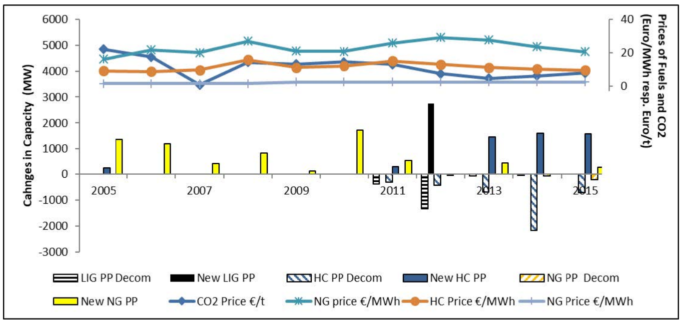


Figure 1: ***Model Results for FLH and Investment for 2010 Modelling Year***

Initial comparisons of these model outputs to actual investment behaviour (Figure 2) show a shift from intensive investment in gas in the first half (2005-2010) to a renaissance in coal in the second half (2010 to 2015). This may be to do with volatile gas prices and the collapse in the carbon price. The real data shows a weak correlation between fuel prices and full load hours for hard coal and gas which suggests other factors are at play in determining full load hours. Lignite is an exception, showing a strong correlation which indicates its fuel-based cost advantage is marginal. This is a discrepancy with model predictions.
Figure 2 shows that there are discrepancies between real behaviour (i.e. the full load hours vs. fuel costs) and model predictions which indicates that there are neglected factors that the investment models do not fully integrate.



Remarks: LIG: Lignite, HC: Hard coal, NG: Natural cas, PP Power plant, Decom: Decommision

Figure 2: ***Changes in Capacities and Key Parameters***

Conclusions

In the paper, we compare two different approaches focusing on investment decisions. In addition, we compare the achieved modelling results with the historical development. An interesting issue is the influence of mechanisms like CO_2 prices, their level and volatility on investment decisions and this will be probed further.

In complementing key input parameters of the two different models, (LCOE and EMME), to explain discrepancies between technologies favored by the models and real behaviour, this work may point to factors overlooked or underestimated when studying investment decisions. For energy modelling, this work indicates where discrepancies lie between predictions and real behaviour and what may cause these differences.

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Christian Haas and Karol Kempa
CLEAN ENERGY INVESTMENT AND CREDIT RATIONING

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Overview
The main market failure that is typically used to justify the promotion of clean energy investments is the negative externality caused by greenhouse gas emissions. Market failures of capital markets, however, are typically not taken into consideration in analyses of instruments for environmental policy. Most of the latter market failures are due to information asymmetries between the borrower (agent) and the lender (principal). We argue that these market failures, although they are not exclusive for clean energy projects, are particularly relevant for these investments. Firstly, clean energy investments highly depend on services provided by capital markets. The cost structure of clean energy investments is dominated by capital costs, as these investments have high up-front investment and low operating costs (Evans et al., 2009; Wiser et al., 1997). Secondly, the information asymmetries between potential borrowers and the lender are particularly high for clean-tech investments, because (i) rather new technologies are used, where the lender has reduced information on the return-risk profile (Carpenter and Petersen, 2002) and (ii) young and small clean-tech firms do not have a relationship with a bank, which further fosters credit rationing (Berger and Udell, 2002).

Some previous papers addressed the role of financial market failures for clean energy (see, e.g., Kempa and Moslener, 2017; Stern and Rydge, 2012). To our knowledge, there is no systematic theoretical analysis of the role of information asymmetries and potential credit rationing in the context of clean energy investments. Our theoretical approach builds on previous studies that analysed whether public intervention on financial markets can correct market imperfections (see, e.g., Arping et al., 2010; Gale, 1990; Philippon and Skreta, 2012). In this paper, we extend the credit rationing model of Janda (2011) by introducing emission externalities. Investors can choose between two types of projects: a dirty investment without risk (e.g. a fossil fuel plant), which causes emissions, and a clean investment (e.g. renewable energy), which is risky and requires a bank loan. There are two types of agents in the dirty sector differing in the amount of emissions associated with production (high and low). In the clean sector, there are two types of potential borrowers that differ in their probability to successfully finish a clean energy project. As there is an information asymmetry between the potential borrowers and the lender (bank), the latter cannot distinguish between both types of potential borrowers.

Our theoretical analysis is structured as follows. We first analyse the model without policy intervention and then introduce an emissions tax to address the negative emission externality. As a next step, we introduce interventions on the credit markets, i.e. interest rate subsidies and loan guarantees, in order to address the remaining capital market failure related to clean-energy investments. We then assume a situation, where an emission tax is (politically) not feasible and analyse, whether investment support instruments alone might lead to a similar outcome compared to the case with emission tax. Finally, we provide comparative welfare analysis of the scenarios and a discussion of dynamic effects.

Methods

We use a theoretical principal-agent model with information asymmetries between potential borrowers (clean energy sector) and lenders.

Results

First, we find that without any policy intervention all agents choose the dirty (fossil fuel) project. When introducing an emissions tax, those agents with high emission levels switch to the clean sector and thus apply for a loan to undertake the clean energy project. Due to information asymmetries, however, there is credit rationing. Some of the potential borrowers, namely those with lower probability of successfully finishing the project, do not receive financing although those projects would be socially beneficial.Second, an additional intervention of the government on the capital market by introducing an interest subsidy or a loan guarantee successfully eliminates credit rationing and hence improves the outcome.

Third, we find that, in the absence of an emission tax, the interest rate subsidy is also capable to induce a switch of some agents from the dirty to the clean sector. Compared to the emission tax, however, this policy intervention induces inefficiency as there is no efficient self-selection of agents that choose to switch to the clean sector.

Fourth, a comparison of the scenarios with and without emission tax shows that the former, where each of the two externalities is addressed with an appropriate instrument, yields socially better results than latter, where the government only intervenes on capital markets.

Fifth, we show that any intervention on capital markets is finite, as credit rationing vanishes due to increasing success probabilities of high-risk borrowers in the clean energy sector. Even when the government does not intervene to address the credit rationing, it will disappear at some point. There are, however, costs of delay if the government only addresses the emission externality, but does not deal with credit market failure.

Conclusions

We offer a novel theoretical approach to jointly analyse emission externalities and capital market failures related to clean energy investments. Overall, we find that these externalities can be best eliminated by addressing both with respective instruments, i.e. a tax on emissions and interest rate subsidies or loan guarantees. We find that, in a world without a CO_2 price, investment subsidies and these financial instruments are also capable to induce a switch to clean energy. This case is, however, more costly to society. These results have high policy relevance as climate policy is increasingly using investment support / financial instruments, such as grants, concessional loans, and guarantees, while a CO_2 price seems to loose relevance. Our findings stress the importance of a CO_2 price and indicate that a shift towards relying too much on investment support instruments bear the danger of substantially increasing the costs of the transition to a clean economy.

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Mario Iannotti

THE MAIN RESULTS OF THE 2nd ITALIAN CATALOGUE OF ENVIRONMENTALLY HARMFUL AND FRIENDLY SUBSIDIES

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Disclaimer: The views and opinions expressed in this article are those of the author and do not necessarily reflect the official policy or position of any agency of the Italian Government.

Overview

The attention to environmentally relevant subsidies by the International Institutions, particularly Environmentally Harmful Subsidies (EHS), has grown in time. In the last thirty years, the environmental impacts of subsidies have been the subject of study and research by IGOs (International Governmental Organizations) such as OECD, International Monetary Fund (IMF), World Bank, UNEP, FAO and European Environment Agency. G7 and G20 have also tired to translate research into policy action. Related to this warning, the Italian Parliament tasked the Italian Ministry of Environment to provide a Catalogue of Environmentally Friendly Subsidies (EFS) and Environmentally Harmful Subsidies (EHS). The purpose of the Catalogue is to support the Parliament and the Government in defining environmental policies aiming to implement, at national level, EU and international recommendations. In order to reach the objectives of the Paris Agreement on Climate Change, subscribed by more than 180 countries in the world, the international community recommends “pursuing efforts to limit the temperature increase to 1.5 °C above preindustrial levels” by the end of the century.

Method

According to the national Law on green economy and resource efficiency (n. 221/2015, article 68)[1] “the subsidies are considered in their broader definition and include, among others, incentives, benefits, subsidized loans, exemptions from taxes”. It is a definition which matches with the OECD definition, widely shared by most of the scientific community. In terms of classification, the Catalogue divides the subsidies into two main categories: direct subsidies (spending laws) and indirect subsidies (or tax expenditures). Moreover, “implicit” subsidies are also included within the indirect subsidies. Implicit subsidies can result from standard taxation system and can promote or encourage environmentally friendly or harmful behavior and choice of consumption (and production). The Catalogue examines some methodologies (e.g. quickscan, checklist), with the aim of providing policymakers the information needed for EHS removal and the adoption, strengthening and efficiency of EFS, as well as it illustrates different methodologies for their quantification (e.g. price gap, social marginal cost).

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[1] Art. 68 of Law 28 December 2015, n. 221, Measures for promoting green economy and limiting the excessive use of natural resources (issued in the Official Journal n. 13 on 18-01-2016, entered into force on 02-02-2016).

The economic estimates and financial impact of the tax expenditures have been sourced from Notes to the Accounts of Central-Government Budget, 2018-20 and the Italian Catalogue on Environmentally Harmful and Friendly subsidies.

Results

In 2017 the estimated financial impact of the EHS and EFS accounts for approximately 41 € billion. The Catalogue

analyses the subsidies by sector: agriculture, energy, transport, VAT and other subsidies. It identifies 161 subsidies, for 2017, and estimates EFS equal to 15.2 billion € and EHS equal to 19.3 billion €. In particular, FFS (Fossil Fuel Subsidies) are estimated at 16.8 billion €.

Conclusions

Authoritative international organizations, such as the International Monetary Fund, include in the definition of subsidies the external costs of economic activities (cfr. IMF 2014). However, the analysis and the quantification of the implicit

subsidies would require a special national monitoring mechanism of the external costs of economic activities, which is currently not available and could be prepared in the near future. Hence, it is recommended to:

improve the knowledge base in support of spatial impact assessment of each type of aid including, direct subsidies, tax breaks and implicit subsidies associated with the incomplete application of the Polluter Pays Principle;

FFSs expenditures are estimated at 16.8 €billion for 2017. These amounts should be cut progressively and could be used for one of the following targets (or a mix of them): the reduction of income taxation, in particular on jobs

generated by green economy; innovation and diffusion of low-carbon technologies and products; financing of sustainable patterns of production and consumption; the revision of the financing of energy production subsidies from

renewable sources; increased financing of energy efficiency measures; the reduction of accumulated public debt.

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Idowu Daniel Onisanwa and Mercy Ojochegbe Adaji

ELECTRICITY CONSUMPTION AND ITS DETERMINANTS IN NIGERIA

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Overview
Low and fluctuating income coupled with epileptic supply of electricity and rising demand for electricity make determinants of electricity consumption an important issue in developing economies like Nigeria; given that electricity is essential for the development of any economy. This paper, therefore, examines the determinants of electricity consumption in Nigeria with emphasis on income per capita, number of electricity customers, and electricity distribution shortages.

Methods
The study is anchored on the Utility Maximizing Behaviour of consumers given their level of income. Data were sourced from the Energy Information Administration (EIA) database and World Development Indicator, 2018. An Autoregressive Distributed Lag (ARDL) technique was used in estimating the factors influencing electricity consumption in Nigeria over the period of 1981 to 2017.

Results
The result reveals that the major propellers of electricity consumption in the long-run in Nigeria are per capita income, population per square kilometre, number of electricity customers as well as electricity shortages. The result refutes the hypothesis that electricity consumption increases with rising level of income. Electricity consumption increased with increasing number of population in a given area and number of electricity customers, while electricity shortages distribution has a differential effect in the short run and long run.

Conclusion
The research focused on the determinants of electricity consumption instead of energy that has been extensively researched. This study contributes to existing literature on the determinants of electricity consumption in Nigeria by including electricity distribution shortages, number of electricity customers, and population per square metre. There is a need for an efficient electric power generation in Nigeria to boost economic activities. Alternative sources of energy that are cost efficient and environmental friendly should be encouraged by policy makers.

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Claudio Alimonti, Davide Scrocca and Elena Soldo
GREEN PERSPECTIVES TO REUSE OIL & GAS WELLS IN ITALY

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Overview

One of the main challenges of the future is the decarbonisation of the energy sector. Finding alternative energy sources to hydrocarbons and integrating different energy sources, are some of the current objectives of R&D departments of many companies.

Since ’90, American and Chinese oil companies have studied the possibility of co-producing geothermal energy from oil and gas wells arrived in the mature stage, in which the production is often associated to a large amount of formation waters. Increasing the maturity of assets, the water production increases, so when the hydrocarbons wells are going to be depleted, they can be converted into geothermal wells. Regarding the use of geothermal energy, the direct use of thermal power or the electrical power generation are the available options. The selection of the final use and the geothermal potential depend on the temperature, pressure and flow rate of water, which are function of local geothermal gradient, well depth, and poro-perm properties of the reservoir rocks.

The paper presents a preliminary evaluation of the potential reuse of oil and gas wells located on Italian territory. In Italy there are 1613 oil and gas well actually opened, 895 on shore and 718 off shore. Selecting only the wells with bottomhole temperature greater than 60°C, 58 wells result suitable for mid enthalpy geothermal applications. A conversion strategy for two wells located in the Ragusa area (Sicily) is proposed: the reuse of the wells takes into account the activities and the land use of the territory.

Method

The information concerning 577 fields located in Italy were available. Among them, only 127 wells result to be opened, as declared from MISE. The proposed selection method is based on the reservoir temperature. In the first step the position of the wells has overlapped with the isotherms at 3000 m and only the wells which are likely to have temperature above 70 °C have been considered. The result of this procedure leads to have 39 wells.

Then the criteria has been extended, extracting the fields with depth in the range 2000÷3000 m with temperatures higher than 70°C. 7 additional fields located in Sicily emerged from this selection.

Other 12 fields in the Fossa Bradanica area have been added considering also the fields with temperature above 60°C and depth between 2000 m and 3000 m.

Two wells in the area of Ragusa have been selected and analyzed in order to propose a conversion strategy.

Results

The analyzed wells have a depth of about 2600 m and an outlet temperature of 40°C. The company has also a 981 kW electrical power cogeneration unit.

The proposed reuse strategy has the target of keeping the cogeneration unit working and to produce gas and eventually other products related to the oil & gas industries. So the produced water is used to feed an Anaerobic digestor in cascade with algae for biodiesel production.

Conclusions

The conversion of hydrocarbons fields into geothermal ones may be an opportunity to create a positive social response in the area where the oil and gas wells are already located. The use of existing wells is a benefit for the oil companies, which avoid the cost of mining closure of the wells and for the geothermal companies, which avoid the cost of drilling new wells. A major obstacle is constituted by the administrative procedures to achieve a transfer from a hydrocarbon license to a geothermal one.

A preliminary evaluation of the existing potential is ongoing. The applied method suggests the suitable range of temperatures, depth, pressure and flow rate for the technologies and uses of geothermal sector. 58 wells have been

selected using the proposed criterion.

The evaluation of the case study demonstrates that the reuse strategy can be adapted to the activities of the territory,

not searching a conventional solution but driving the project towards an approach of circular economy.

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Milan Hudak

ARE WE HEADING TOWARDS GAS OPEC? GAS MARKET INTEGRATION, LNG AND IMPACT ON THE EU.

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Overview

Strategic role of natural gas in the EU energy mix is growing. EU demand for natural gas increased in 2017 by 5% and with the effort to decarbonize electricity generation by 2050 gas is being recognized as a bridge fuel for supporting clean intermittent renewable resources. With this new position, understanding gas market integration and process of price formation is important for policy makers, market participants or industrial consumers. Even so, understanding LNG price dynamic is important with relations to the EU energy security, also from the perspective of changes in supply dynamics with Nord Stream 2 and expiration of Ukraine transit agreement with Gazprom.

This upcoming paper studies how gas prices in the EU, Japan, US and spot LNG integrate. It provides econometric evidence for growing market interdependence around world, while explains some recent patterns in price development with focus on LNG. Research is built on econometric analysis of price formation based on futures prices of Dutch trading hub TTF, German NCG, JKM index for Asian gas prices, Henry Hub for the US gas and EAX for East Asian LNG prices.

Methods

To investigate price integration across major global gas markets, we analyze trading patterns and structure of the European, US and Asian gas markets. We run Johansen test for cointegration to examine presence of market convergence between prices in the studied markets. Scholarly literature already offers evidence of gathering pace of market integration in Western Europe and the US, while these studies cover mostly market integration in the early stages of gas market liberalization. Our research explores price convergence after 2013 when market liquidity across studied markets accelerated and when LNG trading increased in activity following the opening of new liquefaction trains in the US, Qatar and Australia. If we find that prices in studied trading areas exhibit a common stochastic trend, we will consider this as an evidence of market integration.

At second stage we test prices for direction of causality by applying Granger causality tests to identify direction of changes in prices and eventually, we will look at dynamic aspects of convergence in gas prices by applying Kalman filter.

Results

Preliminary results of the ongoing research points towards cointegration between all studies markets and establishes that there are five cointegrating equations at 1% and 5% critical value. Therefore, prices in the studied markets tend to move in the same direction as other markets, what is a sign of existing market integration. This also holds true when testing single markets with each gas trading area separately (e.g. TTF and HH, TTF and JKM etc.). Studied markets are interrelated and follow some common trend.

These preliminary results correspond with findings in Asche, Misund and Sikveland (2013), which detected cointegration between NBP, ZEE and TTF, in Growitsch, Stronzik and Nepal (2013), whose study provides evidence for market integration between TTF and German gas trading hubs, with Dutch prices leading the pricing determination at NCG and GPL, in Siliverstovs, et al. (2005), which focuses on prices in Japan, US and Europe and in (Renou-Maissant, 2012), which showed that even gas prices for industrial use in six European markets show integration over the period 1991-2009.

Conclusions

Focus of the upcoming paper and research is to address and to understand price dynamics in the changing global gas market environment and to review current fundamental developments through prism of gas market prices by applying econometric analysis. Preliminary results confirm that prices converge in the EU markets and at the global level. Observed growing market interdependence between Asia, the US and the EU might be explained by the linkage of local markets with LNG. This development is present not only in the results based on econometric analysis, but also in market realities as supply overhang in 2018-2019 have increased “speed of convergence” between markets. Eventually, early findings from this research point to two observations and potential policy implications. First, infrastructure interconnectedness like in the EU or in the US increases security of supply, supports cross border arbitrage and allows gas flowing between various markets. Diversity of sources recently underpinned also by LNG flexibility offer higher level of security of supply, provides trading opportunities and that might help to limit pricing power of dominant suppliers in the EU, such as Russia or Norway. Second observation is that presence of open well- regulated markets supports transparent price formation, while at the same time it is crucial for reaping benefits from higher gas infrastructure interconnectedness. Subsequently, arbitrage and hedging help to support increase in liquidity, decrease transaction costs, what ultimately benefits utilities and industrial end-consumers.

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Rui Shan, Yaojin Sun and Sylvain Audette

BITCOIN MINING TO REDUCE THE RENEWABLE CURTAILMENT: A CASE STUDY OF CAISO

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Overview

High energy intensity is an enduring problem for the cryptocurrencies, especially for those based on Proof-of-Work like Bitcoin. With electricity as the main cost input, the mining machine are really mining Bitcoin from the public network. Many researchers[1-3] gave estimations of the global energy consumption caused by Bitcoin. Energy demand not only comprises the largest share of the operation cost of Bitcoin mining, but also as the potential to pose a considerable hindrance to the climate agenda[4,5]. An approach to reduce the emission from electricity is to deploy and utilize more renewable sources like solar and wind. However, the rapid development of renewable power plants along with the intermittent nature of solar and wind, causes the curtailment problem which means the excess generation could not be delivered to the grid due to congestion and energy demand. This curtailment problem leads to lower electricity price, sometimes even negative, reducing the financial return for renewable electricity investors and the motivation for more project development[6]. One question investors and regulators would certainly like to explore is to better understand whether or not Bitcoin mining could act as a driver of renewable projects in the future, using the curtailment problem as an opportunity.

This paper will use historical curtailment data from the California Independent System Operator (CAISO) and Bitcoin market information to analyze the profitability of the combination of curtailed energy and Bitcoin mining. Then the sensitivity analysis will tell how it is affected by the Bitcoin market, mining machine market, and the distribution of curtailment energy. Finally, the potential policy implication is discussed.

Methods

Due to the data availability of CAISO data and the monotone increasing price of Bitcoin in the early years, the scope of this analysis is limited to the full year of 2018 at the daily temporal interval. According to the design of Bitcoin[7], we can calculate the amount of Bitcoin mined based on the following equation:

$$B_{machine,t} = \frac{H_{machine} * n_t}{H_{network}} * B_t$$

$B_{machine,t}$ denotes the Bitcoin mined by the machines on day t;
B_t denotes the Bitcoin produced by the network on day t. In 2018, B_t=1800;
$H_{machine}$ is the hash rate of one machine (TH/s);
$H_{network}$ is the hash rate of the whole network (TH/s);
n_t is the number of working machines deployed in the system;

$$n_t = min(N, \frac{E_{curtail,t}}{Power * T_D})$$

$E_{curtail,t}$ is the curtailed energy in CAISO on day t in MWh;
$Power$ is the rated power of one mining machine;
T_D is the time of a day, T_D=24hr
N is the total number of machines in the CAISO system.

$N$is the total number of machines in the CAISO system.
The profit is the revenue of Bitcoin sold everyday minus the initial capital cost of mining machines. The machine
is assumed to be Antminer S9 because of its median performance and price among other products in the market at the end of 2017. The optimal number of machines to purchase is determined through a simple searching algorithm, that is to calculate the profit for every number of machines and to choose the most profitable setting. Specific regulatory and rate issues depending on geographic location of Bitcoin mining facilities in California were not controlled for this first paper on the topic by the authors.

Results
The algorithm reveals that when to purchase 0.4 million mining machines, the system can achieve the highest profit as 18.9 million dollars and reduce 61.21% curtailment. When these mining machines are shifted from the end-user side in CAISO to this setting, the reduced carbon emission is about 0.5 million tons of CO_2 with the same amount of Bitcoin mined

When the price of mining machine changes between -60% and 60%, the maximized profits will change between - 53% and 121%. As for the curtailment, the highest curtailment reduction (-87%) happens with a 60% decrease in machine price. No matter how the machine price changes within ±60\% range, the initial investment remains relatively constant within the range of 7%~-32%. This insensitivity of initial investment to the machine price simplifies the budgeting process.
In terms of the volatile Bitcoin price and the network hash rate, the simulation finds that a higher capacity factor of the machine can increase the probability of making a profit. Since the operation cost is almost negligible and the revenue is always positive, the more curtailment is used, the higher profit it will earn, with a given number of machines. However, the capacity factor relies on the availability of the curtailment and the number of machines. When more machines are purchased, more energy will be consumed, but less energy will be distributed to each of them, lowering the capacity factor, although the total profit may increase.

Conclusions
This paper simulated the revenue and cost from Bitcoin mining if the mining machines used the curtailed energy in CAISO in 2018. The net profit is about 18.9 million dollars and the curtailment also reduces 61%. Although these numbers are subjected to the change of machine price, electricity rate and regulatory issues, bitcoin price and the hash rate, they can qualitatively tell that by combining Bitcoin mining and renewable curtailment, we can mitigate the environmental concerns and generate economic benefits.

Despite the change in machine price, the optimal capital cost is relatively constant, making the budgeting process more reliable. Using curtailed energy for bitcoin mining, the risk of losing money depends on the capacity factor of machines. With a higher capacity factor, it is less likely to lose money. Nevertheless, a high capacity factor may not bring a high profit due to the constraint of curtailment availability and the curtailment usage rate is negatively associated with the capacity factor. If the curtailment is uniformly distributed, the mining machines can work continuously, reach almost 100% capacity factor, and consume the most curtailment energy. However, such an ideal scenario with maximum profit and maximum curtailment reduction is not realistic. On the other hand, this paper contributes to open the discussion about possible rate and regulatory issues we saw in many jurisdictions in North America at the end of 2017 and early 2018. System planner, investors and regulators all need more studies like this one to find a suitable trade-off between environmental goals, reducing curtailment with negative pricing, and maximizing usage of existing public infrastructure, to make reasonable profit with acceptable risk for each players in the market.

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Gianluca Carrino

TURNING ROME INTO A ZERO WASTE CAPITAL: TOWARDS A CIRCULAR ECONOMY SYSTEM

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Overview

In a scenario where the process of transition to a sustainable zero-emission economy has an increasingly growing influence, the uncontrolled production of waste has become an urgent issue for our ecosystem.

With the increase of the population consumption, the total amount of waste produced and thrown irresponsibly into the environment is growing steadily (particularly in Italy the problem is aggravated by poor information of the public and inefficient administration that leaves ample room to illegal methods of waste disposal called " ecomafia").

For this reason, efficient actions must be taken to prevent waste from being dispersed into the environment or in landfills, and to convert them into energy (energy recovery).

Giving an intrinsic value to waste may turn into an incentive to manage it correctly and prevent its dispersion in the environment.

The European Union is at the frontline of efforts to implement an efficient Circular Economy system.

Directive 2006/12/CE, in fact, provides a regulation framework on effective and innovative waste management adapting technological developments to the waste-production scenario at local level.

This would result in the requirement for each Member State to consider waste as a raw material, to reach autonomy in waste elimination, to minimize waste transportation and to optimize disposal processes while minimizing environmental impact.

Are we doing it right?

Method

In order to be aligned with EU Directive 2006/12/CE, Italy needs to invest in technology and in clear policies/regulations which are essential to simplify bureaucracy and to reduce the use of landfills as well as the transportation of waste inside (from a region to another) and outside the country.

Consequently it is fundamental to implement a national strategy and an action plan (consistent with European Strategies) able to exploit Italy's potential and to promote a Circular Economy model.

The Circular Economy focuses on the production, consumption and management of waste concentrating on innovation, development of investments and employments while promoting the bio-economy.

In addition, working on incentives for and the development of a circular economy will support the climate, ecological and social challenges proposed by the "Green Economy" increasing at the same time the competitiveness of Italian' companies.

Under an Italian perspective, the Municipality of Rome is the one facing the most challenges and holding the most critical position due not only to an unsustainable plants - that appears to be affected by a chronic shortage of the system, composed of intermediate treatment plants (MBT and MT), but also because of the non compliance of AMA (the company in charge of waste-collection in the capital).

Taking into account the data from Lazio Region[1] in 2017, the municipality of Rome reached almost 58 % of the total urban waste generated overall within the region. It appears therefore necessary to provide proper technologies to the Lazio region and the municipality of Rome such as composting or energy recovery plants in order to manage in an efficient way the total waste produced and to reduce the level of exportation to other regions or even outside the country.
Moreover, it is fundamental to underline that the 66% of the thermal incinerators are located in the northern regions; according to ISPRA's data in fact, Lombardy has 13 plants follow by Veneto with 8 (Lazio nowadays has just 1)[2]
In conclusion, to manage waste in an efficient way and address them to "waste-to-energy power plants" - creating "clean" electricity and heat - would appear to be essential to invest in facilities and technologies within the Lazio Region and inside the cities. The installation of those plants will create significant benefits increasing the employment rate and reducing in the same time the reliance on third parties.

Results

Nowadays the situation appears to be heavily dependent on extra-regional engineering systems.
In particular, the situation in the city of Rome does not respect European Directive 2006/12 /CE, producing almost 66.4% [3] (166 thousand tons) of the total waste destined for treatment in plants outside the region.
But, why turn Rome into a Zero Waste capital?
Following data from Regione Lazio, in 2017, the Municipality of Rome exported to Austria around 50,520 tons of non-recyclable waste. For each tonne of waste, AMA paid € 139.81, for a total of approx. 7 million €.
If this outstanding amount was invested towards innovative and sustainable technologies, it would have given clear and relevant benefits as proven in other European countries such as Germany, Austria, Netherlands and Sweden.
The process of transition from a linear economy (based on: take-make-dispose) to a circular economy necessarily requires to bear transition costs, but it would bring perhaps significant economic, environmental and social benefits.
A striking and huge example is the Copenaghen's Amager Bakke-CopenHill plant, which cost 470 million € and has replaced the old waste-to-energy incinerator. It burns 400 thousand tons of waste a year to produce electricity and heat for 150,000 homes in Copenhagen, and the only thing released by chimneys, according to authorities, is water vapour, thanks to the new generation filters which are able to retain all harmful fumes and dust.
Moreover, this plant offers different touristic attractions considered a value added and a perfect example of a Smart City where technology, architecture and social life are interconnected in a sustainable way.
Therefore, an efficient circular economy would reduce the demand for imported raw materials, decreasing dependence on foreign countries and reducing the uncertainty caused by factors of scarcity and/or geopolitics.

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[1] Piano di Gestione dei Rifiuti della Regione Lazio - Linee Strategiche, Gen 2019, Regione Lazio
[2] Rapporto Rifiuti Urbani 2018 - ISPRA
[3] Piano di Gestione dei Rifiuti della Regione Lazio - Linee Strategiche, Gen 2019, Regione Lazio

Conclusion

In conclusion, the logic of the circular economy is that waste can function as a “fuel” for other processes. It is therefore an opportunity to significantly improve the ability to obtain economic benefits from the use of natural resources.

The main problem, which makes Rome's current production and consumption model unsustainable, is how to dispose waste.

In the Lazio region, the possibility of allocating new sites to landfills has become increasingly difficult. It is fundamental therefore to find alternative solutions.

The European directives of the "Circular Economy Package 2018 " set the goal of reaching the 65% in urban waste-recycling and shifting to below 10% in the use of landfills by 2035 (recycling capacity in Italy is just over 50% and landfill is still 25%).

Nevertheless, the National Report “The Circular Economy in Italy - 2019” has found positive results; the report highlights that Italy can not be satisfied because looking at the progress of the circularity index, it is slowing down. At the same time, other countries are instead growing thanks to the new measures required by EU Directives (in 2018, Italy grew by just one point in comparison to the previous year; while France grew by 7 and Spain by 13).

In order to focus on research and innovation it is necessary to improve specific tools to re-launch the role of cities and urban regeneration, to accelerate the approval of European directives and dedicated infrastructures.

Recovering more resources from waste means using raw materials more efficiently and diversifying them, designing, distributing and selling products according to another conception of value creation - from a product to a service.

However, it is essential to underline that factors such as corruption and “eco-mafia”, slow down the actual development of effective solutions, especially in Rome, Lazio (according to Legambiente’s report on "eco-mafias" 2019, the Lazio Region appears to be in the top position for illegal waste disposal crimes - one of the most lucrative and dangerous field of eco-mafias’ activities).

A cocktail that, mixed with a slow and confusing bureaucracy, reduces the development of an efficient Circular Economy (for example it takes 7 years to begin construction works of an incinerator).

Therefore, the plant configuration of the Lazio Region does not allows the closure of the urban waste management cycle which it should guarantee not only the location of undifferentiated urban waste but also waste produced by intermediate treatment plants (MBT and MT).

Tamara Favaro

BLOCKCHAIN TECHNOLOGIES FOR ELECTRICITY TRADING REGULATION

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Overview

Nowadays, there is an increasing interest for the adoption of Blockchain technologies within the energy sector, especially for peer-to-peer trading applications. However, there are at least two trends typically emerging in most of the literature. Firstly, the application of Blockchain technologies and its principles are often transposed in the energy sector without focusing on the particular advantages or disadvantages that different platforms may bring. In fact, in order to validate the reasons behind Blockchain adoption, it is common to generically recall the characteristics of the first Blockchain, namely the Bitcoin's one, often forgetting that such a model loses its main features and advantages when applied to different and more specific contexts. As an example, a Blockchain specifically implemented for a microgrid in order to guarantee secure peer to peer exchanges between private individuals should also consider that, if the network is composed only by few nodes, there is not a great level of cybersecurity, since the so called "51% attack" becomes feasible.

Secondly, and more importantly, it is currently missing to our knowledge a focus on how Blockchain platforms applied to energy sector may concretely affect energy market regulation. In particular, it is not clear yet whether and how it could guarantee that new form of interaction between regulators, citizens and industries often emphasized by optimistic literature (Aste et al., 2017). Usually, when analyzing the relationship between Blockchain technologies and regulation, the starting point is the technology itself, and regulation is at most considered as a possible unidirectional incentive or disincentive driver of technology adoption. The aim of this work is to revert this relationship, namely analyzing how Blockchain technology might affect the regulatory mechanisms and the need of public intervention in the electricity market.

Methodology

The state of the art will be analyzed with the aim to investigate if and why Blockchain should be implemented among well-defined peer-to-peer energy trading contexts and, if so, what specific key features Blockchain should have. Then, the evaluation of some case studies will be aimed to explore how Blockchain could affect the need of regulation and its potential ability to solve market failures. A special emphasis will be given to Blockchain application in the emission trading contexts, considering the growing interest of such topic also for economic literature (Gerbeti & Catino, 2019). The purpose is to consider if Blockchain may even replace the current systems of certification and – more broadly – the creation of ex lege market mechanisms.

Results

Blockchain platform would guarantee a new form of consumer empowerment, boosted by the so-called "Winter Package" recently approved. Furthermore, it seems able to replicate some types of regulatory interventions. However, assuming that Blockchain may actually be able to solve market failures, the need for public intervention should still be ensured.

At this regard, I suggest that smart contracts – used to allow peer-to-peer trading – could also represent an "entry point" for regulators in private transactions, assuring them a capillary, fast and efficient control of single energy exchanges, which nowadays is not possible.
So, smart contract should not be assimilated only to private-law contracts, but also considered as a mean of guaranteeing an instantaneous public control on single elements of private transactions.

Conclusion

This work analyses the adoption of Blockchain technologies in peer-to-peer energy transactions under a novel point of view, as a tool for promoting not only the advantages of decentralization, but also a new form of public intervention. Contrary to conventional wisdom, Blockchain peer-to-peer trading does not define only a relationship of "mutual suspicion and un-easy co-existence" between Blockchain technologies and traditional regulation (Yeung, 2019), but it allows a "virtuous cooperation", namely an evolution of public intervention modes in energy markets: peer-to-peer trading transactions could permit a new form of granular public control.

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Ionut Purica

IRREVERSIBLE THERMODYNAMICS VIEW OF THE NEED FOR A CIRCULAR ECONOMY

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Abstract

On a macro-economic scale the application of irreversible thermodynamics considerations shows that a more efficient economic organization (i.e. local decrease of entropy), has an impact on the environment that can be measured by the energy intensity dynamics. This component of environmental temperature increase, may be estimated as temperature increase values for selected economies. The reduction of this temperature increase may be done, in this case, by using circular economics actions that make more efficient the exchange of energy, resources and waste with the environment and generate technologies that turn the waste liabilities into assetts.

Key words: irreversible thermodynamics, climate change, energy intensity, circular economy

Karim L. Anaya and Michael G. Pollitt

UNDERSTANDING THE FUTURE OF THE ELECTRICITY DISTRIBUTION SYSTEM OPERATOR: AN EXAMINATION OF THE LARGEST NATIONAL FIRMS

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Overview

The traditional role of electricity distribution firms is thought to be evolving. A more active role is required in agreement with the proliferation of more decentralised generation and other resources that can help to deal with network constraints and balancing system issues. However, the evolution and maturity of the electricity distribution sector is very different across the world. There are a number of reasons that can explain this, such as a lack of or missing implementation of sector energy reform (usually associated with the sector re-organisation, unbundling rules and privatisation), government' intervention (in the form of subsidies and non-cost reflective tariffs), and other political and economic factors. Based on the important role envisaged for electricity distribution firms in the transition to a low carbon economy this study looks at the largest national electricity distribution firms in over 170 countries. We think that looking at the largest firm provides an important and concrete indicator of the current situation and capacity for involvement of the distribution system operator (DSO) in the future of the electricity sector. We observed key differences among them in terms of size (number of customers), level of unbundling, type of ownership, market concentration, and capacity for innovation.

Methods

The paper looks at the largest electricity distribution firms in over 170 countries. The analysis made in this paper is mainly qualitative, but some quantitative analysis is also provided based on the information collected for the largest nationwide firm (number of customers, market concentration) and key country development indicators. Information has been acquired mainly from primary sources and/or provided in some cases by representatives of the firms.

Results

An important dispersion is observed in the number of electricity distribution firms (per country) and customers.
Legal unbundling is observed especially in Europe, however ownership unbundling is ruled in few jurisdictions.
Some firms also provide in addition to electricity, gas and/or water services.
Most of electricity distribution firms are state-owned, others are private and few of them under mixed ownership.
High level of market concentration (over 80% national share) is exhibited in some liberalised markets, for example by Enedis (France) and E-distribuzione (Italy).
Electricity sector regulatory framework is constantly evolving with new/updated rules that facilitate the integration of distributed energy resources (DER). Some countries are more advanced than others.

Leading jurisdictions – where the future of the DSO is discussed most actively - such as New York, the UK and Australia are globally unusual in having medium sized, privately owned distribution firms.

The electricity distribution sector is changing but the level of the progress differs worldwide. Vertical integration and public ownership are still dominant characteristics. The role that firms have in the transition to a low carbon economy and the incentives for innovation are very different. This is supported by a set of interventions from government and national authorities to increase the share of renewable generation. However, this does not apply in less developed economies were the key supportive policies are still a work in progress.

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Larissa Fait, Elke D. Groh and Heike Wetzel

PREFERENCES AND WILLINGNESS TO PAY FOR REGIONAL AND GREEN ELECTRICITY - A STATED CHOICE EXPERIMENT IN GERMANY

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Overview

Facing the consequences of climate change, the shift in electricity generation from fossil fuels and nuclear power to more environmental friendly, renewable energy sources is a main target in order to drastically reduce CO_2 emissions. Therefore, the share of renewables in electricity generation has already increased significantly in the EU and Germany. In 2018, for example, 37,8% of Germany's final (gross) electricity consumption has been covered by renewables, mainly solar and wind power (UBA 2019). However, to limit the global temperature increase to 1.5 or 2 degrees compared to preindustrial levels, the share of renewables must expand further. This necessary expansion faces several challenges – not only technical and economical, but also social ones. Although consumers generally agree to the expansion of renewables, regional projects, especially wind power plants, face resistance. To address this lack of acceptance, the German legislator has amended the Renewable Energy Sources Act (EEG) to allow energy suppliers to provide their consumers with regionally produced green electricity. However, in order for this 'regional green power labelling' to actually increase acceptance, a demand for regional and green electricity is necessary. For this purpose, our paper aims at disclosing such preferences and willingness to pay (WTP) for regional green electricity, if any exist. Furthermore, we aim to identify specific consumer groups that are more attracted by new regional tariff options and should therefore be targeted.

Methods

In order to identify preferences for various products, including electricity tariffs, stated choice experiments (SCE) are frequently used in energy economics. A SCE is a stated preferences technique, which aims to determine trade- offs between different products features, so-called attributes. For this, respondents choose between two or more alternatives consisting of several attributes varying at different levels (Burky et al. 2015). Thereby, it is assumed that the choices correspond to the actual preferences of the decision makers (Hoyos 2010).

As regional green power labelling has only been legal since the beginning of 2019, stated preferences and a SCE are the best available approach to study preferences for regional green electricity. The SCE conducted in this paper consisted of six choice sets, each with three alternatives and a status quo option. The alternatives consist of five electricity-related attributes, each with five levels.

There are different econometric approaches to analyse stated choice data. In our paper, we used a mixed logit model (MLM) to estimate the preferences for the different attributes considered. MLMs offer crucial advantage over less flexible models, e.g. multinomial or conditional logit models. In particular, they allow us to estimate preferences taking into account individual taste heterogeneity of the decision makers.

Furthermore, WTP can be determined by weighting the estimated parameters of the attributes with the estimated cost parameter.
In addition, in order to identify different consumer groups, we conducted a latent class analysis. The latent class analysis allows to identify preferences under consideration of various socio-economic and attitudinal characteristics of the decision makers. Therefore, both preferences as well as WTP are estimated for the different groups.
Finally, our analysis provides insights into the preferences and prices for regional green electricity and can be used for further policy implications and the marketing of new regional tariff options.

Results
Our results confirm that consumers show significant preferences for electricity based on 100% renewable sources and show negative preferences for all other mixes considered. In addition, they prefer electricity which is produced regionally and are willing to pay a price premium for its use. This price premium amounts on average to 24% of current electricity costs for 100% regionally produced electricity compared to no regional production. In this regard, our results suggest that offering new tariff options under the regional green power labelling is reasonable. However, it should be noted that our results are likely to be overestimated due to a hypothetical bias and setting. Furthermore, switching behaviour of electricity tariffs is generally reluctant, as our results also indicate. Therefore, consumers with particular strong preferences for regional green electricity should be targeted. In this regard, our latent class analysis reveals that there are different consumer segments with varying preferences for regionally produced electricity. However, our results do not provide many significant insights into socio-demographic and attitudinal characteristics of these groups. For example, age and fear of climate change seem to reduce the probability that a consumer will belong to the group that has particularly strong preferences for regional production. Therefore, no clear marketing recommendations can be derived from this analysis.

Conclusions
Offering regional electricity tariffs is reasonable for energy suppliers since our results suggest high preferences and WTP for regional green electricity. Although the location of electricity generation seems to be less important compared to the electricity mix, consumers are on average willing to pay more for regional production. Therefore, our results differ significantly from previous studies (e.g. Kaenzig et al. 2013, Kalkbrenner et al. 2017). Accordingly, regulations like the regionally green power labelling seem to be reasonable.
However, in our study we only aimed at determining preferences for regionally produced green electricity. Whether new regional tariff options will actually increase the acceptance for the further expansion of renewable energies, and whether the regional green power labelling will thus fulfil its objective, remains to be investigated.

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Sabine Pelka and Marian Klobasa

APPLICATION FIELDS OF ARTIFICIAL INTELLIGENCE IN THE ELECTRICITY SECTOR - A SYSTEMATIC OVERVIEW

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Overview

With forecasting, scheduling and billing, the electricity sector is traditionally a data driven industry. At the same time, industry specific or general examples for planning or process improvements due to artificial intelligence (AI) are emerging. A comprehensive and systematic overview for application fields of AI in the electricity sector is missing. By creating a matrix for categorizing applications and clustering, the contribution of AI in the electricity sector and further development opportunities are highlighted.

Methods

For the development of a matrix for the systematic overview of applications a two-step literature review is conducted. In the first step, categories for the representations of energy or AI applications are respectively evaluated for their comprehensiveness and conciseness. These categories are combined and complemented for clustering the applications in one matrix with an energy and AI dimension.

In the second step, applications of AI in energy industry and research are extracted from the literature and classified in the matrix. In the last step, applications are clustered into application fields. Reasons for generating a cluster can be a high density
of applications in one category at the energy or AI dimension (e.g. different forms of predictive maintenance) or a similar composition of the applications (e.g. decision basis based on external forecasts and internal evaluations). Additionally, superordinate categories of the application fields are highlighted to give an overview of state of the art research and applications for AI in the energy sector.

Results

The matrix is based on the smart grid architecture model by Dänekes et al. 2014 for the energy dimension and a combination of application categories for AI by Döbel et al. 2018; Hammond 2016; World Economic Forum 2018 for the AI dimension. For the latter dimension, the three extracted sections image and face, voice and audio and general data processing are added by a combination of those in the form of robotics and assistance systems. For the energy dimension, the smart grid architecture model is chosen instead of the energy value chain, as it expresses the dynamic within the creation and new organization of energy applications in the course of the energy transition.

Several narrow AI applications for data processing to support decision-making processes

Narrow AI is already used in several applications focusing on data processing. These applications are based on forecasts, the analysis of the given conditions for one asset or actor and a matching of both elements to create recommendations for an optimized operation in the short term or an optimized asset base in the long term.

AI **in this category called "support in the decision making process"** enables the processing of more data, the identification of non-linear developments (Sharma et al.2011; Crespo-Vazquez et al. 2018) and detailed, tailored analysis for large- and small-scale applications

(Li 2003; Dai et al. 2018; Le Cadre et al. 2015). The latter is especially relevant for the participation of the consumer within in energy transition
(e.g. power-to-grid applications) (MacDougall et al. 2016; Lopez et al. 2019; Valogianni 2016; Jurado et al. 2015).

First broader AI applications to maintain and operate power plants and grids

Some applications focus on the technical aspect of asset management. For this **category called "the maintenance and operation of the grid and power plants**", more complex forms of AI are in use. Data processing is used for planning the tailored maintenance (predictive maintenance) (Boldare 2019; Merizalde et al. 2019) and detecting anomalies to prevent supply disruptions due to cyberattacks or malfunctions (Stetco et al. 2019; Campbell 2018). The data can be based on sensors, audio or visual collection. In case of maintenance, assistance systems and robotics using different forms of AI technologies help to find solutions based on categorization of the problem and putting it into practice.

AI applications to improve customer specific solutions

The last category focuses on the improvement of customer care. Whereas former business intelligence approaches are based on static, limited and predefined parameters, AI considers more data, automatically identifies new relevant parameters and enables more detailed recommendations for customer retention, customer acquisition or cross selling (Matz et al. 2017; Berman et al. 2019). At the same time, process automation for metering, billing and other retail activities help to cut down the costs (e.g. self-services, automatically categorized mail and generated responses) (Ilg 2018).

Need for research for organizing data autonomy, handling of black box models & reducing of computation time. Different authors highlight the shortcomings and need for further research. The most important aspects are the transparency, autonomy and pricing of data usage (Palmetshofer et al. 2016; Schweitzer and Peitz 2017), the handling of black box models (Stetco et al. 2019) and the reducing of computation time (Jurado et al. 2015).

Conclusions

Overall by using AI in the energy sector, the three categories show potential for a higher degree of automation and a more detailed data analysis. This could enable a higher level of utilization of the given assets and could raise efficiency gains along the entire value chain. The state of the art research and application in the electricity sector focus on narrow AI applications mainly to optimize decision making and related system operation. Promising fields for AI applications are customer focused solutions that allow to participate in the energy markets more directly. The main research aspects to develop more comprehensive and interlinked applications are shortcomings of data autonomy, handling of black box models and general feasibility of the implementation.Publication bibliography

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DYNAMIC ELECTRICITY TARIFFS - DESIGNING REASONABLE PRICING SCHEMES FOR PRIVATE HOUSEHOLDS IN GERMANY

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Overview

Renewable energy sources are essential for a low-carbon economy and are an integral part of virtually all climate protection strategies. However, their rapidly growing deployment poses severe challenges to the security of the German energy system, in particular the electricity grids. Due to the volatile production of electricity, the efforts and costs required to maintain grid stability increased sharply in recent years. To reduce the technical and economic pressure on the electricity system, many economists argue to link demand and supply via dynamic electricity tariffs. Following economic theory, consumers will react to these time-varying price signals to save money. Since the price signal will mirror any over- or undersupply within the electricity market, this will simultaneously relieve the electricity grids. Yet, dynamic electricity tariffs are accociated with many concerns and lack popularity among private households. Therefore, the aim of this paper is to design and develop reasonable dynamic pricing tariffs that overcome acceptance barriers of residential customers in Germany. Hence, we will answer the question how much cost savings households actually require to switch to a dynamic electricity tariff. Furthermore, we will look at different types of residential customers, to identifypotential target groups and formulate precise policy implications.

Methods

In a nutshell, we set up a microeconomic model to compare all costs assigned to a dynamic electricity tariffs, e.g. investment costs, yearly metering costs and behavior adaption costs, to the potential savings. To do so we need information regarding the costs and savings of such tariffs.

While information on investment and metering costs can be found directly in the relevant literature and enacted laws, we rely on stated preferences to depict the costs of the needed behaviour adaption. Studies exist that use choice experiments to estimate so called ’willingness to pay’ for a different electricity tariffs. These estimated ’wtps’ are usually negative for dynamic electricity tariffs (compared to flat tariff designs), and reflect the minimum savings that households request to choose the dynamic over the flat tariff.

We build our analysis of the saving potential on the model designed by Freier et al. (2019), who evaluate different approaches to develop dynamic tariffs. We following their idea to construct dynamic components of the electricity price (i.e. the EEG and KWKG surcharge or grid operation fees) based on normalized EEX spot prices for the year 2018. Hence, we generate multiple dynamic electricity tariff designs, each with a 15-minute resolution.

Utilizing the standard load profile for residential households (H0), which contains information on the average electricity demand for each 15-minute interval of the year, we will further model the load-shifting behaviour as reaction to the price signals. To do so, we will build upon existing literature, especially large-scaled field studies, which evaluate the potential of dynamic tariffs to create load shifting behaviour. Uniting the information of the constructed dynamic tariffs and the load shifting behaviour, we can calculate the financial savings of implementing a dynamic electricity tariff for different types of households.
Finally, comparing costs and savings associated to the different dynamic tariff designs, will allow us to draw conclusions on the optimal price spread (i.e. the number and size of dynamic price components) of the dynamic electricity tariff.price.

Results
We are aware that our identification strategy builds upon potential uncertainties. Therefore we do not aim to identify one unique optimal pricing design, but rather a price corridor that covers these uncertainties. Furthermore, we will conduct several robustness checks, especially regarding the wtp-figures, which are usually overestimated, and the load-shifting algorithm, which we construct to model consumers reaction to price signals.
Since this is work in progress at an early stage, we are currently unable to present comprehensive results. However, the already collected data and first approximated calculations show promising information.

Conclusions
Our approach will allow us to postulate profound policy implications regarding the optimal price spread of dynamic electricity tariffs for different types of residential costumers in Germany. Furthermore, it allows to evaluate which individual components of the electricity price can and should be designed dynamically. Hereby, we will contribute to the existing literature and provide valuable and comprehensive information for policy makers.

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ELECTROLYTIC OXYGEN, ONLY A BY-PRODUCT?

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Overview

Electrolysis is often mentioned as a well-established and mature technology to produce hydrogen. This is an environmentally friendly process that requires water and electricity, best when this last is derived from renewable
energy sources (RES). One of the main disadvantages of water electrolysis is the cost of the electrical energy, so also the hydrogen produced is more expensive than that obtained by methods based on fossil fuels, such as the conventional steam methane reforming (SMR). It is mainly for this reason that electrolysis currently accounts for only 4% of global hydrogen production; while 96% of hydrogen comes from fossil fuels (48% from natural gas, 30% from oil, and 18% from coal) [1].

Based on our previous studies [2-3], an extra revenue could be obtained by considering the amount of oxygen produced
as a by-product from electrolysis: 8 kg of oxygen are produced for each kilogram of hydrogen. In agreement with considerations recently reported by IEA [4], the by-product oxygen can be used at a smaller scale in the health care sector, or at a larger scale for industrial purposes (feedstock).

In this new contribution, we reverse the point of view, by considering a hypothetical enterprise or business activity (public or private) adopting an electrolysis plant to fulfil its needs of oxygen for a particular application, while the obtained hydrogen could be sold to external users to achieve additional revenues. The objective is to verify if the proposed approach is economically attractive, compared to the case when the same enterprise simply buys the oxygen from local gas distributors/resellers.

Methods

The examined system consists of 1 MW photovoltaic plant and an alkaline electrolyser rated at 0.8 MW; compressor
and storage units are also included in the analysis. This plant is assumed to be located in the South of Italy. The amount of gaseous oxygen produced is about 120,000 Nm3 per year, which is assumed as a target value for our hypothetical enterprise.

Based on the method proposed by Kuckshinrichs et al. [5], and adopted in our previous work [3], we perform an economic-financial analysis of the investigated solutions. In particular, the investment costs to realize the plant,
operative and maintenance (O&M) costs and taxes have been evaluated, in order to determine the corresponding net
present value (NPV). The avoided costs related to the non-purchased oxygen are also considered, by assuming a (market) price of gaseous oxygen varying between 1 and 7 €/kg [6].

Results

By assuming the above-reported target production, if the market price of gaseous oxygen is above a certain value (about 4 €/kg), it is economically feasible to self-produce the oxygen by a proprietary PV-powered electrolysis plant. In fact, in such a case, the NPV of the proposed investment – calculated assuming a plant lifetime of 20 years – results to be positive, indicating a profit margin even when the co-produced hydrogen is not sold to third parties. Therefore, this would be an ideal solution for enterprises that could use the co-produced gaseous hydrogen for their requirements or applications, or even for the needs of the same industrial chain.

On the contrary, if the market price of gaseous oxygen is lower than the above-mentioned value, the NPV results to be negative, but it is possible to recover – at the end of the 20 years – at least 3/4 of the initial investment and about 40% of the global expenses (investment, O&M costs, and taxes). Besides, a balance between expenses and incomes (or avoided expenses), i.e. an NPV null, can be obtained by selling the co-produced hydrogen.

Conclusions

In this paper we carried out an economic analysis to evaluate the attractiveness, for an enterprise that needs gaseous oxygen for a specific purpose, to produce it by a proprietary plant based on water electrolysis. It seems that, based on some preliminary results and evaluations, the examined opportunity could be an interesting alternative to the use of oxygen purchased from the local gas market.

It should also be remarked that the use of a green (carbon-free) process to produce hydrogen and oxygen can represent a value-added for the enterprise, in terms of image and benefits (e.g., carbon credits).

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A P2X SYSTEM FOR LIQUID METHANE AND LIQUID OXYGEN PRODUCTION COUPLED TO A GEOTHERMAL PLANT

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Overview

After the end of the incentive programs adopted in some countries (for example Italy) for geothermal plants, it is appropriate to find alternative solutions to properly exploit this electricity production. In many cases, a geothermal system produces electricity and CO_2, in different quantities depending on the type of geothermal field exploited, which emits into the atmosphere. The availability of electricity and CO_2 makes it possible to use an integrated Power-to-Gas system, relying on the processes of electrolysis and methanation of CO_2, for the production of methane and oxygen easily liquefiable and storable for short-range distribution.

Method

This solution allows the emission of CO_2 to be moved away from the location of the plant, also reducing the apprehension of citizens living nearby. An assessment of the economic sustainability of the proposed plant for the production of liquid methane and oxygen was carried out for different values of the market price of the two products. Standalone plant was deeply analysed with Aspen Hysys and Aspen Plus simulations. A grid-connected plant, operating with electrical energy price strategy has been investigated. Aiming to provide more detailed and robust outcomes, the start-up costs, stand-by charges and start-up time of the metanator and its liquifying system has been considered.

Results

The economic analysis has shown the significant contribution of oxygen sales and that, having high purity liquid oxygen, this can be, in whole or in part, sold in the healthcare sector with greater revenue than the sale for industrial purposes, improving, therefore, economic sustainability. In the case of a grid-connected plant, operating only when electricity price is lower than a certain value, a storage of hydrogen could be added. The size of the storage is highly affected by the high costs, resulting to be only a small storage for few hours.

Conclusions

The price of liquid oxygen is more relevant than liquid methane one. For a standalone plant only the year average market price of electricity should be considered for economic evaluation. Instead, in the case of grid-connected plant, all the hourly prices should be considered to optimize the running strategies of the proposed system.

Mario Valentino Romeri

THE HISTORY COULD REPEAT ITSELF: HYDROGEN-OXYGEN FUEL CELL IS THE 'GAME CHANGER'

Mario Valentino Romeri, Energy Consultant, Italy

Overview

Saturday 20 July 2019 marks the 50th anniversary of the moon landings, and while most of us are very familiar with the iconic scenes of this 'giant leap for mankind', many of us are completely unaware that the hydrogen-oxygen fuel cell invention made Neil Armstrong's 'small step' possible. *"Without you, we would not have gotten to the moon"* said President Richard Nixon to Francis Thomas Bacon, referring to Bacon's invention of the first practical hydrogen-oxygen fuel cell.

The Bacon fuel cell was perfect for powering NASA's spacecraft: it was lighter and much less bulky than batteries of the time, it was more efficient than 1960's solar panels, and hydrogen and oxygen were already going to be on board the ship for use as rocket fuel. What's more, the only waste product from the reaction was water – needed on Apollo 11 for the astronauts to drink.

The Bacon hydrogen-oxygen fuel cell was been the 'game changer' and made Neil Armstrong's 'small step' possible.

During last 50 years a tremendous technological progress are made in all fields, also in the field of hydrogen-oxygen fuel cells.

Hydrogen has seen several waves of interest in recent history, none of which fully translated into rising, sustainable investment.

For long time hydrogen energy vector and fuel cells technologies seem to be a Cinderella low-carbon solution in energy, transport and climate change debates but recently something happened. In recent months this low-carbon solution has made a strong comeback in energy portfolio options and it is considered as one of possible 'game changer', especially after the recent Japan's G20 and the publication of the report *"The Future of Hydrogen"* prepared by the IEA. According to Fatih Birol words: *"Hydrogen is today enjoying unprecedented momentum. The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future"*.

From longtime I underlined the possible relevant implication of hydrogen and fuel cell use in stationary and transport applications and, in recent years I presented works in which I argued that it's time to consider Fuel Cell Vehicle (FCV) as a relevant possible low-carbon solution in energy debate. The electricity produced by a hydrogen fuel cell can be used both for stationary and transport application and the traditional model to link transport to energy sector is the Vehicle-to-Grid (V2G) approach. But I think that it is time to consider the link between the transport sector and the energy sector not only in a V2G approach but in another perspective more direct, relevant and disruptive. In fact the Hydrogen Fuel Cell Powertrain (H_2FCPowertrain) or, in other words, the propulsion system of a FCV, is a small power generation plant (typically the H_2FCPowertrain size is around 100 kW). In the coming years the high volume associated with the possible FCVs mass production will permit to reduce dramatically the FC system manufacturing costs, in order to be competitive with gasoline in hybrid-electric vehicles.

In a mass production perspective, H_2FCPowertrain will be so cost competitive to be useful adopted also for stationary power generation application, also in LCOE terms.

From 2010 I wrote, presented and published studies where I compared the H_2FCPowertrain LCOE, based on the U.S. Department of Energy (DOE) public data, with the traditional power generation technologies with very promising results, in the U.S. context and in many other contexts around the world. From 2017 in my analysis I started to use also the International Energy Agency (IEA) data for the H_2 production costs.

In this paper, starting from the conclusions of my 2018 *"Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5°C Perspective"*, I analyse the most recent published data and elaborate other new considerations in light of:
- The *"climate emergency"* highlighted by Greta Thumberg;
- The next year event "*Economy of Francesco"* that, in the words of Holy Father Francesco: *"will help bring us together and allow us to meet one another and eventually enter into a 'covenant' to change today's economy and to give a soul to the economy of tomorrow"*;
- The statement by Ursula von der Leyen new President of the European Commission: *"our most pressing challenge is keeping our planet healthy. This is the greatest responsibility and opportunity of our times. I want Europe to become the first climate-neutral continent in the world by 2050. To make this happen, we must take bold steps together. Our current goal of reducing our emissions by 40% by 2030 is not enough. We must go further. We must strive for more. A two-step approach is needed to reduce CO_2 emissions by 2030 by 50%, if not 55%. The European Union will lead international negotiations to increase the level of ambition of other major economies by 2021 because, to achieve real impact, not only do we have to be ambitious at home – we have to do that, yes – but the world also has to move together. To make this happen, I will put forward a Green Deal for Europe in my first 100 days in office. I will put forward the first ever European Climate Law, which will set the 2050 target in law. This increase in ambition will need investment on a major scale. Public money will not be enough. I will propose a Sustainable Europe Investment Plan and turn parts of the European Investment Bank into a Climate Bank. This will unlock EUR 1 trillion of investment over the next decade. It means change."*

Methods
LCOE analysis

Results
In a perspective of more and more rapid development of hydrogen and fuel cell application, the H_2FCPowertrain technology appears competitive, in LCOE terms, with many of the power generation technologies and, in the most favorable conditions of low H_2 production costs, with almost all the technologies currently adopted.

Conclusions
This analysis confirmed, in LCOE terms, the economic advantage *"to consider an H_2FCPowertrain as power generation plant"* and explained related possible long-term effects in power generation, but this option has still not been considered.
According to IPCC SR15 in the next few years it will be necessary to start unprecedented changes and to speed up CO_2 emissions reduction. For these reasons next few years are probably the most important in our history. So, other detailed analyses seem to be needed in order to well understand the relevance of hydrogen and fuel cells in "*1.5°C"* perspective and to suitably assess all the economic, financial an geopolitical implications.

The history could repeat itself. In 1969 the hydrogen-oxygen fuel cell invention made Neil Armstrong's 'small step' possible. Today, the 'state of the art' hydrogen-oxygen fuel cells seems to be able to be, in next future, the 'game changer' against the "*climate emergency*", to play a relevant role in the "*economy of tomorrow*" and maybe to be a new 'giant leap for mankind'.

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RENEWABLE ENERGY SOURCES AND CAPACITY BUILDING FOR SUSTAINABLE DEVELOPMENT.

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The future for renewable energy sources in the developing world, if properly harnessed, looks bright and the prospects are good. There are vast reserves of and high potential for the use of different renewable energies (RE), be they solar, hydro, wind, wave, hydrogen, waste, etc. However, these remain largely unexploited due to a combination off; particularly economics, lack of appropriate research and development and the absence of important enabling policy instruments. At the same time, access to modern, commercial energy services is usually too low to facilitate meaningful eco-nomic development in developing countries. Sub-Saharan Africa, the world's most under-developed region, with 17 % of the world population and blessed with abundant mineral resources, consumes less than 3 % of the world primary energy supply. Most of the developing world's energy needs could be met by the vast renewable energy potential.
It is in line with these that the UN Sustainable Development Goals (SDGs) can be met through deployment of green energy and promotion of capacity building activities to ensure continuity and community ownership of Renewable energy projects through which the locals are able to build their own local economies, foster innovation, education and public awareness, expose them to an array of technologies available. Therefore, Renewable energies should be promoted as one of the energy options that can help achieve affordable and clean energy while combating climate change.

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ILICETO SHIELD WIRE SCHEME (ISWS): A LEAPFROG TECHNIQUE FOR LOW-COST RURAL ELECTRIFICATION, MICRO-GRIDS CONNECTION AND RES PROMOTION IN DEVELOPING COUNTRIES. A PRECIOUS LEGACY FROM PROFESSOR FRANCESCO ILICETO

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In Africa over 600 million people do not have access to electricity. Of these, over 110 million (GTM Research, 2017) live near electricity grids or directly under power lines ("under the grid"). The World Bank estimates that less than half of Africans who live "under the grid" have access to electricity. The "Center for Global Development" estimates that in 5 African countries (Nigeria, Kenya, Ghana, Tanzania, Liberia) as many as 95 million people live in "under the grid" areas. There is therefore an urgent need for innovative approaches to supply electricity legally and safely to communities "under the grid" in African countries, especially in Sub-Saharan Africa, in line with the sustainable development goals (SDG) of the Agenda 2030 UN.

An innovative technology, conceived and engineered since the 1980s by Professor Francesco Iliceto of the University of Rome Sapienza, potentially disruptive for the aforementioned purposes, is the so-called ISWS ("Iliceto Shield Wire Scheme"). It consists in using the metal shield wires of the power lines that transport high voltage electricity as conductors for the transport of medium voltage electricity, without the need to create new HV / MV transformation stations along the route and / or new MV lines with origin in the starting substation of the power line itself. In fact, the same power line becomes a transport line for electricity in both high voltage, to connect two points of the electricity network, and medium voltage, to directly feed the users that arise along the power line ("under the grid") in a corridor about 100 km wide around the axis of the power line itself. Since depending on the type of power lines there may be one or two shield wires, in the first case the medium voltage will be single-phase with return through the ground, in the second case three-phase with return through the ground.

In terms of intervention, it is a question of isolating the shield wires at each tower, using special medium voltage insulators, which in no way deprive the shield wires of their function of protecting the power line from lightning strikes. In addition, it is a question of connecting the shield wires to a medium voltage winding of the HV / MV transformer present in the substation of origin of the power line. Along the power line itself, the medium voltage is transported near the user and transformed into LV with a special special transformer, which reconstructs a symmetrical electrotechnical system. The idea is very simple, but it took many years of research by Professor Iliceto's team to be engineered, as it consists in a three-phase asymmetric system for the study of which traditional analysis methods are not applicable.

Worldwide, no. 8 ISWS plants are still in operation, respectively in Ghana (the first, built in the 80s), in Brazil, in Laos (2 plants), in Sierra Leone (the most recent, built in 2010), in Togo, in Burkina Faso, in Ethiopia . In 2017 the World Bank posthumously published the technical manual written by Professor Iliceto: "*Rural Electrification with the Shield Wire Scheme In Low-Income Countries*" (esmap.org/node/57786).

In fact, Professor Iliceto did not patent the invented technology, but left it as a technical-scientific legacy for the benefit of the poorest populations. In addition, Professor Iliceto left as a legacy a fund intended for scholars from poor countries, aimed at promoting studies on the electricity system. The "*Francesco Iliceto Association for the promotion of studies on the electricity system*" is using this fund to support, among other things, a project to spread the ISWS method in Tanzania, one of the nations most affected by the phenomenon of energy poverty of the populations living"under the grid ".
The main benefit of the ISWS method is economic. In fact, the cost of an ISWS system is roughly a tenth of the cost of traditional electrification, on a par with all other performances. The quality of the power supply is in fact exactly the same as traditional methods, as demonstrated not only by theoretical studies, but also by the cases that have already been operating in the world for several decades. In addition, the electrical losses due to the Joule effect and the voltage drops are reduced, considering the electrical characteristics of the shield wires, as well as the environmental impact, given that a single power line is used to transport two lines (one HV and one MV), as well as the risk of vandalism and damage to the high voltage power line, given that the communities "under the grid" are powered by it and therefore stimulated to protect it.
In 2019 a collaboration program was started between the Tanzanian utility TANESCO, the University of Dar Es Salaam (UDSM) and the Ass.ne Francesco Iliceto, to carry out a pilot project in Tanzania and, starting from this, start a large-scale ISWS plant construction plan, given that the Nation is well suited to the application of the method being very large and substantially empty, with a very low population density and therefore very low load density.
In July 2019, a first research – through a master's thesis in energy engineering from Sapienza University – studied a pilot project in the rural area of Shinyanga, currently not electrified. The feasibility study showed that the electrification of the area with the ISWS method would cost 15% of the cost of traditional methodologies. Subsequently, on Tanesco's indications, a pilot application along the Chalinze-Hale-Tanga HV power line was deemed more advantageous and the project for this first-mover is currently being developed. At the same time, UDSM and Sapienza are working on a capacity building program which, by enabling Tanzanian engineers to independently apply the ISWS method, allows its systematic and large-scale adoption across the nation, making it the first case in the world and hopefully allowing an acceleration in the Country's electrification process.
Moreover, ISWS technology could also be profitably used "upside down", to connect isolated micro-grids powered by renewable sources locally available, in order to increase their safety and promote their expansion. In fact, where remote communities are reached by normal power lines connected to the main network, the use of micro-grids has little meaning, while a low-cost connection increases their performance, emphasizing their usefulness and thus promoting their development. In this sense, for "under the grid" communities (within corridors 100 km wide around the axis of HV/UHV/EHV power lines) ISWS technology can be a leapfrog and allow to completely skip the electrification programs with traditional methods, saving the 80% -90% of the costs.
The authors, former students of Professor Francesco Iliceto, thank him for the precious teachings and for this legacy that, with commitment and pride, they are trying to carry on.

Luis María Abadie, José Manuel Chamorro, Sébastien Huclin and Dir-Jan van de Ven

A NOTE ON FLEXIBLE HYDROPOWER AND SECURITY OF SUPPLY: SPAIN BEYOND 2020

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Overview

Generation adequacy is a key ingredient to security of electricity supply (SoS). In some countries environmental concerns are pushing toward a future decrease in the number of coal-fired stations and an increase in renewable installed capacity. This forecast, along with the future reduction of nuclear capacity, will lead to a combination of less baseload plants and sizeable intermittent generation. Hence there is a risk that generation adequacy will suffer.

Abadie and Chamorro [1] develop a stochastic model that explicitly matches power demand and supply (if possible). From this interplay it is possible to assess generation adequacy by means of several metrics that account for different attributes of potential supply shortfalls. Next they look at Spain (an 'electric island' right now and in the near future at least) beyond the year 2020. Monte Carlo (MC) simulation allows them derive the risk profile of several key variables. According to their results, the system's adequacy worsens in 2020 and does so dramatically in 2040 and 2050, when coal and nuclear stations are completely replaced by renewable plants. These results consider all power technologies (hydropower included) as feeding their potential output in the system irrespective of demand.

The empirical evidence shows that hydro operation does follow demand to some extent. These stations generate relatively more power during peak hours and less in non-peak ones. This paper is an extension of [1] on at least two accounts. First, it considers that positive correlation to check the potential of flexible management to reinforce SoS. Second, we disaggregate hydro stations between run-of-river (RoR) stations and the remainder (non-RoR) stations; this way we want to account for their different degree of freedom when it comes to flexible management. For these two reasons, now the numerical application (via MC simulation) gets more complex than in [1].

Methods

[1] addresses the risks to SoS by evaluating the adequacy of the Spanish power generating system up to the year 2050. The average growth rate of power demand in Spain is uncertain. The Spanish Ministry of Energy, Industry and Tourism adopts a central rate of 1.9% (with lower and upper levels of 1.7% and 2.3%, respectively). On the other hand, Bailera and Lisbona [2] consider two scenarios of power demand growth over the next decades, namely 1.36% and 1.73% per year. [1] sticks with these two demand scenarios and several others: a flat demand in the future, and a demand 5% lower than initially anticipated. In the end, [1] simulates the performance of the Spanish peninsular generating system under ten different scenarios.

The starting point is a stochastic model for power demand and generation technologies. Power demand is random; this holds for both annual demand and maximum hourly demand (the latter is considered a function of the former).

On the supply side, thermal stations can be on or off with specific probabilities. Renewable technologies display a load factor that subsumes both their availability rate and intermittent nature; we assume that it follows a Weibull distribution. Unlike [1], here we are going to disaggregate hydro stations. RoR stations are relatively more dependent on natural (re)charge and less amenable to strategic management. Consequently, we are going to estimate an independent Weibull distribution for them. Non-RoR stations include conventional reservoirs and pumped storage stations. In principle they are more amenable to strategic operation and lend themselves more easily to track demand surges. Again, we assume that the load factor of these stations can be characterized by a Weibull distribution; however, now this distribution is going to be correlated with peak demand.

The model explicitly matches both demand and supply, thus allowing assess generation adequacy from a physical/technical viewpoint. Next comes the estimation of the underlying parameters from official data sources. The model can then be simulated a number of times. MC simulation allows derive the risk profile (or cumulative density function) of any adequacy metrics, whether deterministic (reserve margin) or probabilistic (expected energy not served, loss of load expectation, their respective 95th percentiles, and loss of load probability). Together they allow draw an overall picture of the system adequacy under a high degree of isolation.Results

We focus on two specific cases, namely when annual demand grows at 1.36% and 1.73% but the associated hourly peak demand levels are cut by 5% if necessary from 2030 onwards while natural gas-fired generation capacity grows by 3,000 MW every decade. This corresponds to the lower block of Table 7 in [1]; the upper part of the Table below replicates it for convencience. Note that these demand growth scenarios envisage a wide deployment of renewable sources of electricity in [1].

Table 4. Spanish peninsular system: Simulated mismatch between 'enhanced' supply and 'shaved' demand.

		Inflexible hydro generation (S_1^+, D_1^-)				*Inflexible hydro generation* (S_2^+, D_2^-)			
	2017	*2020*	*2030*	*2040*	*2050*	*2020*	*2030*	*2040*	*2050*
AD	253,082	263,621	302,026	346,026	396,436	266,564	316,909	376,762	447,920
MHD	42,398	44,013	47,365	53,661	60,801	44,463	49,502	58,023	68,023
AC	99,311	113,232	121,430	126,948	141,648	110,832	126,630	140,648	168,548
EENS	23	48	1,415	151,248	317,338	85	3,485	258,069	547,173
*E*95	0	0	4,814	483,212	874,788	0	21,963	736,823	1,342,998
LOLE	1.44	2.54	53.01	2,945.50	4,980.68	4.27	115.01	4,219.63	6,614.56
*L*95	0	0	420	7,500	10,920	0	840	9,600	12,780
LOLP	0.55	0.88	10.40	93.72	98.24	1.36	18.21	97.33	99.43
RM	1.34	1.57	1.56	1.37	1.33	1.49	1.56	1.42	1.48
		Flexible hydro generation (S_1^+, D_1^-)				*Flexible hydro generation* (S_2^+, D_2^-)			
AD	253,082	263,621	302,026	346,026	396,436	266,564	316,909	376,762	447,920
MHD	42,398	44,013	47,365	53,661	60,801	44,463	49,502	58,023	68,023
AC	99,311	113,232	121,430	126,948	141,648	110,832	126,630	140,648	168,548
EENS	23	2	98	46,124	124,546	3	301	92,784	247,847
*E*95	0	0	0	171,687	387,350	0	847	307,807	667,387
LOLE	1.44	0.10	4.80	1,218.85	2,617.18	0.21	13.12	2,046.40	3,993.92
*L*95	0	0	0	3,660	6,540	0	60	5,400	8,520
LOLP	0.55	0.12	3.35	92.01	98.43	0.24	7.45	97.08	99.69
RM	1.34	1.57	1.56	1.37	1.33	1.49	1.56	1.42	1.48

The Table shows the annual demand observed in 2017 along with the simulated levels from 2020 through 2050 (AD, in GWh). Next comes the maximum hourly demand (MHD, in MWh). They are then set against the available generation capacity (AC, in MW). The first adequacy metrics, EENS, stands for the average energy not served and is measured in MWh; its probability distribution allows compute the 95th percentile, E95. Similarly, LOLE denotes the expected load lost (in minutes per year), while L95 is the 95th percentile. LOLP is the probability of load being lost (an interruption in power supply, in %). The reserve margin RM is the only deterministic metric.

Conclusions

As expected, the positive correlation between hourly peak demand and flexible hydro's load factor tempers the severity of the negative impacts of demand surges. For instance, in 2020 EENS changes (with respect to inflexible management) either from 48 MWh to 2, or from 85 MWh to 3 (depending on demand growth rate). This is obviously a dramatic reduction in the supply shortfall. Yet the impact fades over time as demand keeps on growing (whether at 1.36% or 1.73% per year) despite the broad deployment of renewable sources The same dynamics applies to the other adequacy metrics (whether we look at their average values or the 95 percentiles). Thus, the positive correlation certainly softens the problem, but in no way solves it.

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Kristina Govorukha, Alexander Golub, Philip Mayer and Dirk Rübbelke

HOW DOES CLIMATE CHANGE AFFECT THE TRANSITION OF POWER SYSTEMS ALREADY NOW: THE CASE OF GERMANY

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Overview

Climate change will pose new region-specific challenges on technical and socio-economic systems. The summer of
2018 gave us a preview of possible adverse future developments. It was characterized by an enduring heat wave accompanied by droughts in various regions throughout Germany that lasted until November [1].

The energy sector is the largest contributor to greenhouse gas emissions in the EU [2] and therefore is a major driver of climate change. At the same time, the energy sector is itself affected by climate change and some of these effects became already apparent [3]. While national energy policies aim towards a strong deployment of renewable energy
capacities to reduce the CO_2 intensity of the energy sector, these energy sources are highly dependent on weather conditions. Thus, policy measures towards a low-carbon energy transition (e.g. coal phase-out) can lead to a higher
vulnerability of the power system to climate change. A dual effect of droughts and persistent heat waves affects variable renewable energy sources, for example run-of-river, or biomass power plants. However, also thermal power plants like coal-fired and nuclear power plants are affected by changes in water temperature and availability, as they have high cooling requirements. Furthermore, this problem is exacerbated by regulations that define maximum water intake (<30°C) and outtake temperatures (<28°C) [4].

During the transition process the stability of a power system with a high share of variable renewable energy generation will depend on the existence of flexibility options and (thermal) balancing capacities [5,6]. At the same time, those options are dependent on sufficient water supply, which could be observed recently. The heatwave in 2018 together with a long-lasting drought resulted in forced complete shutdowns of coal-fired power plants in some areas of Germany [7].

Methods

This study assesses possible effects of climate change on the German power system, by analysing the effect of extreme weather events. In order to do so, this study utilizes meteorological and electricity market data with a high geographical and temporal resolution to assess the effects on German power plant locations (See Figure 1). Table 1 presents an extract of the main data sets.

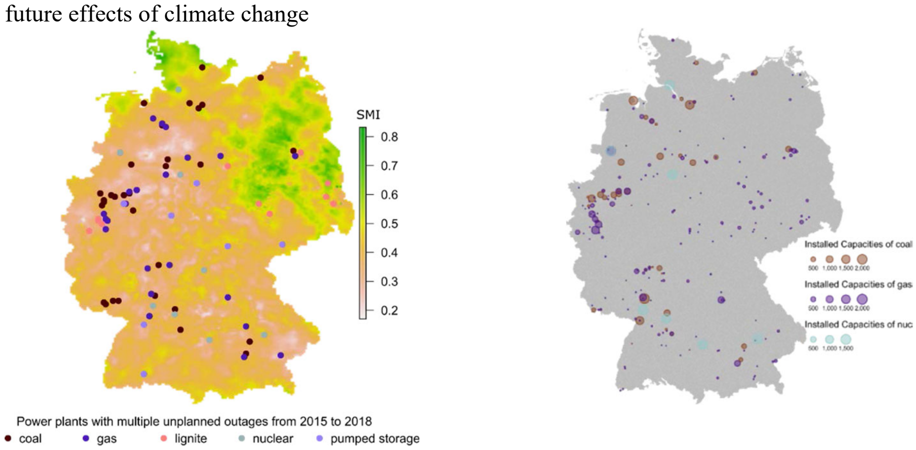
Table 1 **Data sources**

data	source	time horizon
Spatial precipitation data	German Drought Monitor (UFZ Leipzig)	1951-2018
Spatial temperature data	Climate Data Center (Deutscher Wetterdienst)	1983-2018
Control area balances	German TSOs‘ control area balances (50Hz, Ampiron, Tennet, TransnetBW)	2012-2018 (15 min)
Power plant outages (for each prod.	ENTSOe Transparency data	2015-2018

While analyzing the interrelation between security of electricity supply and thermal power plants in the context of
extreme weather events, a diverse set of aspects has to be taken into consideration: reducing generation capacities, increasing balancing needs, price peaks, system resilience, etc. These aspects are enriched with an analysis of meteorological data at each power plant location. Econometric analysis tools are used to quantify physical effects of climate conditions on power plants production schedules. By building technology specific impact response functions of thermal generation units to droughts and heat waves, we are able to assess risk-adjusted economic costs of climate change for the power system.

Results

The methodology introduced in this work allows for a comprehensive analysis and the identification of measures
that reduce overall vulnerability of the electricity system and to provide guidance for policy measures on how to design the energy transition while accounting for current and possible future effects of climate change



(1) (2)

Figure 1 – **Mapping of drought intensity and location of thermal power plants**

(1) Drought intensity - mean of monthly average soil moisture index (SMI) from 2010 to 2018[1] built against power plants that had unplanned outages[2] during droughts. Colour scale, with drought intensity indicated by values from 0.3 (“abnormally dry”) to less than 0.02 (“exceptional drought”).

(2) Thermal power plants, installed capacities and their locations as of 2019[3]

Conclusions

The question arises how climatic changes will affect the stability of future power systems and what implications can
be concluded for the security of electricity supply [8,9] if extreme weather conditions exacerbate in the future. Such concerns are also expressed in the European Commission's initiative to protect critical infrastructures: "Natural disasters, terrorist attacks, and criminal activity can all disrupt the critical energy infrastructure that Europeans depend on" [10].

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Alexia Ponziani
MIGRATION RELATED TO CLIMATE CHANGE

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Immigration and climate change are among the hottest and most divisive topics in politics today. Climate change has been and is being caused by greenhouse gas emissions, deforestation and the burning of fossil fuels during industrial development and affects all areas of life including health, productivity, food and water availability, security and migration. The term migration encompasses people from different backgrounds, cultures, religions, skills, etc. and is motivated by multiple factors such as economic, social, political, cultural, environmental, security, etc.
The majority of immigrants are forced to leave their homeland due to pull or push factors. To further complicate matters, these factors are usually interconnected when speaking about population movement. According to the United Nations the number of international migrants reached 258 million in 2017. The number of push factors that can be listed for having induced environmental migration and that might lead people on the move are:

1. Natural disasters;
2. Development projects that involve changes in the environment;
3. Progressive evolution of the environment;
4. Industrial accidents;
5. Environmental consequences due to conflicts.

Migrations induced by non-climatic events listed in points 2, 4 and 5 are the consequence of human activities and are difficult to foresee and estimate. In fact, it is true to say that the vulnerability of a population to climate change varies greatly depending on government policy, population growth, income distribution or in other words all those variables that push people to live on marginal lands. Therefore a population's vulnerability may increase or decrease due to factors that have nothing to do with greenhouse gas emissions. These non-climatic drivers can in any case be as important as the "climate signal" itself.
Notwithstanding the importance of these non-climatic drivers, it should be noted that according to the IPCC (Intergovernmental Panel on Climate Change 2007b) forecast for the end of the 21st century, the three most threatening potential causes of migration are all due to global warming and are:

- Stronger tropical hurricanes and increased frequency of heavy rains and flooding, caused by increased evaporation induced by the rise in temperatures;
- The growth in the number of droughts, with evaporation contributing to a decrease in soil humidity, often associated with food shortages;
- The increase in sea levels resulting from both water expansion and melting ice.

The first two phenomena result in sudden natural disasters whilst the third is something that occurs over a long period of time.
A potential driver of migration is a change in the environment which makes the territory no longer habitable, thus spurring people to migrate. It is a very complex matter. Due to the interplay of these factors, people may be pressed either to move or stay in a place. Hence, it is often difficult to establish any particular driver as being necessary or sufficient.

Human mobility is also influenced by the community's or family's vulnerability and capacity to move or stay in their homeland. "Vulnerability" can be quantified according to how susceptible people are to falling victims of a crisis such as floods, conflicts or economic downturn; whilst "capacity" is the individual's, community's or country's ability to cope, respond to and acquire new skills to deal with crisis situations.

Migration in fact implicates both opportunities and challenges. This is true for the migrant, the host destination and for

those remaining in the place of origin as these two factors depend greatly on policies and cultures at the receiving location as well as individual circumstances.

To date there is no clear international legal regulation to protect "climate refugees" and this is a difficult problem to address for a number of reasons. One of these reasons is that it is not easy to identify those who have been forced to migrate primarily because of climate change. This makes it hard to define the legal scope and application of the provision and also makes it an arduous task to make sure that those entitled to be covered actually are.

The immigration phenomenon will never be presented with reliable and definite data as there are too many uncontrollable flows to make a definitive picture at a certain point in time. In situations of climate migration some family or community members may be left behind giving rise to a change in responsibilities, roles and vulnerability. Although this type of migration may have negative aspects, it usually has a more positive overall outcome than normally believed. Those who leave the place of origin may only opt for temporary migration and once they find employment send remittances to their family or community. They therefore help them financially to adapt successfully to the changes in the living conditions in the place of origin. Over hundreds of years, migration has contributed to the richness and emerging of various cultures worldwide. On the whole, migration, when done in a regular manner , goes to benefit all, the individuals first and foremost, the country of origin and the host country.

What will happen in the future? – There are no certainties, but only developed forecasts.

Several factors that will influence the degree of impact that climate change as a driver may have on future forced migration are:

- the quantity of future greenhouse gas emissions;
- the rate of future population growth and distribution;
- the meteorological evolution of climate change;
- the effectiveness of local and national adaptation strategies.

We do not know if global warming will lead to more violent and frequent hurricanes. However, the climate change and migration phenomena we are facing today can be coped with through mitigation and adaptation strategies that are launched by governments and institutions. Furthermore, migration should not be seen as an emergency but rather as a long-term change in the geopolitical and demographical structure which will affect the upcoming decades.

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LOW-CARBON IRON AND STEEL PRODUCTION: A TECHNO-ECONOMIC METHOD TO EVALUATE TRANSITION PATHWAYS TO A RENEWABLE-BASED DIRECT REDUCTION PROCESS IN A BROWNFIELD PLANT

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Overview

The iron and steel industry has a 4.7% share in the EU's total carbon dioxide emissions [1]. Conventional primary steel making along the dominant blast furnace (BF)/basic oxygen furnace (BOF) route is already close to the theoretical minimum in terms of emission levels [2]. The alternative, recycling-based secondary steel production via the electric arc furnace (EAF) route is limited by scrap availability and the achievable steel qualities [3]. A technically feasible alternative that promises high emission reduction potentials is the direct reduction (DR) process based on hydrogen from renewable electricity. However, any shift to DR will require considerable investments in new production infrastructure. Its introduction in Europe implies a successive transformation of existing brownfield steelworks. An important question for reducing emission levels is under which conditions and when manufacturers would install new infrastructure as part of the transformation. This article aims to explore this question and describes a techno-economic case study of the transition of hot metal production towards a low-carbon renewable-based DR process.

Methods

The chosen approach combines a technical simulation model with a combinatorial algorithm to determine the economics of the transition. The technical simulation model implemented in Aspen Plus yields mass/energy flows [4] for the current set-up of individual plants at the production site and for various potential future configurations. These configurations ultimately lead to a fully electrified hydrogen-based DR process with onsite electrolysis. The combinatorial algorithm implemented in VB.net is based on these plant configurations and generates multiple transition pathways for the period 2020 to 2050. Each pathway describes the plant canfiguration used in each year of this period. To ensure that the very large number of theoretical pathways can still be processed, assumptions about feasible configurations are made in order to reduce the possible combinations to mere millions. For each pathway, the net present value (NPV) is calculated based on projected cash flows using the technical simulation results on mass/energy flows, current and future energy carriers and resource prices. The calculation also incorporates information on construction and reconditioning dates of existing and future plants as well as recurring costs from various other categories, e.g. personnel, operation and maintenance.

Results

The model yields the NPV of the least-cost pathway from a manufacturer's perspective including information about the plant configuration in each year.

Thus, the method enables a manufacturer to understand the pathway with the highest NPV and indicates when a particular shift to a different site configuration will occur. Since these shifts strongly depend on the economic framework conditions, the analysis is made for several scenarios which feature varying prices for resources, electricity and emission certificates. This can also aid policymakers in recognizing the conditions needed to trigger a low-carbon transformation based on the considered DR setup in the iron and steel industry.

Conclusions

The suggested model combines a technical with an economic perspective to illustrate the economic implications of a transition towards a low-carbon iron and steel industry. The preliminary results indicate that such a transition will only take place if the economic conditions offset the additional investments in the DR process. However, we point out that this analysis has only been carried out for an individual case study. A broader empirical study is required for more generalised conclusions. Furthermore, the study is limited to the economics of the transition and does not consider the non-economic barriers identified in the literature [5] that are also relevant for a low-carbon transition of the iron and steel industry.

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Akira Maeda and Makiko Nagaya
WHAT DRIVES OR HINDERS AUTONOMOUS ENERGY EFFICIENCY IMPROVEMENT

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Overview

This study analyzes what is behind energy efficiency improvement as a determinant of it. In typical energy modeling, energy efficiency improvement is one of key factors that influence the model behavior and calculation results. While there are several types of energy modeling, for example, optimization models, general equilibrium models, agent-based models, etc., parameters used in the model are generally critical to the model building. In particular, the parameters that reflect assumptions for energy efficiency improvement are one of the most critical ones. They are usually set as annual rates of improvement, and in most cases, they are set as constant numbers. Such a constant annual rate of improvement assumes that energy efficiency improves at a constant rate regardless of other economic conditions. This is sometimes called Autonomous Energy Efficiency Improvement (AEEI).

The introduction of the assumption of AEEI into the modeling framework is practical in that otherwise there must be some mechanisms that can shift rates of improvement in the model, which needs some theoretical background for these mechanisms. In other words, there is no consensus among modelers about theory of driving force for energy efficiency that can explain how energy efficiency improvement happens. In the context of general economic theory, there are some theories that try to explain the source of technological change and/or technology innovation, including so-called endogenous growth theory (e.g. Romer, P. (1990), Acemoglu, D. (2002)). However, these existing theories are understood to be still subject to empirical study and have not gained full support from economists for the purpose of practical use such as energy modeling. So does with the mechanism of energy efficiency improvement. In fact, it is even more ambiguous. This study is an attempt to challenge that ambiguity.

Methods

The analysis is done with a simple partial equilibrium model. We consider an energy-related good and work on its supply and demand market equilibrium. Supply and demand functions are written as follows:

$$Q_D = ap^{-\varepsilon}$$
$$Q_S = bp$$

where *b* represents a technology parameter.

With this setting of the market, AEEI is understood as autonomous and constant increase in the parameter *b*. Then, the question is whether or not the increase in the parameter b brings benefits to stake holders including consumers, producers, and the economy as a whole. If the change is beneficial to some of them, that economic entity may let that autonomous change happen. Otherwise, it will try to hinder such change. To investigate the answer to the question, a comparative statics analysis is utilized.

Results

To examine benefits to stake holders, standard welfare measures are a useful tool.

We calculate consumer surplus, producer surplus, and social welfares as functions of the parameter *b*. Examining the signs of derivatives of these measures helps identify who is welfare-improving and who is not. The result shows in any cases, consumers and the whole economy will get better off with the increase in the parameter *b*, which is quite natural to our intuition. To the contrary, the effect on the producer is ambiguous. In fact, the increase in *b* does not necessarily help the producer, which means that as a subjective entity of introducing or accepting better technology, they may be willing to stop or hinder such technology improvement, staying with an old-fashioned technology. It is found that the difference between a possible driver and a possible obstacle for efficiency improvement is entirely due to the price elasticity of demand, ε, and nothing else.

Conclusions

The result that only the price elasticity of demand determines whether the energy producer is motivated to the improvement or not is making sense, but it is quite insightful. Improvement is considered to be done by the subjective entity. Thus, the justification of it is entirely determined by the producer in a liberalized economy while the criterion is related only to the demand-side, not supply-side. Moreover, it has nothing to do with producer's technology itself. This means that any intervening policy by the government that intends to promote more efficient technologies should be targeted to demand-side, not directly technology-holders. It may allow us to emphasize an importance of financial measures rather than efforts on hard technology itself.

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Pierpaolo Perna and Armando Castro

ASSESSING ENERGY EFFICIENCY: ECONOMETRIC EVIDENCE AND IMPLICATIONS FOR ITALIAN ENERGY POLICY

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Overview

Energy efficiency is enshrined in European legislation and represents one of the key objectives of the Clean Energy Package of the European Commission. Within such Europe-wide framework, individual Member States are tasked with the role of determining the optimal set of policy options in order to achieve energy efficiency targets. The set of efficiency targets mandated by European legislations are based on energy intensity measures, which represent imperfect proxies for energy efficiency.

In Italy, the National Energy and Climate Plan (NECP) outlines the main policy measures. Compared to period 2016-2018, NECP estimates for 2030 a cumulated saving in total final energy consumption amounting to 51,4 Mtep, or 9,3 Mtep per year, the largest share of which coming from the residential sector, followed by transport, tertiary and manufacturing.

Limited information is available on the methodology used and the sources of evidence considered. For this reason, such targets are assessed against the econometric evidence, which can shed light on country-level efficiency performance. Therefore we develop a more robust approach to assessing efficiency and the trade-offs between policy measures targeting different sectors.

Methods

Scholars (e.g. Filippini, Hunt and Zorić, 2014) have developed a definition of energy efficiency consistent with standard production theory and have used energy demand and stochastic frontier models to asses energy efficiency in the EU residential sector.

Consistent with this framework, a stochastic frontier analysis (SFA) is employed to estimate a "frontier" energy demand function for all main energy consumption activities (residential, industrial, transport) using panel data for EU member states over the period 1996 to 2016, based on data from the European Odyssee dataset energy efficiency indicators and energy consumption as well as Eurostat. Separate econometric specifications will be developed for each consumption category. The panel data models considered include Battese and Coelli (1995) (BC95) and so-called the four component panel data model.

Results

Our initial results show different levels of relative performance depending on the consumption category under assessment. Overall, Italy shows efficiency levels above the sample average. Over time, the relative efficiency score does not seem to have changed significantly. Compared to other sectors, the residential sector appears to be show that there exist potentially large efficiency savings. Transport efficiency also shows average efficiency above average but has been on a downward path over the last years. The industry sector shows mixed evidence.

Conclusions

The analysis shows that Italy's country-level efficiency scores vary significantly across consumption areas.

For this reason, it is important to put in place more robust approaches to assessing efficiency and the trade-offs between policy measures targeting different sectors.So far, some of the largest energy efficiency policies (e.g. white certificates, feed-in tariffs) have targeted in most part the industry sector. In addition to such measures, it appears appropriate to strengthen energy efficiency schemes in other sectors (e.g. household, transport) which appear to show greater scope for efficiency savings.

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Paula Brezovec and Nina Hampl

EXPLORATIVE EVIDENCE OF ADOPTION OF MULTIMODAL MOBILITY PACKAGES FROM A CHOICE-BASED CONJOINT STUDY IN AUSTRIA

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Overview

Electrification, automatization, connectivity and sharing represent the major trends in the transport sector (European Commission, 2019), which is the greatest contributor to climate change with almost a quarter of all global energy-related greenhouse gas (GHG) emissions (IEA, 2016a, 2016b). Despite all the attention and measures regarding clean technologies, e.g. electric vehicles (EVs), the current transport system is still inefficient and unsustainable as private cars are still the core of day-to-day mobility. One promising concept promoting more sustainable transport behaviour is Mobility-as-a-Service (MaaS). Till now, numerous MaaS-related pilot programs have been implemented across Europe and beyond. So far, most of the work has been done by practitioners and there is still lack of scientific research, especially regarding the configuration of multimodal mobility packages. Building on the work by Matyas and Kamargianni (2018) we conducted a choice-based conjoint experiment representative for Austrian citizens (N = 590). The aim of the present study is to investigate the effect of different attributes of multimodal mobility bundles/packages on purchase intention. Our key findings can be summarized as follows: the most important attribute is price (monthly payment), followed by transport modes (transport modes that are included in the package), transfer time (between the different transport modes on a trip) and reachability (of the first transport mode). The last two attributes (transferability and allotment expiration) seem to be "nice-to-have", rather than "must-have". Attribute preference, however, varies among different segments of potential customers, underlining the need for individualisation and customised packages. We discuss implications of our findings for future research as well as practitioners and policymakers.

Methods

The present study follows a two-step methodological approach: qualitative interviews and a questionnaire including a conjoint experiment. First, after a thorough literature review, a dozen of qualitative interviews with experts from different fields (e.g. academia, public transport, firms active in the MaaS sector etc.) and potential customers were conducted from November 2018 to February 2019 in order to gather insights on current MaaS initiatives and offerings as well as criteria and preferences related to the decision to use multimodal mobility packages. This was the basis for the development of the questionnaire and the conjoint experiment. We conducted an online survey with Austrian citizens (N = 590; 18-70 years) in order to identify preferences related to features of multimodal mobility packages and the respondents' willingness to pay (WTP). The data was collected during May and June 2019. The first part of this survey included questions to evaluate respondents' travel preferences and behaviour. The second part included the conjoint experiment. Choice-Based Conjoint (CBC) is a well-established research method to study decision-making processes and criteria (Green & Srinivasan, 1978, 1990). The conjoint study conducted included 12 choice tasks, which is a common practice in other conjoint studies (e.g. Hampl and Loock, 2013; Kubli et al., 2018).

Each choice task comprised three options of hypothetical multimodal mobility packages, which are described along six pre-defined attributes. Each of the attributes consisted of four to five levels. Furthermore, a “none option” (if the respondent would not prefer any of the presented options) was included as a fourth option to better reflect real purchase behaviour. Sawtooth Software products were used for both the questionnaire design and setup as well as the statistical analysis of the choice data. In contrast to a traditional mixed- logit model, where only aggregated data is included, we applied a hierarchical Bayes (HB) model where individual part-worth utilities can be estimated (Rossi & Allenby, 2003; Huber & Train, 2001). Besides HB for the analysis of the conjoint data we used latent class analysis (LCA) to identify different segments among the respondents (Sawtooth Software, 2004).

Results

Related to the relative importances of the attributes in our conjoint experiment (e.g. transport modes, transfer time, reachability, transferability, allotment expiration and price (per month)) we can report the following results. As assumed, price was the most important attribute with 39.51%. The attributes transport modes (18.63%), transfer time (12.43%) and reachability (12.16%) had a similar relative importance score. Finally, transferability (8.44%) and allotment expiration (8.44%) seem to play only a minor role in the purchase decision and can be seen more as “nice-to-have” services of the mobility package. The results of the HB analysis revealed that potential users of mobility packages most prefer lower prices (on a monthly basis), packages that include all offered transport modes (public transport (PT) + bike sharing + car sharing), a maximum waiting or transfer time between the different transport modes on a trip of 5 minutes and a maximum distance to the first transport mode of 200 meters. Another benefit of the conjoint analysis is the possibility to convert part-worth utilities into aggregated monetary WTP scores (Green & Srinivansa, 1990). In the present study, WTP relative to a default option (i.e. PT + bike sharing, 25 min, 1000 m (approx. 15 min), non-transferable package and unused allotment expires monthly) was calculated. Finally, in order to identify heterogeneity in user preferences regarding the mobility packages we conducted an LCA. We chose a 3-group solution: convenience adopters, price-sensitive adopters and likely non- adopters. Based on the preferences for the mobility packages the findings indicate that two of the three costumer segments are potential adopters. The third segment with the part-worth utility of the none option as the highest score was labelled as likely non-adopters.

Conclusions

Multiple trends like urbanization, digitalization, demographic and societal changes as well as increased awareness of environmental issues are drivers that transform the mobility sector (Hoppe et al., 2009). Further, shifting norms and attitudes towards transportation change how people travel. Especially the younger generation – the millennials – own fewer cars, drive less and are less likely to own a driver’s license compared to older generations (Klein & Smart, 2017; Kuhnimhof et al., 2011; Raimond & Milthorpe, 2010; Sivak & Schoettle, 2011, 2012). Combining this with the fact that the average car is parked 92% of the time so that its capacity is not nearly optimally used (MacArthur et al., 2015) it becomes evident that new business models such as MaaS are in demand (Ambrosino et al., 2016). In recent years, a growing body of literature has shown interest in the MaaS concept, especially in the context of services and technological developments (Kamargianni et al., 2016; Jittrapirom, Caiati, Feneri, Ebrahimigharehbaghi, Gonzalez & Narayan, 2017). Consequently, to promote the diffusion of such mobility packages the preferences and characteristics of future users are of high relevance. The present study shows that the most important feature of such offerings is price, followed by the transport modes included in the package, transfer time and reachability.

Furthermore, our findings from latent class analysis reveal that the preferences for package features differ between different groups of potential users underlining the need for individualisation and customisation. These findings represent important insights for marketers and policymakers to better identify and understand potential adopters of multimodal mobility packages. Considering the high impact of the transportation sector on climate change further research is of high relevance. Thus, the implementation and evaluation of MaaS concepts will shape future of mobility discourse and the further development of mobility services.

Cesare Pozzi, Ernesto Cassetta and Umberto Monarca

THE EU AUTOMOTIVE INDUSTRY AND THE ELECTRIC VEHICLE REVOLUTION: IMPACTS ON THE VALUE CHAIN AND INDUSTRIAL POLICY OPTIONS

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Overview

The history of the developed countries and the history of the automotive industry are strongly intertwined. The article discusses the possible evolving scenario for the EU automotive industry deriving from the deployment of the Battery Electric Vehicles (BEVs). The electrical technology is able to change radically the entire automotive value chain. As a consequence, there is a need for carefully considered industrial policies to cope with the overall socio-economic effects of the expected changes.

Method

Starting from the current landscape of the automotive industry at global level, the socio-economic impact on the automotive value chain is derived from a desk analysis of car manufacturers plans, market outlook by industry experts and analysis by IT and battery developers to define potential deployment scenarios of BEVs. The article then analyses how the value chain would be affected by the shift to electric vehicles by identifying which and to what extent single activities are modified by the BEV technology and by taking into account the patterns of industrial specialisation of single EU countries.

Results

Our findings highlight that the socio-economic impact of the transition to BEV technology would be pervasive. The deployment of the BEV technology is likely to determine an excess of production capacity in the assembly plants and a loss of many markets related to automotive parts and components. The magnitude of this impact depends on the relative exposure to the incumbent ICE technology and on the speed of transition, which is in turn related to the evolution of battery technologies. Moreover, as the single activities of the value chain will be differently affected by the EV revolution, prospective changes in the automotive industry structure will hit EU countries in different ways. Those countries, which have progressively specialised in the assembly of traditional vehicles produced by foreign players and/or in the production of car components, will suffer comparatively more. The industrial policies to cope with the overall socio-economic effects of the expected changes would be consequently different.

Conclusions

The article draws industrial policy implications to cope with potential socio-economic effects of BEV technology. A distinction is made between countries, such as Germany (and to a lesser extent France), which still retain the opportunity to continue to support the industrial strategies of their national players to offset the potential negative effects on their territory, and other countries, which on the contrary need fundamental changes in their policies to prevent the definitive disappearance of the automotive industry.

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Matthias Kühnbach and Marian Klobasa

DOES DEMAND RESPONSE MAKE IT WORSE? IMPACTS OF AVALANCHE EFFECTS OF PRICE-OPTIMIZED ELECTRIC VEHICLE CHARGING ON SYSTEM LOAD AND ELECTRICITY GENERATION

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Overview

In course of the electricity sector's shift towards low-emission generation technology, controllable power plants are being replaced by renewable energy sources (RES). As a large share of the renewable generation units is weather-dependent, alternative forms of flexibility are needed to satisfy the demand for electricity at any times. Demand response (DR) has proven to facilitate this transformation process by shifting demand according to flexibility needs. Due to substantial growth rates of electric mobility, controlled charging of electric vehicles (EV) is expected to possess a substantial potential for DR in the future [1].

There are several options to offer demand flexibility, such as on ancillary markets or by using hourly variable tariffs, which depend on spot market prices. In order to meet prequalification requirements for the majority of market options in terms of offered capacity, it seems sensible to aggregate a critical mass of electric vehicles.

Beyond systemic benefits, controlled charging can also prove to be economically attractive for vehicle owners. Both the systemic and the economic efficiency depend on the signals used to incentivize a load adaptation. However, shifting the charging load of a critical mass of load could have noticeable consequences such as the creation of new load peak. This avalanche effect has been observed in the framework of simulating DR of other demand processes, such as in the residential sector [2]. However, due to the expected high impact of electric vehicles on the system load, an avalanche effect caused by electric vehicles could have incomparably stronger implications.

We thus identify the following research questions:

- Under which circumstances does controlled EV charging provoke avalanche effects?
- Do avalanche effects have an impact on the electricity system?
- Can avalanche effects be avoided? Does this affect EV-owners' income?

Methods

We look at controlled charging of electric vehicles in Germany in the years 2030 and 2050. We use the eLOAD model[1] to simulate demand response of electric vehicles with a mixed-integer linear optimization approach: to target peak shaving, residual load is applied as a price proxy. The flexibly share of the load is allocated in a cost-minimizing way.

To assess possible impacts of an avalanche effect, we disaggregate electric vehicles into cohorts and vary the number of cohorts between model runs. Within each model run, the optimization signal is dynamically updated after each cohort's load shifting activity.

Additionally, the eLOAD model allows the generation of a country's system load curve based on a database of process-specific load profiles, weather data and annual electricity demand projections.

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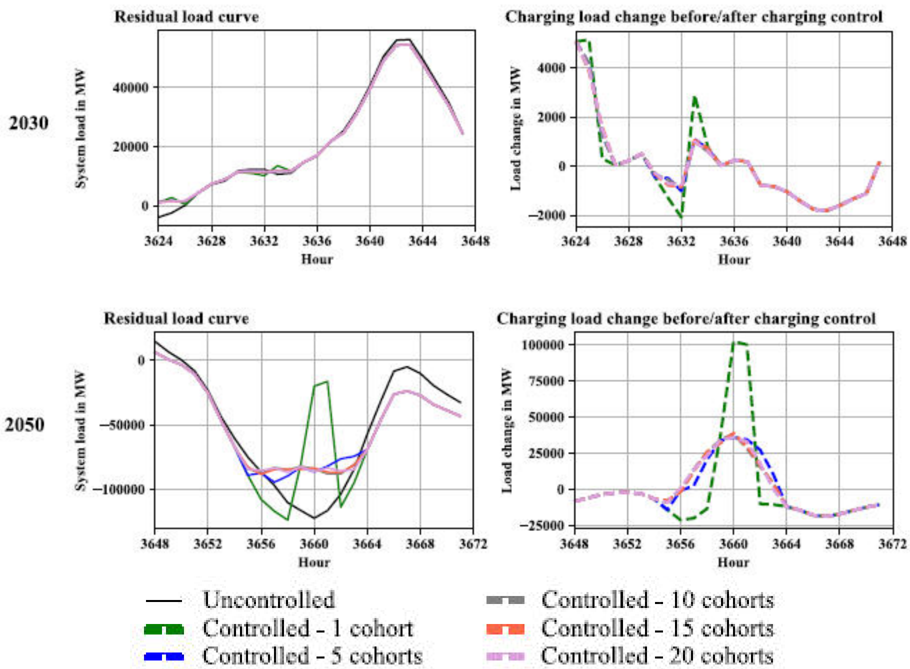
1 https://www.forecast-model.eu/

Thus, technological and structural changes on the demand side leading to an evolution of the system load curve are also considered for the simulation of controlled charging of EV.
In the last step, eLOAD is coupled with an electricity market simulation model to assess how the resulting system load curves affect marginal costs of electricity generation and to quantify potential monetary savings for vehicle-owners.

Results
Our modelling results show that controlled charging of EV has a noticeable impact on the system load.
Assuming that 50% of all EV are suited for controlled charging, maximum residual load is reduced in all cases, underlining that the impact of EV charging load on the system load is substantial. Concerning the assessment of avalanche effects, Figure 1 shows residual load (left) and load change through controlled charging (right) for a summer day in 2030 and 2050. EV cohorts are varied from one to 20 groups. If all EV are shifted at once (i.e. in one cohort), we observe large differences in the course of the day and between neighboring hours increasing the volatility of the residual load. Thus, an avalanche effect is possible. For the year 2050, due to the even larger charging load, the impact of avalanche effects could be even more significant. Yet, our results also illustrate that new load peaks can be avoided by disaggregating the flexible EV load. As a consequence, each cohort perceives a different price signal, which is, however, less attractive and lowers financial benefits for vehicle owners.

Figure 1: ***Residual load and process load changes due to controlled charging of electric vehicles with varying number of vehicle cohorts for a summer day in the years 2030 and 2050***



Conclusions

Demand response of electric vehicles addresses the need for a more flexible electricity system. Shifting the charging load from peaks to hours of low or negative residual load facilitates integration of RES and reduces electricity generation costs. However, our results show that controlled charging without a dynamically updated price signal can incentivize unwanted avalanche effect. Avoiding avalanche effects is possible but raises further questions concerning financial compromising and compensations for system-friendly behavior. From a systemic perspective, there is thus a trade-off between providing sufficient incentives in order to activate DR potential and avoiding unwanted effects.

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Naoyuki Otani, Ryoichi Komiyama and Yasumasa Fujii

ASSESSMENT FOR ECONOMIC IMPACT OF STRUCTURAL CHANGES IN AUTOMOBILE INDUSTRY BY DYNAMIC MULTI-SECTOR ENERGY ECONOMIC MODEL

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Overview

In this paper, we develop a dynamic multi-sector energy economic model that takes into account the difference in the automobile industry, the production cost, and the fuel consumption due to vehicle types or engine types. In the previous research, an economic model is developed considering the inter-industry linkage of the electric power sector and the material industry. The novelty of this paper is the point that newly considered the automobile industry. This paper evaluates the impact on the economy and energy supply and demand due to the structural changes in automobile industry such as spread of next-generation vehicle (NGV) in an integrated viewpoint from the economics and the engineering. Simulated results show both positive and negative effect of structural changes on industries and implies that the spread of NGV, the appearance of car sharing service and the charge and discharge of electric vehicle to power grid do not always have a positive effect in the society as a whole.

Methods

This paper performs an assessment of economic impact of structural changes such as the increase of NGV and the appearance of car-sharing service by developing an dynamic multi-sector energy economic model. The model can uniquely specify an automobile industry considering engineering characteristics. From initial transport demand, the model estimates vehicle production cost and fuel consumption cost from 2010 to 2050 (5-year interval) with the input parameters such as annual mileage, load factor, population forecast, fuel efficiency and so on. Then calculated cost is incorporated into supply and demand balance considering inter-industry linkage. This paper assumes the spreading scenarios of NGV and sharing cars which has unique parameter in fuel efficiency, production component breakdown, annual mileage etc. Through these scenarios, the economical impact on society is analyzed. In addition, this paper considers the charge and discharge of electric vehicle to power grid with hourly resolution through 8,760 hours. The contribution of electric vehicle to supply and demand adjustment of power grid is also analyzed.

Results

Computational results reveal that the spread of NGV has negative effect on petroleum industry because of the decrease of petroleum fuel consumption, compared with the result in reference scenario. On the other hand, it has positive effect on some industries such as electricity, non-ferrous metal, and chemical product manufacturing industry because of the increase of their demand due to the changes in fuel consumption and vehicle production. The simulated results imply that the negative effect on petroleum industry is too severe to be offset by positive effect on other industries. Other results show that the appearance of sharing car leads to the decrease of production of passenger vehicle. But they imply that it is not so effective in the viewpoint of whole automobile industry.

Conclusions

For considering the engineering characteristics of the automobile industry and the inter-industry relationship structure such as intermediate input and capital investment, this paper develops an dynamic multi-sector economic energy model characterized by engine types and vehicle types with hourly temporal resolution through 8,760 hours in power sector. The results suggest that the spread of NGV and car sharing service does not always have a positive effect in the society as a whole.

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Franco Del Manso
FUELS FOR FUTURE MARITIME TRANSPORTATION

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Overview
The shipping sector has grown significantly in recent decades, due to economic development in a number of emerging economies and in general to the increased globalisation of trade. Maritime transport is now central for the world economy with over 80% of the total volume of goods annually transported. It's a sector that reached near 18,0 billion tons of goods transported in 2018. Food and energy security around the world therefore rely on the distribution of goods by international shipping.
Although today, due to its characteristics, maritime transport is the transportation mode with the lowest environmental impact (emissions per ton/km of goods transported), in the future, without dedicated actions, the environmental externalities of shipping will increase a lot. To govern the growing demand for maritime transportation and gradually reducing the environmental impact of the sector, multiple actions will be necessary, both on the ships side and on the energy sources side.
This paper will explore the range of alternative fuels and technologies currently available toward a future greener shipping.
Current and future environmental policies in shipping sector – Bunker fuel quality and long-term CO_2 reduction
Bunker fuel quality. A very significant first constraint is the one that will come into effect starting from 1 January 2020, when the new IMO legislation on sulphur content of marine bunkers used in all international shipping will have to comply with the Global Sulphur Cap of a maximum of 0.5%. There are different options available to the shipping industry that could be implemented to comply with this Sulphur regulation ranging from the installation of SO_2 scrubbers onboard (gas cleaning systems which would allow them to use high sulphur fuel oil (HSFO)) to the use of low sulphur fuel oil (LSFO), marine gasoil (MGO) or retrofitting vessels to switch to another type of fuel (e.g. LNG).
The most up-to-date information on the number of ships equipped with scrubbers, LNG or other alternative feeds has the following data: about 3300 ships equipped with scrubbers, 3/400 ships powered by already operating LNG, or about to be, and a few dozen of hybridized or methanol vessels. Considering that the world fleet adds up to over 70,000 ships, the marginality of alternative options compared to the supply of low sulphur bunkers is evident.
Oil products. On the bunker supply, a sufficient availability of IMO-specific bunker petroleum products emerged, even if they will be very different products: marine diesel / gasoil; heavy distillates; traditional fuel oil. The most significant problem related to the different nature of the products that ships will be able to find in global ports is that linked to instability phenomena in the mixtures between them, with potential consequences on the correct functioning of the ship's engines and consequent safety problems. The current specification that establishes the environmental and performance characteristics of the bunker worldwide, ISO 8217, is being revised (expected for 2022) but in the meantime a lower ranking specification will be available Publicly Available Specification (PAS2363), destined to govern especially the problems of stability and compatibility.
Scrubbers. The use of scrubbers will allow shipowners to continue using the traditional high sulphur bunker fuel. With the current price differentials of the different products, the payback time of the scrubber appears however very short (from one to two years). However, several problems remain for this choice because local authorities do not always allow full use and their use in ports and territorial waters of specific countries could be critical.

The ships preferentially equipped with scrubbers are the bulk carriers, the container ships and the oil tankers. Many cruise ships have also chosen this option. A great difficulty for the large-scale development of scrubbers is however linked to the limitation of firms suitable for installations.

LNG. The transformation of ship feeding with LNG systems has many advantages. First of all, sulfur is almost completely eliminated. Particulate emissions are also strongly reduced while it is certainly easier to manage NOx emissions. Finally, CO_2 is reduced by a good 20% compared to petroleum fuels. The potential of LNG is therefore considerable and the interest in this type of supply is very high among shipowners. In Northern Europe in Spain and the US coasts, LNG storage and supply terminals are widespread, but worldwide they are still insufficient to guarantee supply in every area and for every type of journey. In Italy there are several deposits under construction and with authorization, while others are still in the phase of expressing interest. The LNG market will develop worldwide with some tens of millions of tons over the next few years with increasing shares also in the Mediterranean. At least three cruise ships, some container ships and many ferries will operate at LNG in the Mediterranean, expanding this market.

Long-term CO_2 reduction. Shipping is estimated to have emitted over 1 billion tons of carbon dioxide (CO_2) in 2018, which equates to 3% of all global GHG emissions in the same year. The International Maritime Organisation's (IMO) emissions forecasts show that by 2050, in the absence of new policies, total emissions from the shipping sector may grow by as much as 150% (compared to 2007 levels) to 250% as the industry continues to grow. Based on these assumptions, the IMO recently decided to fix a GHG emissions target to international shipping of at least 50% GHG reduction by 2050 compared to 2008 emissions. This ambitious goal is not yet supported by specific measures and different technologies could be envisaged to contribute.

Technical and operational measures may increase the sector's energy efficiency, thus helping to reduce GHG rates by between 25% and 75% per tonne-kilometre below current levels. Although many of these measures appear to be cost-efficient, non-financial barriers may discourage implementation. It is important to note in this regard that from a regulatory perspective, the control of CO_2 from ships should follow an approach that takes into account at least all the emissions of the fuel life cycle from their production to the ship's propeller. In essence, the measures can be really effective only if the entire fuel chain is decarbonized, avoiding taking into consideration only the CO_2 emissions from the ship's chimney. Moreover, in any reduction of CO_2 emissions, the effects of carbon leakage need to be avoided, which will require that all measures adopted have to be applied on a uniform and global basis.

Currently, there is a big number of specific measures that could be implemented globally to reduce CO_2 emissions (Biofuels, LNG, Electric Energy, Hydrogen, e-fuels such as synthetic diesel, Methanol or Ammonia).

Although technically possible, the use of first-generation **biofuels** may pose some on-board storage and handling challenges (e.g. plugging of filters, microbial growth), along with issues relating to limited availability and uncompetitive prices. **LNG** has the best chance of becoming economically viable, principally for ships operating within Emission Control Areas (ECAs) and where LNG is available. The use of LNG involves an immediate reduction in CO_2 emissions of 20% provided that all possible methane leaks (which have a potential for greenhouse effect 28 times greater than CO_2) are completely eliminated. However, remember that of the approximately 70,000 ships that make up the world fleet, only 3 - 400 are LNG, and even in the presence of strong interest, future growth will inevitably proceed in small steps.

Electrification and hybridization of the ship. Today there are about twenty fully electric ferries and the construction of the same number is planned in the near future. They are very small numbers and they are boats that, while emitting zero CO_2 in the place where they operate, must consider the emissions deriving from the construction of the batteries and those deriving from the production of electricity. More numerous are the achievements of Plug-in hybrid and hybrid ships but always within the range of the hundred ships.
Biofuels. The ISO 8217/2017 standard regulates the use of biofuels in the bunker. These can be added to distillates to an extent not exceeding 7% by volume, respecting all the other characteristics of the specification and must be appropriately marked as not suitable for all engines. For all other bunker the tolerated level of biocomponents in the fuel cannot exceed 0.1% by volume. This limitation is justified for some criticalities that can derive from the presence of products of biological origin in sensitive applications such as the naval ones. Therefore, in the presence of biofuels in the bunker it is necessary to pay particular attention to the tendency to oxidation in long-term storage as well as the predisposition to develop bacterial growth and fungi, to prevent any problem of filterability at low and high temperatures.
Other feeds. Other feeding systems are intended to use fuel with a lower carbon content (methanol - 12 ships) or with zero carbon content (a ship's hydrogen being tested) but these are operations still confined to research rather than already commercial.

Conclusions. With the systems to reduce polluting emissions to the exhaust and with the increasing use of LNG as fuel for the supply of ships, the problems linked to SOx, NOx and Dust pollution will be completely resolved in the short and medium term. However, the ambitious IMO target to reduce the CO_2 emissions of maritime transport by 2050 remains to be achieved.
The combination of the above different options with a transport management that avoids non-operational waiting, will allow completing the transport with considerable savings in terms of emissions of CO_2. These initiatives, together with ever more efficient engines with increasingly renewable or decarbonised fuels, should ensure the long-term compliance with the ambitious IMO targets.

Carsten Herbes and Benedikt Rilling

GREEN GAS RETAIL PRODUCTS ONLY PARTIALLY MEET CONSUMER PREFERENCES: A COMPARATIVE STUDY OF FOUR MARKETS IN EUROPE

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The end energy consumption of private households for heating purposes accounts for a large part of total end energy consumption in many developed countries. In Germany for example the share of households in total final energy consumption stood at 26% in 2016, of which 69% were for space heating (Umweltbundesamt, 2019, 2018). Many households use natural gas for heating: In all EU 28 countries in total, gas accounts for 43% of final residential heat demand (Fleiter et al., 2017). This opens up opportunities for introducing renewable energies into the heating sector, namely in the form of biomethane-based gas products that can be used with established heating technology for the residential sector. Biogas is an established technology in many countries, but still requires substantial subsidies to be competitive (Cucchiella et al., 2019; Rajendran et al., 2019).

In some markets, however consumers can already chose biomethane-based gas products for heating their homes, which is one option to market biomethane without subsidies (Herbes et al., 2018; Herbes et al., 2016). However, in order to be successful, biomethane-based gas products need to meet consumers' preferences. Past research has established that consumers prefer gas products with a high share of biomethane, carrying an eco-label and stemming from regional sources and from waste-based biogas plants rather than from plants that use energy crops (Forsa, 2013). Moreover, consumers prefer, for green electricity, cooperatives as providers over big utilities (Sagebiel et al., 2014). But do the products in the market really meet these preferences? And do product prices reflect these positive attributes? So far, these questions concerning the supply side of the biomethane market are rather under-researched, with the exception of one study on the German market (Herbes et al., 2016)

Methods

In order to answer the above research questions, we carried out an online content analysis of green gas products
on providers' websites in two major natural gas markets, i.e. Germany and the UK and in two innovative small markets with a well-developed biogas industry, i.e. Austria and Switzerland. For the samples we used provider compilations provided by either national regulatory agencies (ofgem for the UK, E-Control for Austria), by a national industry association (gaz energie for Switzerland) or by an established trade journal (Germany). We validated our samples by cross-checking with the results from online gas tariff comparison portals.

Results

Attribute		Germany	UK	Switzerland	Austria
Total number of biomethane-based tariffs		126	24	188	25
Total number of providers		88	9	62	10
Average biomethane content		22.9	32.5	41.6	32.2
Feedstock	Tariffs with mixed feedstock	30	12	5	10
	Tariffs based on waste	27	2	162	10
	Tariffs based on energy crops	3	1	0	0
	Tariffs without disclosure of raw material	28	9	22	5
Origin of biogas	Tariffs with regional origin	23	0	58	19
	Tariffs with national origin	15	0	41	0
	Tariffs with international origin	1	0	53	0
	Tariffs without disclosure of origin	92	24	37	6
Tariffs with labels		53	1	27	13
Provider type	Regional providers	61	1	62	5
	National providers	19	8	0	2
	International providers	2	0	0	3
Provider commercial orientation	Municipal utilities	62	0	19	0
	Pureley commercial providers	21	8	43	10
	Cooperatives	1	1		0
Purely green suppliers		8	5	6	1

Should the abstract be accepted we will add statistical analyses on the question if attributes that are favored by consumers are linked to price premia,

Conclusions

The tariffs in the market only partially meet consumers' preferences. In Germany, despite the widespread reservations about energy crops, there are still biomethane tariffs in the market that are fully or partly based on energy crops. Providers in all countries are, overall, rather intransparent about the geographic origin of the biogas and in the UK none of the tariffs is of a regional origin. In Switzerland, a large part of the tariffs (58) is of regional origin, but almost the same number (53) is imported from abroad, probably from Germany. Purely green providers are a minority, except for the UK where they are dominant. Overall, the supply side has room for improvement in meeting consumer preferences and making biomethane a successful product in retail gas markets.

However, being in line with consumer preferences, regional providers are strong, except for the UK. Eco-labels are most used in Germany and Austria where about half of all tariffs carries a label, although providers are rather creative in what labels they put on their websites. Not all labels are real eco-labels that certify superior environmental attributes.

Regarding overall market structure, the German market is influenced by the historically strong position of municipal utilities and in Switzerland regional monopolies have led to a rather small-scale structure while the UK market with its early and strong liberalization is dominated by an oligopoly of big commercial providers.

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Stella Oberle, Till Gnann and Martin Wietschel

HOW RELEVANT IS THE NATURAL GAS DISTRIBUTION GRID IN COMPARISON TO THE ELECTRICITY DISTRIBUTION GRID AND HEATING GRIDS?

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Overview

Current studies, investigating the developments of the energy system in light of the energy transition, predict an increase in natural gas demand until 2030, followed by a significant decline until 2050 (DLR et al. 2012; EWI 2017; Öko-Institut and Fraunhofer ISI 2015; OECD/IEA 2017). New competitors to the natural gas suppliers are entering the market to equip industry and buildings with electricity and heat. This development leads to new challenges for the natural gas sector and especially for the distribution grid operators, since a decrease in natural gas demand with a constant gas grid length leads to an increase in operating costs and consequently to higher network charges (Wachsmuth et al. 2019). To investigate these new challenges a more interconnected approach is necessary. Hence, this study focuses on sector coupling on a distribution grid level by a combined analysis of the grid-based electricity, heat and natural gas supply. We aim at contributing to the following research question: How relevant is the natural gas distribution grid in comparison to the electricity distribution grid and heating grids?

Methods

To investigate the new synergies and competition for the gas distribution grid, we first analyze the current state and future development of the natural gas demand on an international and national level. Therefore, recent study results on this issue are compared and their expected developments are investigated regarding their implications on the natural gas distribution grid. This analysis gives further insight about the changing usage of natural gas and potential alternatives to natural gas based applications.

Further, the different structures of the competing grids, heating, electricity and natural gas, are outlined and the main energy consumers on these grid levels are identified. This permits us to show synergies and competitions between technologies within and across the different levels of distribution grids, such as high, medium and low pressure or voltage grid.

Lastly, economic parameters for the three different grids, such as investment, network charges and withdrawal volume, are compared and the revenues are estimated by multiplying the withdrawal volumes with the average network charges.

Results

Natural gas is used in all demand sectors, such as energy economy, industry, buildings and transport. In future, there will remain potential applications for natural gas in the different sectors but also alternatives. For example in the building sector, natural gas is currently used in a natural gas boiler for heating, however more and more heat pumps or heating grids are implemented, establishing a strong competition between natural gas, heating and electricity grid. The preliminary techno-economic analysis of the historical data shows that the length in kilometers and the height of investment in the electricity distribution grid are higher than those of natural gas and heating grids (BNetzA 2019; AGFW 2018).

However, the withdrawal volume is significantly higher in the natural gas distribution grid than in the two other grids (BNetzA 2019; AGFW 2018). Consequently, the network charges are far lower in the natural gas distribution grid than in the electricity distribution grid. Because of the absence of network charges for the heating grid, a comparison between the three grids based on the revenue for the grid operators is not possible. However, this comparison shows that the electricity distribution grid operators achieve nearly double the revenue compared to the natural gas distribution grid operators.

For a comparison including heat, the expenses of the household customers are calculated based on the price and withdrawal volume. It shows that the heat price is slightly higher than the gas price. Yet, because of the higher withdrawal volume, the expenses for gas are higher than for heat. The electricity price includes higher shares in taxes, leading to a far higher price than the one for gas and heat. Consequently, the expenses for households are significant higher.

Conclusions

The preliminary results of the techno-economic analysis show that the electricity grid operators achieve the highest revenue, which leads to the conclusion that the natural gas distribution grid is economically of lesser relevance. Taking into account that the future development might lead to lower withdrawal volumes from the natural gas distribution grid and consequently, to higher network charges the question arises if this will actually influence the user behavior, since currently, the network charges are far lower than the ones for the electricity distribution grid. It further shows that the market structure of the heating grids is different to electricity and natural gas distribution grid, making it difficult to compare all three grids. Based on the current expenses for the households, heat from heating grids has the lowest relevance. However, considering future developments, there is the potential to an increased relevance of heating grids.

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Arnold C. Dupuy, Daniel Nussbaum, Stefan Pickl and Paul Michael Wibhey

ENERGY SECURITY IN THE ERA OF HYBRID WARFARE: A VIEW FROM NATO

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Overview

The European Center of Excellence for Countering Hybrid Threats identifies the hybrid threat as, "…an action conducted by state or non-state actors, whose goal is to undermine or harm the target by influencing its decision-making at the local, regional, state or institutional level. Such actions are coordinated and synchronized and deliberately target democratic states' and institutions' vulnerabilities. Activities can take place, for example, in the political, economic, military, civil or information domains. They are conducted using a wide range of means and designed to remain below the threshold of detection and attribution."
(https://www.hybridcoe.fi/what-is-hybridcoe/)

While the basic parameters of hybrid warfare are firmly grounded in insurgencies or asymmetric warfare, it is the inclusion of modern information communication technologies which makes it so unique and potentially impactful to society at large. Hybrid warfare, which includes cyberwar methods, allows states to impact political conditions of their adversaries. Moreover, hybrid warfare is significant because it gives states, terrorist organizations or criminal actors a low cost, high yield method to influence the politics and policies of other states, or even capture territory without the use of conventional military force.

As energy is the key to maintaining a technologically advanced civil society and ensuring state viability, the unimpeded flow of affordable energy is critical. Indeed, energy security has become a topic of considerable concern within the NATO Alliance, to include the availability and deployment of both fossil fuels and renewable sources. The latter point is particularly relevant; as we experience a transition from fossil fuels to renewable resources, it is important to understand the potential vulnerabilities inherent in this process. Therefore, an important component of hybrid warfare is the ability of aggressors to attack and negatively impact the civilian energy infrastructure. In fact, many hybrid warfare operations have been directed against the energy sector, both the power grid, as well as fuels production and distribution.

NATO acknowledges the threat posed by hybrid warfare, particularly as it relates to the energy industry; the Energy Security Section has recently taken on the hybrid threat portfolio. Yet, while the Alliance has embraced hybrid warfare as a relevant security threat to the broader energy infrastructure among the member states, there has not been a systematic and rigorous analysis of this nexus. More specifically, the dependence of NATO's military activities on the civilian energy infrastructure cannot be overemphasized, where virtually every aspect of the supply chain is owned and operated by the private sector. Additionally, the ability to negatively impact military operations through a hybrid warfare platform is profound. For example, the delivery of natural gas, crude or refined product to Europe is highly vulnerable to a variety of threats. Moreover, the delivery of bulk fuel to the so-called 'last tactical mile', via pipeline, road, rail, air or barge can be challenged through any number of attack vectors. Therefore, it is safe to say that an experienced practitioner in hybrid warfare could impact mission assurance with potentially devastating results to Alliance military effectiveness.

Methods

The authors of this paper hope to bring attention to this topic by establishing an analytic structure or 'roadmap.' The proposed methods of our analysis look at four key 'pillars'. These are:

1. What are the main threats to the civilian infrastructure?
2. Data acquisition, analysis and modeling.
3. Understanding the adversary, and
4. What are the current and future mitigation efforts and countermeasures?

Results

Initially, there are a handful of key takeaways from our analyses. These include a clear demand for better cooperation between the NATO member states and the need for a lessons learned/best practices data base. A case study analysis could provide some of this material. Several questions that must be asked and analyzed further. These include:

1. Can the energy-hybrid threat destabilize any NATO state?
2. Are there benchmarks which highlight the minimal destabilizing impact?
3. How does this affect NATO as a whole?
4. How can we operationalize these benchmarks?

Moreover, we must acknowledge the importance of energy markets as a component of the security field, and ensure human factors are included as part of the hybrid warfare framework, including considerations such as countering propaganda or malign influences.

Conclusions

The proposed paper and presentation will raise the strategic awareness of this topic within NATO and among the member countries. We hope to raise awareness of the energy-hybrid warfare nexus by understanding its component parts and identify its broader impact in the civilian and military realms. Ultimately, we believe there is an urgent need to define courses of action to mitigate the impact on civilian and military infrastructure and interests and develop countermeasures and analytic rigor to this vital topic.

Hideaki Fujii

THE CHALLENGES AND PROSPECTS OF JAPAN'S ENERGY SECURITY IN EAST ASIA SINCE 1990S

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Overview

After the US-Soviet Cold War ended due to the collapse of the Soviet Union in 1991, market opening of information and communication technology to the private sector have progressed, and rapid demand expansion and technological progress of ICT services have been realized. Among these, With the progress of regional economic integration such as the European Union (EU: European Union), the reduction of economic regulations concerning the movement of goods and services, and the liberalization of the market, it has been easy for us to make the movement and transfer of goods, money, people and information on a global scale.

The globalization has triggered the expansion of the market economy and the convergence of economic levels on a global scale. Developed countries accounted for about 70% of the world's energy demand in 1965, but in 2014 about 60% came to be consumed in developing countries. The movement of the geographical center of energy demand has also changed the global energy supply and demand structure.

On the other hand, it is pointed out that this phenomenon has been the cause of new isolationism, protectionism, and regionalism. It is necessary for Japan to rethink energy security based on the new concept, because the environment surrounding Japan has dramatically changed from the US-Soviet Cold War period, with East Asia accounting for about one third of the world's energy consumption. Therefore, this paper examines Japan's non-traditional energy security issues since the latter half of the twentieth century and discusses the major issues to be recognized in the first quarter of the 21st century.

Methods

Since the end of the Cold War, the concept of energy security has changed significantly in East Asia. This paper aims to clarify the structure and challenges of Japan's energy security issues by comparing traditional and non-traditional energy security concepts.

Results

Transformed from a traditional concept to a non-traditional concept, security targets and risks have been expanded to form a multi-layered structure, so security measures have required a wide range of solutions, and a multilateral cooperation framework has been called for. In considering Japan's non-traditional energy security strategy, the following six important changes in the externality of Japan's energy markets should be noted.

(1) The Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant accident that occurred in 2011(the general safety assessment for the commercial use of nuclear energy prior to the accident was denied.)
(2) Upward revision of global resource reserves assessment and progress of shale revolution
(3) Expansion of renewable energy generation
(4) Research and development of new technology and diffusion
(5) Economic development and energy supply and demand trends of China that is a population-rich country located in the west of Japan

(6) Backlash against "discontinuous change in common sense" (paradigm shift) triggered by globalization after the end of the Cold War

Conclusions

The following two points as additional Japan's energy security strategies should be emphasized in the first quarter of the 21st century.

(1) Japan's energy policy should focus on promoting energy technology development, and it should be necessary not only to "get out of the fossil energy-dependent hydrocarbon society" but also to have an innovative strategy of "full management of energy demand".

(2) In East Asia, a comprehensive and enforceable multilateral legal framework should be needed, and East Asian countries and regions should need to seek the formation of common values that could be shared regarding order, justice and peace.

Pierre Cayet, Arash Farnoosh and Lionel Ragot

LARGE SCALE RENEWABLE INTEGRATION IN THE FRENCH ENERGY SYSTEM: COSTS AND ENERGY SECURITY VERSUS ENVIRONMENTAL AMBITIONS?

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Arash Farnoosh, Professor at IFP School, Paris, Center for Energy Economics and Management, France
Lionel Ragot, Professeur d'économie à l'Université Paris Nanterre, Paris, France

Overview:

The recent French law for energy transition and green growth (LTECV, 2015) has introduced a new tool for steering the energy policy called Programmation Pluriannuelle de l'Energie (PPE). The PPE expresses the main orientations and priorities of public authorities in the management of energy sources in order to meet the energy policy targets set by the law. Using the tools of linear and dynamic programming, we develop an innovative stochastic optimization model, defined at the regional and seasonal level, that allows us to calculate the optimal electricity investment schedule and production dispatch while respecting the techno-economic constraints and requirements of the PPE. To the best of our knowledge, optimization models using combinations of quantiles haven't been used for studying electricity systems, the closest being Shenoy & Gorinevsky (2015). We perform optimization over a continuum of net demand values that result from combinations of demand and renewable production quantiles. We derive robust results at relatively low computational costs.

We use this general framework to study both the consequences and the evolutions of the French nuclear fleet and storage capacities. As nuclear power currently represents about 75% of domestic power generation, this work carries a sensitivity analysis so as to evaluate the techno-economic impacts of various nuclear scenarios (dismantling, maintenance of current nuclear plants) and compare them to scenarios of large scale renewable integration with storage.

Methods

Our paperwork is mostly based on the stochastic optimization and linear programming literature. Examples of such models include Loulou, Goldstein, Noble (2004), Lund et al (2009), and Farnoosh, Percebois, Lantz (2014). These models directly derive electricity prices from marginal production costs, and allow optimization under both technical, economic and environmental constraints, as in De Sisternes (2016).

However, stochastic optimization problems are usually simplified into deterministic ones by the introduction of a set of scenarios and their expectation is either maximized or minimized. This is equivalent to reducing the parameters' distribution to their expected value, which makes results less robust. In our study, so as to cope with this shortfall while avoiding the conservative nature of robust optimization, we discretize the distributions of parameters (electricity demand, wind and solar production) into quantiles and derive the joint probability of each 3-elements combination of quantiles. Optimization is performed for each combination of quantiles, which yields for every region a distribution of optimal investment schedules and a set of production dispatch distributions.

Results

The results show for a continuum of regional-level net demand combinations the optimal investment schedule and economic dispatch at the national level. This allows including regional complementarities in the production of renewables and optimal geographical dispatch of solar and wind power plants. Technical and environmental assumptions (learning curves for storage technologies, discount rates and CO_2 prices) can highly impact the final results in addition to the feasibility of the PPE's goals concerning the reduction of the nuclear share in the energy mix.

Conclusion

This paper will allow us to derive energy policy recommendations regarding the French energy system and the optimal path for meeting the objectives set by the PPE. We carry out a cost comparison between the scenario of complete nuclear fleet maintenance until 2030 versus the phasing out scenario targeted by the PPE, challenging Cany et al. (2016). The results are expected to be highly sensitive to the relative costs of technologies. A budget constraint will be introduced in the future to further develop this comparative analysis. Our paper finally proposes an innovative and robust tool that allows accounting for heavy-tailed distributions and deriving statistical properties of optimal results, in addition to providing more stable results than policies based on high-order statistics such as expectation and variance (see Kim & Powell, 2011).

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Andre´ Cieplinski, Simone D'Alessandro and Francesco Marghella

ASSESSING THE RENEWABLE ENERGY POLICY PARADOX: A SCENARIO ANALYSIS FOR THE ITALIAN ELECTRICITY MARKET

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Overview

Recent contributions have shed new light on the limits of renewable energy expansion in liberalized markets due to the combination of low marginal costs and intermittency Blazquez et al. (2018) . The gradual expansion of solar and wind power tends to reduce prices during their pro- ductive hours, thus limiting the profitability and willingness to invest in these proven renewable technologies.

This study develops a macro-simulation model for the Italian economy which jointly simulates the endogenous evolution of macroeconomic variables and the electricity market. We assess whether under the current conditions Italy's electricity prices are projected to follow a downward trend due to the increase in intermittent renewable energy supply. Moreover, we consider if demand management policies could help ease this trend by increasing demand during daytime and the likely impacts of a coal phase-out in 2025.

Methodology

Model. The following simulations are based on the NET – New Electricity Trends Althesys – model: an integrated bottom-up-top-down model system dynamics tool calibrated for the Italian economy. The model is composed of two main modules. The first simulates the endogenous evolution of macroeconomic variables through interactions of heterogeneous households and industries. Its main causal relations and behavioral equations follow the post-Keynesian tradition (Lavoie, 2014). Therefore, NET simulates a demand-driven economy in which industries produce and employ workers to fulfil their final demands while productive capacity and labour supply adapt accordingly in the long-term.

Moreover, industries output and demand for intermediate goods are determined by an input-output productive structure with dynamic technical coefficients. The latter, as well as labour productivity, evolve according to an endogenous process of technological progress in which each industry chooses the cost-minimizing technology among a randomly extracted technologies.

The main heterogeneous agents, industries and electricity generation technologies as well as the main relations between them are presented in *figure 1*.

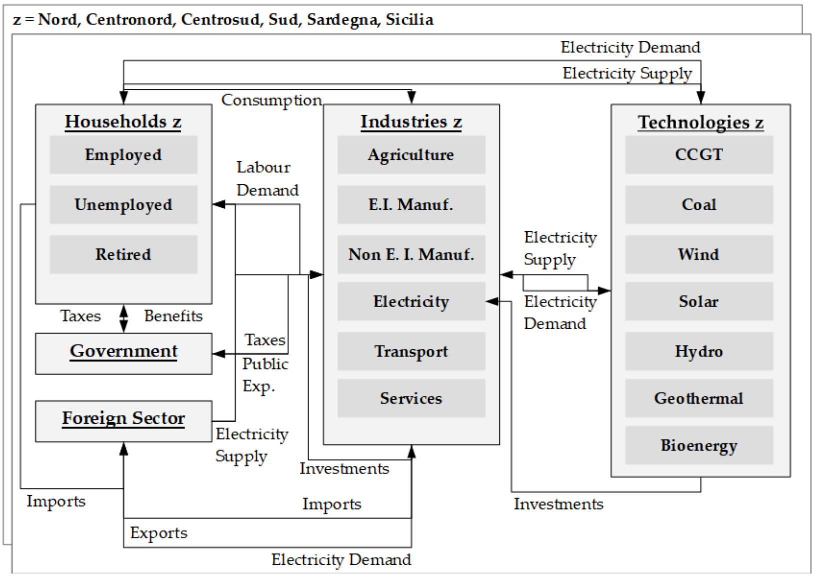


Figure 1: **Macroview. List and main connections among the heterogeneous households, industries and technologies included in NET model**. The abbreviations in the industries column refer to Energy Intensive Manufacturing (E.I. Manuf.) and Non-Energy Intensive Manufacturing (Non E. I. Manuf.), respectively.

The second module simulates the electricity market. It starts from the electricity demand, divided into the 6 geographical zones of the Italian electricity market, obtained from the macroe-economic module which, together with the initial values for installed capacity by generation technology, is used build hourly demand and supply demand curves using the actual distribution of electricity demand and supply observed in the past 5 years.[1] While intermittent technologies supply their full capacity whenever they produce, the remaining technologies and the foreign sector cover the remaining demand. This excess hourly demand is allocated to non-intermittent generation technologies according to their relative productive capacity. That is, the supply capacity of each of these technologies in a certain hour relative to the sum of non-intermittent productive
capacity.

Hourly electricity prices – by zone and at the national level (PUN) – are determined as a function of the marginal cost of each technology weighted by their actual supply in a hour-month period.

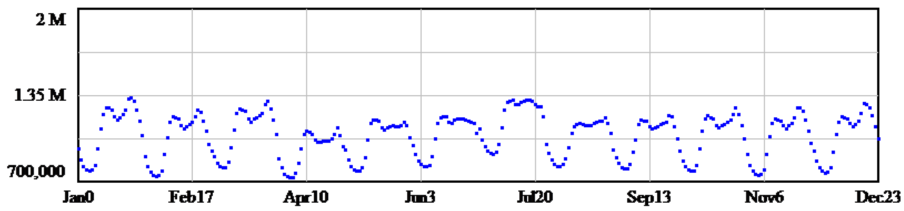
[1]Annual values of demand and capacity are distributed among 288 categories that are given by 12 months divided into 24 hours. Hence, our hourly model implicitly assumes that electricity demand and supply is homogeneous among the days within a month. For instance, the hourly demand for January at 1 p.m. corresponds to the demand at this hour for the 31 days of January.

Thus, hourly supply by technology is not determined by summing up the quantities offered by each technology, ordered from the lowest to the highest marginal cost, until they meet the total quantity demanded. However, hourly supply capacity of all production technologies follows the expansion of their installed capacity which, in turn, depends on their profitability. Therefore, the shares of total electricity supply covered by each technology adapt according to their market viability, thus assuring that prices reflect market conditions and follow changes in technological parameters that affect efficiency, emissions, operational and investment costs.

Scenarios.
The results presented in the following section plot three scenarios. In addition to the baseline or business as usual, we simulated two additional scenarios: demand management and coal phase-out. The first promotes gradual changes in the distribution of electricity demand within a year, starting from 2020 until the end of the simulation (2050). It is meant to reflect improvements in storage technology and demand management to render the demand profile more similar to the supply of intermittent renewables, thus allowing for their expansion.

Figure 2 plots the distribution of electricity demand for Italy within three selected years. The top graph plots the simulated distribution in 2020, before the introduction of demand management. The middle and bottom graphs plot the same distribution in 2030 and 2050, respectively. There is a clear difference between the demand management (red) and the baseline (blue) scenarios. The former peaks around 12 p.m. together with the supply from solar energy, while the later displays a more stable demand profile during the day.
The third and final scenario considers a phase-out of coal plants in 2025.
Figure 3 plots the shares in total installed capacity, in MW, by technology in the baseline (left) and phase-out (right) scenarios.

We present some preliminary simulation results in the following graphs.
Figure 4 presents some evidence in favor of the renewable energy policy paradox. The increase in the share of electricity supply from renewables (right graph) is met with a decrease in prices (left graph) in the baseline scenario. Moreover, the projected renewable share remains well below the 55.4% expected for 2030 (MATTM-MiSE-MIT, 2019, p. 43). Moreover, both the demand management and phase-out scenarios results in lower simulated prices by the end of the simulation, except for a sharp increase in the year of the coal phase-out, without a corresponding increase in the share of electricity supplies by renewable energy



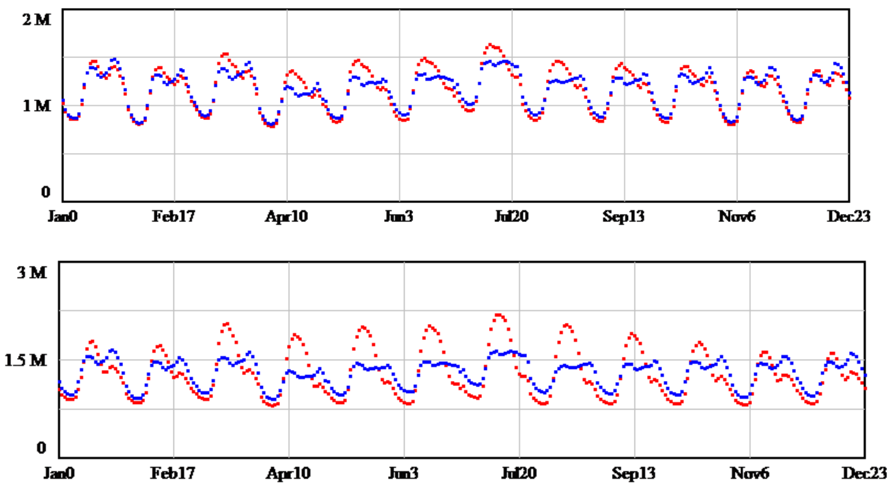


Figure 2: **Hourly national demand in MWh - selected years.**
Scenarios: Baseline, Demand management.

The three graphs present the distribution of yearly national demand in 288 periods given by 24 hours x 12 months in three simulated years: 2020 (top), 2030 (middle) and 2050 (bottom). For instance, *Apr10* in the *x-axis* of the graphs refers to the total demand at 10 a.m. during all the days in the month of April. The demand management scenario is implemented from year 2020 on.

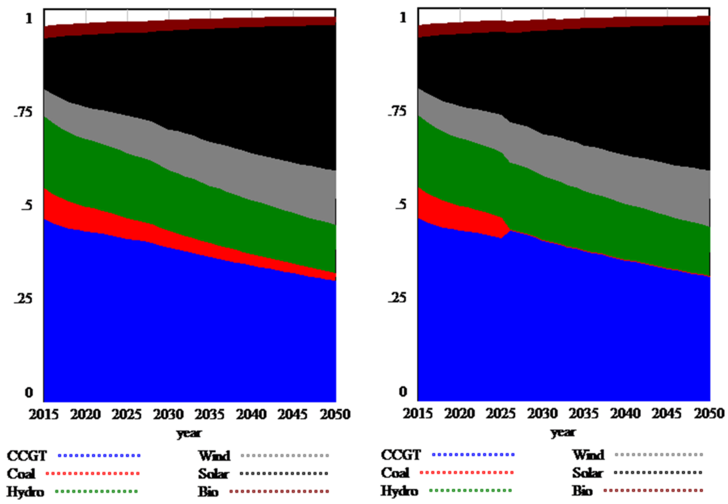
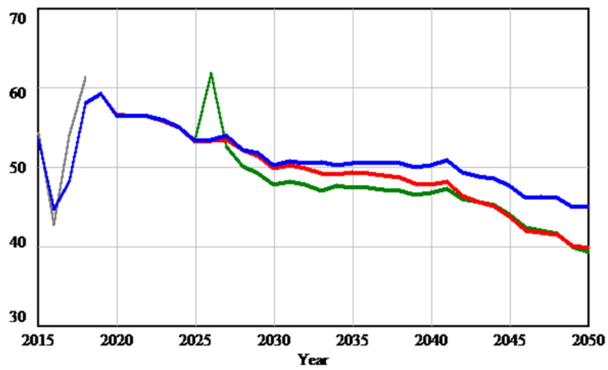
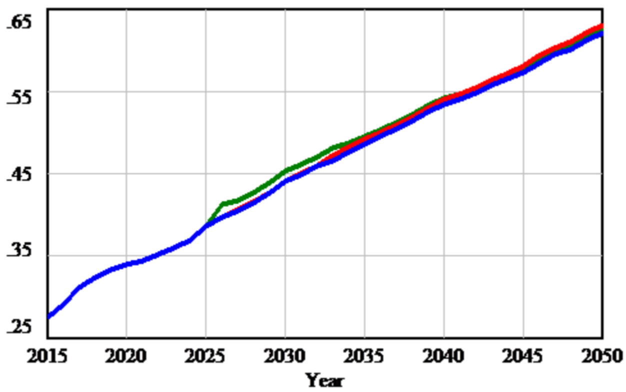


Figure 3: **Percentage of total installed capacity (MW) by technology**.
Scenarios: baseline (left), coal phase-out (right). The blank space on top of both graphs represents the installed geother- mal energy capacity.

We can make sense of the results interpreting *figures 5* and *6*. The four graphs in *figure 5* plot the annual average prices received by four different generation technologies: CCGT (north-west), solar (north-east), wind (south-west) and hydroelectric (south-east). These plotted values correspond to the hourly values weighted by the supply of each source in those hours. The demand management scenario indeed increases the average price paid to solar energy, with respect to the baseline, due to the increase in demand during its peak production hours. It also decreases the average prices relevant for CCGT (gas) and hydroelectric that tend to sell in hours whose demand share is reduced under this scenario. However, solar energy still receives less per MWh than non-intermittent technologies.



(a) National Single Price (PUN – e/ MWh)



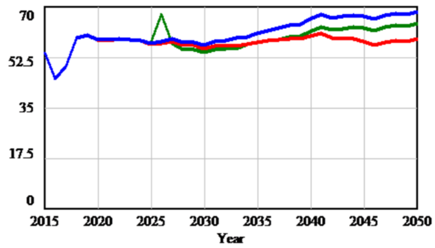
(b) RES-e quota (% of total supply)

Figure 4: **Main results.**

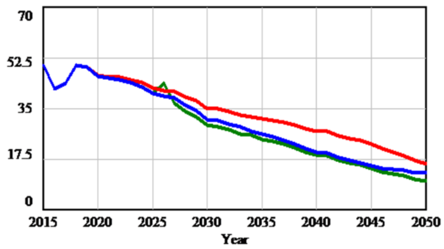
Scenarios: Baseline, Demand management, Coal phase-out and Actual past values.

The left graph plots the yearly averages of the national single price (*Prezzo Unico Nazionale*) calculated as the average of hourly prices weighted by the quantities purchased in each hour. The right graph plots the share of renewable energy – solar, wind, geothermal, hydroelectric and bioenergy – as a percentage of total electricity supply per year. The grey line in the left graph plots the actual values of the yearly PUN.

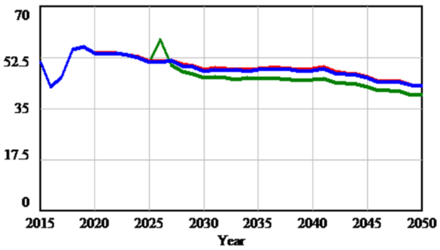
The coal phase-out scenario also leads to a reduction in the average prices. With the exception of year 2026, immediately after the phase-out the subsequent expansion of productive capacity from renewables is responsible for this fall.



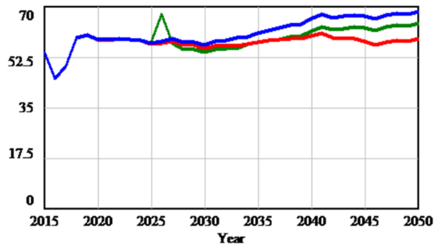
(a) CCGT - average sale price (e/ MWh)



(b) Solar - average sale price (e/ MWh)



(c) Wind - average sale price (e/ MWh)



(d) Hydro - average sale price (e/ MWh)

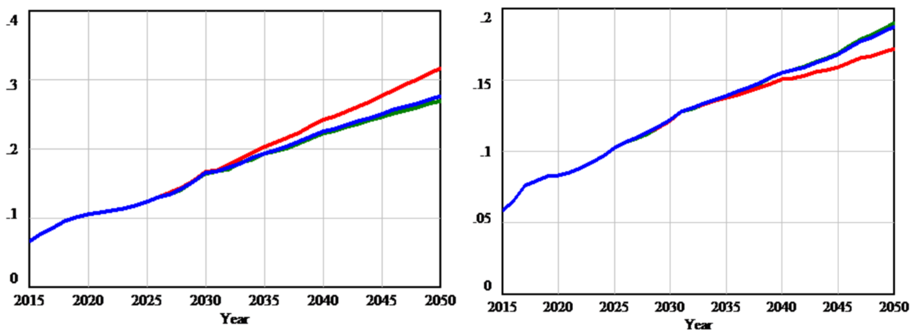
Figure 5. **Yearly average sales price - main technologies.**
Scenarios: Baseline, Demand management, Coal phase out.
The four graphs plot the average price received by four technologies: CCGT (north-west), Solar (north- east), Wind (south-west) and Hydroelectric (south-east). These are calculated as the average of hourly prices weighted by the quantities supplied by each technology per hour.

Finally, *figure 6* presents the share of total electricity supplied by solar (left) and wind (right).The significant increase in solar energy, from 27 to about 32% by 2050, on the demand management with respect to the baseline scenario, is followed by a decrease, from about 19 to 17%, in the share of wind. This compensation effect follows from the reduction of prices between 6 and 10 p.m. which is less than compensated by the increase during daytime which, in turn, reduces the profitability of wind and hydroelectric plants and compromises the expansion of their productive capacity.

Conclusion

The simulation results support the renewable energy policy paradox hypothesis. Moreover, they shed some light on the limits of demand management to boost renewable energy production in a liberalized market. The expansion of demand during daytime increases prices and the profitability of solar energy, however, that results in further expansions in intermittent energy sources installed capacity which drives prices further down in the future.

These results support the necessity of changes in market design to promote a low-carbon transition as suggested by (Newbery et al., 2018; Hu et al., 2018).
Acknowledgements. This research is jointly developed by the University of Pisa and Althesys Strategic Consultants. It is financed by Althesys Strategic Consultants which owns all the rights.



(a) Solar quota (% of total supply) **(b)Wind quota (% of total supply)**

Figure 6: **Solar and Wind Supply.**
Scenarios: Baseline, Demand management, Coal phase-out.
The two graphs plot the share of renewable energy supplied by solar (left) and wind (right) as a percentage of total electricity supply per year.

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María Teresa García-Álvarez, Blanca Moreno, Laura Cabeza-García and Isabel Soares

ASSESSING THE EFFECTIVENESS OF PROMOTION SYSTEMS FOR ELECTRICITY GENERATION FROM RENEWABLE ENERGY SOURCES IN THE EUROPEAN UNION

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Overview

The EU policies and targets have meaningful impacts on electricity markets as the increase of renewable
energy sources to efficiently deliver climate friendly electricity. In that sense Smart grids and Virtual Power Plants help to better integrate renewable energy under distributed generation resources, such as photovoltaic as well as wind or small hydro or combined heat and power units. In this context, many EU countries have adopted support schemes and subsidies to encourage electricity generated from renewable sources (RES-E).

Regulatory options to encourage deployment of RES-E may be divided into two large schemes: price- driven and quantity-driven. In this context, previous studies have analysed mainly the influence of RES-E support policies based on prices on RES-E development. We try to contribute to this empirical evidence studying not only the effect of feed-in tariff (FIT) policy but also of policies based on quantities (quota system, also known as renewable portfolio standard, RPS) on RES-E development.

In fact, this research provides an empirical evaluation of some renewable policy supports as feed-in tariff and renewable portfolio standard policies in the EU-28. In fact we try to test the impact of FIT design elements (contract duration and tariff price) on RES-E installed capacity and the impact of RPS design elements (certificate prices, award rate and validity lifetime for certificates) on RES-E installed capacity.

Methods

To test the impact of RES-E policies on RES-E deployment, we specify a econometric model. In the model the dependent variable is the RES-E installed capacity and as independent variables we introduce variables related to RES-E support, variables related to the socioeconomic context and variables related to government commitment toward environmental policy, among others.

As estimation method we use a pooled Ordinary Least Regressions clustered on the firm level. Besides, in order to control for endogeneity problems in the models proposed, explanatory and control variables are lagged by one year.

Results

The results show that only feed-in tariff policies and their main policy design elements have significant impacts in terms of installed renewable electricity capacity. The results indicate that only feed-in tariff policy has significant impacts in terms of installed capacity.

RPS and their main design elements do have not a significant impact on the development of onshore wind energy in our analysis.

Conclusions

Our results show that FIT derives in better results in terms of RES-E installed capacity in the EU-28.

Their main policy design elements (contract duration and tariff price) have significant impacts on the development of that clean production technology. However, policy-makers should consider a reduction of the regulatory uncertainty about the tariff price in the enactment of these policies. Regarding RPS elements, policy-makers should consider the importance of not changing or revoking retroactively some of those elements in order not to increase regulatory uncertainty.

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Lise-Lotte Pade, Lauge Truels Larsen and Claire Bergaentzlé

NORTH SEA OFFSHORE GRID INTEGRATION - BARRIERS AND SOLUTIONS

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Overview

The ambitious EU greenhouse gas emission reduction target for 2030 as well as the goal to reduce greenhouse gas emissions by 80-95 pct. relative to 1990 [1] by 2050 is expected to drive a significant offshore wind (OW) development across Europe. Because of its large OW potential, a large share of the development is expected to take place in the North Sea. Another ambition of the EU is to further integrate and liberalise the internal energy market. Integrating the European electricity market with the large OW potential in the North Sea requires a significant amount of new transmission capacity in the North Sea.

As wind energy production is dependent on the available wind resources future wind farms may be located far from shore and existing network infrastructures. Traditionally offshore wind farm (OWF) have been connected by building an offshore extension line to the existing national transmission grid. This simple stand-alone connection is often referred to as a radial connection. In the future some wind farms are expected to be installed at distances up to 250 km from shore potentially significantly increasing the costs of the offshore transmission grid. The far from shore OW development requires more advanced infrastructure solutions. One approach uses the complementarity between subsea interconnectors and OWFs, e.g. connecting a wind farm or a cluster of wind farms to cross-border transmission lines. An example of this hybrid integrated grid infrastructure is the meshed offshore grid.

The present report identifies the relevant regulation towards the development of massive offshore wind as well as the hybrid integrated grid infrastructure in the North Sea. Furthermore, the report addresses potential barriers related to the relevant regulation. Finally, possible solutions to overcoming these barriers are presented.

Methods

In order to assess the regulatory pathway towards and offshore meshed grid in the North Sea we identify the relevant regulation and divide it into regulation regarding investment in and operation of OW and grid development. We identify the barriers embedded in the current regulation with respect to investment and operation and pinpoint the key regulatory issues, i.e. the regulatory framework conditions deemed vital for the development of a meshed grid. Having clarified the key regulatory issues and their characteristics we compare these with the present regulation in the North Sea countries and present recommendations towards offshore meshed grid friendly regulation.

Results

Among the identified regulatory barriers we analyse three key regulatory issues

- The distribution of connection costs: Connection cost allocation across all involved stakeholders has been identified by as a “critical” risk factor in the development of the hybrid integrated grid.

- Transmission tariffs: The design of the transmission tariff significantly affect the business case of the wind farms and hence their location.
- Investment incentives: The regulation affecting incentive instruments concerns the recovery of investment cost related to grid investments. The incentive instruments has been studied with respect to developing an integrated European Electricity market, we apply a similar approach in the case of the hybrid integrated grid.

We find that the following preferred regulatory designs for the three regulatory issues:
- Grid connection cost allocation: The super-shallow approach removes the risks, reduces the complexity associated with the legal definition of the assets, and reduces the financial risk for the OW developer.
- Grid access charge: Tariffs should apply to the energy component only, this complies with Regulation (EU) No 838/2010 and would be OW developer friendly. Further, locational signals should be avoided, thereby enhancing the chances for the development of a HIG.
- Investment incentives: We should strive for harmonisation across countries. Preferably the incentive package reflect the effective investment risk in terms of limiting financial risk on CAPEX, incentivise innovation through full cost recovery of R&D spending and clear R&D incentive and finally couple profits to HIG-based benefits through incentives on OPEX.

Conclusions
We found that among the regulatory framework of the North Sea countries Germany's regulatory framework is best suited to the development of a HIG followed by Denmark and Norway. The regulatory framework of Belgium and Netherlands need to be adjusted and the regulatory framework of the UK is lacking behind with respect to supporting a HIG.

Hassan Ali, Han Phoumin, Steven R. Weller and Beni Suryadi

COST BENEFIT ANALYSIS OF HELE AND SUBCRITICAL COAL FIRED ELECTRICITY GENERATION TECHNOLOGIES IN SOUTHEAST ASIA

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Overview

Currently, coal-fired electricity generation plants with a total capacity of about 1700 GW account for over 41% of the electricity generation worldwide. Coal fired electricity generation is responsible for over 28% of global carbon dioxide (CO_2) emissions and scientific studies suggest that CO_2 emissions are responsible for global warming and associated devastating public health and environmental impacts.

To decarbonize the electricity generation sector under the International Energy Agency (IEA)'s 2°C scenario (2DS), electricity generation from less-efficient subcritical coal plants needs to be completely phased out by 2050. Across Southeast Asia, there is a vital need to deploy high-efficiency low-emission (HELE) technologies, rather than employing the less-efficient subcritical technology. Deployment of HELE technologies is progressing in Southeast Asia, but the overall rate of deployment falls short of achieving the 2DS. Association of Southeast Asian Nations (ASEAN) countries should therefore make increased efforts to eliminate generation from subcritical plants and increase generation from HELE plants to meet the 2Ds targets.

Method

A cost benefit analysis of HELE technologies against the less-efficient subcritical electricity generation plants is thus carried out to find a persuasive scenario supporting quicker transition from subcritical stations towards HELE technologies in the ASEAN region. A levelized cost of electricity (LCOE) analysis is carried out for both the coal-fired technologies under four potential policy scenarios. To evaluate LCOEs, the Scenario 1 does not take into consideration any carbon pricing and costs associated with the desulfurization (deSOx) and denitrification (deNOx) facilities. The Scenario 2 (Scenario 3) incorporates carbon pricing (costs associated with the deSOx and deNOx facilities), and the Scenario 4 includes both carbon pricing and costs associated with the deSOx and deNOx facilities. Under each scenario, a sensitivity analysis is performed to evaluate the uncertainty affecting the future coal prices on coal plants of 20- and 25-years life span.

Results

The study reveals that the pollution control scenario (i.e., implementation of carbon pricing policy) surpasses the other scenarios in displacing subcritical plants sooner than earlier to pave the way for HELE technologies.

The study also confirms that:

- reduced coal prices and increased life spans benefit both HELE and subcritical coal-fired power plants;
- HELE coal-fired power plants are economically competitive against subcritical plants; and
- Advanced ultra supercritical (A-USC) coal-fired power plants are the most economically attractive choice for deployment 376 in Southeast Asia, followed by ultra supercritical (USC), and supercritical (SC) plants.

Conclusions

The conclusion is that HELE plants are economically competitive against the subcritical plants and in the short run the Southeast Asian economies should focus on devising and implementing carbon pricing to support quicker deployment of HELE and displacement of subcritical technologies. Ultimately, in the log-run, a strong carbon price signal will be needed with strict emission standards to enable HELE transition.

While this study focuses specifically on ASEAN countries, its broader lessons are applicable for global deployment of HELE coal plants.

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Simona Bigerna, Carlo Andrea Bollino, Maria Chiara D'Errico, Paolo Polinori

THE DETERMINANTS OF ENVIRONMENTAL AND ENERGY EFFI CIENCY OF EU ELECTRICITY INDUSTRY USING A BAYESIAN SHRINKAGE DYNAMIC ESTIMATOR

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The electricity sector has become crucial in the policy debate of the design of energy markets. We provide evidences on the effects of stringency of market and environ- mental regulation in the electricity sector for the major 18 EU countries from 2006 to 2013.
The regulation effects on effi ciency are characterized by a strong heterogeneity due to the different policies' interactions (environmental and market policies) within each country. We model heterogeneity avoiding bias aggregation problems using the Bayesian Shrinkage Estimator.This captures the different effects of regulation sce- narios on environmental and energy effi ciency whose dynamic is computed with the Total Factor Productivity growth expressed by the Malmquist Index (MI). This lat- ter is decomposed in its main three drivers:
i) the pure effi ciency change,
ii) the scale effi ciency change and
iii) the technological change, measured by the effi cient frontier shift.

Results highlight that there are differential in policy response across countries, implying that a "one size fit all approach" is not recommended.

Keywords: Electricity Industry, Green House Gas Emissions, Regulation Stringency, Malmquist Index, Two Stage Approach, Bayes Shrinkage Estimator.

Rolf Golombek and Simen Gaure

TRUE OR NOT TRUE: CARBON-FREE ELECTRICITY GENERATION IS POSSIBLE

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Research questions

Signatories to the Paris Agreement aim to keep the rise in global average temperature well below 2 degrees Celsius above pre-industrial levels. A key component in the transition to a low-emission society is a radical emissions reduction in the electricity generation sector. The EU, for example, aims at reducing emissions from electricity plants by 95 percent as part of their goal of lowering total GHG emissions by at least 80 percent by 2050. This paper examines how the EU can reach the emissions target for the electricity generation sector.

Which electricity technologies are available to meet the EU policy goal of a 95 percent emissions reduction? Obviously, conventional fossil-fuel technologies have to be phased out as these generate the problem. Due to political resistance or lack of resource availability, there will hardly be a significant increase in output from nuclear, bio power or hydro. Hence, in the future electricity production in the EU must mainly come from other technologies, which means wind power and solar.

A key characteristic of wind and solar power is intermittency; the level of production cannot be controlled; it is determined by installed capacity and the weather conditions (wind speed or solar irradiance). This is in stark contrast to fuel-based power plants. Due to the intermittency of wind and solar, there will in general be a mismatch between production from these sources and consumption. Intermittent production will fluctuate much more than consumption, and the "average" daily path of production may also differ from the standard consumption profile over the day. Therefore, it might be socially desirable to link production from intermittent power stations to a storage technology, thereby ensuring that production in each point in time matches the load. Below, we will assume that batteries are used as the storage technology.

The purpose of the present study is to examine whether it is possible to design an electricity generation sector in Europe that is carbon free. To make the problem as tough as possible, we neglect existing electricity capacities; some of these, in particular, reservoir hydro and nuclear, will make the EU goal of a 95 percent emissions reduction easier to accomplish. Thus, we study the design of an electricity generation sector consisting of wind power, solar power and a storage technology, here batteries, for Europe. However, if necessary for making the system work, we allow for investment in a back-up technology that can rapidly change its production over the day.

Previous research

There is a growing literature on whether it is possible to transform the electricity sector, and even the whole energy system, into one without any, or only tiny, emissions. One example is Jacobsen et al. (2015), which argues that it is possible to electrify all US energy sectors without any use of natural gas, biofuels, nuclear power and stationary batteries. The resulting social cost of a 2050-55 US energy system based entirely on wind, water and solar, is, according to this study, lower than the cost of a fossil-fuel based system. Clack et al. (2017) dispute the main finding in Jacobsen et al. (2015). They argue that the Jacobsen et al. study has significant short-comings, for example, invalid modeling tools, modeling errors and that it relies on implausible assumptions.

They advise policy makers to treat studies proposing energy systems that relies almost exclusively on wind, solar and hydroelectricity with much caution.We will demonstrate that the EU can design an electricity generation sector where around 98 percent of total production is generated by wind power and solar.

Data

To simulate production from wind and solar, we need data on weather conditions. From MERRA-2 (The Modern-Era Retrospective analysis for Research and Applications, version 2), see Gelaro et. al (2017), we have access to hourly weather observations for the period 2006-2015 for each of 23 European countries, with a latitude-longitude grid of cells of 0.5° × 0.625°. Roughly, each cell is 50 km by 50 km of size.

Because wind and sun conditions differ between cells within a country, we mainly focus on the 10 percent best cells within each country; this rule is applied for each of the three renewable electricity technologies covered in the present study; onshore wind, offshore wind, and solar. It seems reasonable that development of renewable electricity mainly will take place in these areas.

We use Merra-2 data for wind speed at 50 meter above the ground, and the surface roughness coefficient, to estimate wind speed 100 meter above the ground. Further, surface incoming shortwave ground flux (SWGDN) data is used to estimate solar power production. We distinguish between direct and indirect radiation to tilted solar panels, and take albedo (diffuse reflection) as well as temperature into account. Whereas Merra-2 had detailed information on direct radiation and albedo, we had to estimate diffuse radiation. As part of the calculations, we find optimal (fixed) tilting across the high resolution grid in each of the 23 European countries for solar farms. Because we are interested in the mismatch between intermittent production and consumption, we need data also for the load. From ENTSO-E and NORDPOOL we have hourly data on national consumption for each of 23 European countries for the period 2006- 15.

Results

We want to construct an electricity system with three renewable technologies - onshore wind, offshore wind and solar - one storage technology (batteries) and, if necessary, use a flexible backup electricity technology if there are no other options available in order to meet hourly demand (load). We use the batteries to even out the time paths of renewable supply and load, imposing that the battery capacity is minimized, provided that in each hour, the load is met.

Let residual load be defined as the difference (in an hour) between load and total renewable supply. We impose the following simple battery strategy:

i) If residual load is negative in an hour, load the battery
ii) If residual load is positive in an hour, discharge the battery provided there is stored electricity in the battery
iii) If residual load is positive in an hour, but there is no stored electricity in the battery, use a back-up technology to ensure that total production (from intermittent electricity and the back-up technology) is equal to consumption.

Hence, batteries are used as a plan B. We solve this minimization problem (of battery capacity) under two restrictions:

i) the battery strategy, which ensures that load will always be met, and ii) total supply of renewables over the period 2006-15 is equal to total consumption of electricity. First, we solve the minimization problem for each country assuming no trade in electricity. Next, we open up for trade to explore gains from trade, that is, the benefit of negative correlation between supplies of renewables and load from different countries.

For the case where there is trade, our main results are as follows: First, the EU can design an electricity generation sector where around 98 percent of total production is generated by wind power and solar. Second, whereas the market share of the backup technology is only 2 percent, its capacity has to be sufficient to meet average hourly demand. Third, a large amount of batteries must be installed to make the system work. In the most demand hour in the period 2006-15, an amount of electricity corresponding to 4 percent of average annual consumption of electricity has to be stored in the batteries. Finally, in order to avoid any backup production, total renewable production has to be 38% higher than total consumption of electricity over the period 2006-15.

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Marcos Tenente, Carla Henriques and Patrícia Pereira da Silva

ECO-EFFICIENCY ASSESSMENT OF THE ELECTRICITY SECTOR: EVIDENCE FROM 28 EU COUNTRIES

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Overview

The purpose of this study is to carry out the eco-efficiency assessment of the electricity sector in 28 European Union (EU) countries, taking into account its economic and environmental performance over time, considering the years of 2010 and 2014. The novelty of our work resides in the combination of Data Envelopment Analysis (DEA) through the Directional Distance Function (DDF) approach with Input-Output (IO) analysis to perform the eco-efficiency evaluation of the consumption and production supply chains of the electricity sector.

Method

This study aims at filling the main gaps identified in the eco-efficiency assessment of the electricity sector through the use of Environmental Extended Input-Output (EEIO) tables in conjunction with DEA, considering the years of 2010 and 2014. This work has been inspired by a combination of studies in the field of eco-efficiency which were carried out by Lábaj et al. (2014) and Zurano-Cervelló et al. (2018). Lábaj et al. (2014) studied the economic growth in terms of welfare in 30 European countries through the use of DEA models while Zurano-Cervelló et al. (2018) combined the use of DEA models with IO tables to evaluate the eco-efficiency in the manufacturing sectors both considering production and consumption-based approaches.

Results

The three countries more often selected as benchmarks regarding the direct production chain of the electricity sector were, in 2010, Malta, Germany and Belgium, while, in 2014, the top four countries mainly considered as a reference in terms of best practices were Ireland and France followed by Malta and Luxemburg. Since the type of efficiency under analysis is not only economic, but also environmental, it is expected that countries who invested in renewable energy deployment efficiently, progressively replacing fossil fuel generation, will have a higher potential in terms of eco-efficiency. For example, in the case of Portugal, Ireland and Bulgaria, the enhancement of eco-efficiency performance seems to be the result of improving the average productivity of capital and labor, with a reduction in fossil fuel generation and the increase of renewable energy generation. In the efficiency assessment of the direct consumption supply chain, the three countries more often selected as benchmarks in 2010 were Luxembourg, Denmark and Sweden, whereas, in 2014, the top three countries mainly considered as a reference in terms of best practices were Denmark followed by Cyprus and Sweden. In this case, the evolution of the sectors directly linked to the electric sector are the main drivers of the efficiency scores obtained.

Finally, if the indirect consumption supply chain is evaluated, the three countries more often selected as benchmarks were, in 2010, Sweden, Luxembourg and Germany, while, in 2014 the top three countries mainly considered as a reference were Sweden, Luxembourg and Ireland. In this last situation, the main determinant of the efficiency scores is the intermediate consumption of the sectors directly engaged with the electric sector.

Conclusions

This study proposes a comprehensive eco-efficiency assessment of the electricity sector in 28 EU countries by combining the application of the DEA DDF model with EEIO tables, also taking into account the production and consumption supply chains of the electricity sector. Our findings provide a further understanding on which sectors increase and reduce, both directly and indirectly, their contributions in terms of environmental impacts and on which countries have the main role in this behavior.

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BLUEPRINT FOR 100% RENEWABLES

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Energy Storage has long been considered the critical component to achieving high degrees of grid penetration from intermittent renewable resources such as solar and wind. This makes intuitive sense because it is readily apparent that the sun does not always shine or the wind does not blow when energy is being used. Storage is indeed an increasingly important tool to bridge the “firm spread”—the gap between renewable production and customer demand.

In this presentation, we show that we do not need as much storage as we might think to achieve high degrees of renewable energy penetration. A counterintuitive solution -- renewable energy production curtailment -- combined with storage enables the achievement of very high renewables penetration at much lower cost than with storage alone.
We argue that enabling this solution depends less on new technology than on new regulatory thinking. Monetization of firm kWh production and handing production controls to grid operators should be at the center of this new thinking.
We show that this new regulatory approach can be implemented gradually by first tackling load imbalances issues and then moving on to firm power generation and to the seamless displacement of conventional power generation.

Ilaria Colasanto and Antonino Bonfiglio

DECARBONIZATION PROCESS PAY OFF: STUDY CASES AND PERSPECTIVES

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Abstract:

Since the 1980's, the international community has become more and more aware about climate changes, energy and the environment. There are some milestones in this process, namely the Panel on Climate Change (1988), the Rio conference (1994) and the adoption of the Kyoto protocol (2005). In the wake of these events, energy and the environment have become main points of the global agenda and within the European Union very early it was realised that policies at a national state level were not effective and that the involvement of the Union in these fields was needed. Therefore, starting from the '80's, the idea of a common policy strategy about energy and the environment has gained momentum.

The paper will come across the Emission Trading System, the treaty of Lisbon, the 20/20/20 Strategy and even today's policy, encapsulated in the newest EU's strategy document: Roadmap 2050. Furthermore, there will be an analysis on Italy's situation and potentialities for new possible infrastructural investments, starting with the acknowledgment that since the early 1970's the demand for energy of the country has been met by continuous changes in its energy matrix.

During the last decades, natural gas replaced fuel oil in electricity generation, while the wind and solar sources, that up to 2005 were struggling to integrate hydro and geothermal power, since that year have been expanding more and more. Coal has been able to gain space with great difficulties, despite having significantly lower variable costs than other thermal power sources. As of today, this is the source that is expected to shrink the most, up to complete disappearance.

Afterwards, the paper will go deeper into the analysis of Italy's energy situation by reviewing its southern part, which is commonly known for the potentialities of its territory for the development of renewables. Thus, the paper will go through the scenario that was assumed for this part of Italy: "*Mezzogiorno 2030*", a document that highlights which changes are possible in order to maximize the contribution of this part of the country to the achievement of the climate-energy objectives at 2030 imposed by the European Union upon its members.

After the analysis on Italy's situation and in particular on its southern part, the paper will describe how energy companies cope with the EU standards and the internationals ones and how they have shifted their priorities towards environment-friendly policies. In particular, the paper will highlight how these companies are investing in new infrastructures that permit to head towards a zero GHG emission energy. The example that has been taken into account throughout this part of the paper is that of the Italian utility Enel, today a multinational group, leader in electricity generation from renewable sources, whose ambition is to get to zero carbon emissions by 2050.

Cambini Carlo, Raffaele Congiu, Tooraj Jamasb, Manuel Llorca and Golnoush Soroush

ENERGY SYSTEMS INTEGRATION: IMPLICATIONS FOR PUBLIC POLICY

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Overview

As decarbonisation policies push towards further adoption of Renewable Energy Sources (RES) generation, there is a need for an approach that allows to simultaneously streamline Distributed Generation (DG) integration while providing a sustainable and reliable energy system. Energy Systems Integration (ESI) is an emerging paradigm which proposes a holistic view of the energy systems, rather than a perspective based on single segments within a specific sector. The goal of ESI is to reduce total system costs while contributing to achieve a clean, affordable and secure energy system. The rationale behind ESI is the existence of synergies within and between energy sectors that can achieve efficiency gains. Their existence is attributable to vertical and horizontal economies of scope and to the possibility of lowering transaction costs between grid users.

Method

This work provides an economic overview of innovative technologies which can be used for an efficient ESI, such as conversion and storage systems and ICT. We discuss how different regulatory frameworks can stimulate adoption of these technologies, and we analyse current regulatory schemes adopted in some EU countries (Germany, France, Italy, the UK) to understand how they foster investment and innovation. We provide an overview of the impact of regulatory approaches on the adoption of new technologies by reporting the innovative projects that are being promoted by national authorities of selected EU countries. We discuss policy and economic barriers to implement ESI and provide some policy recommendations.

Results

Techno-economic studies on ESI-enabling technologies underline the benefits they can provide to various parts of the energy systems, either through cost savings or by providing flexibility. However, their capital-intensive nature requires either large investments by end-users and/or large-scale service providers to operate them or large investments by system operators to accommodate them into the networks. For this reason, regulatory solutions play an important role in achieving ESI by providing incentives for technological adoption. While some EU countries directly incentivise innovation through their regulatory frameworks, others drive it mainly through national funding.

Table 1: **An overview of policies of four EU countries to foster network innovation.**

	United Kingdom	**Germany**	**France**	**Italy**
Type of regulation	Revenue cap with output, efficiency and innovation incentives.	Revenue cap with expansion incentives.	Hybrid: revenue cap with cost of service elements. Efficiency incentives.	Hybrid: revenue cap with cost of service elements. Efficiency incentives.
Regulatory period length	8 years.	5 years.	4 years.	8 years electricity; 4 years gas.
Innovation incentives	Innovation stimulus packages: adjustments to revenue allowance and competition for funding.	50% cost recovery for innovative projects that fall under ministerial funding programs.	Full cost recovery for innovative projects approved by the regulator.	WACC mark-up for innovative projects.
Costs added to the RAB (Regulatory Asset Base)	Capex and Opex.	Capex and Opex.	Capex	Capex
Innovation funding	Regulation-based	Government-based: grants given under ministerial funding programs.	Hybrid: regulation, government and EU-based.	Hybrid: regulation, government and EU-based.

While investments are being made for smart grids, smart meters, storage systems and conversion technologies, we do not find much evidence of investment in networks and systems integration. We observe that there are barriers of various nature to the integration of energy systems, such as the cost of some of these technologies, the lack of adequate incentives, coordination problems within and across sectors, regulatory difficulties in defining outputs and technologies to be incentivised, acceptance by consumers.

Conclusions

ESI can be an effective solution to incorporate RES into the energy systems and to reduce overall transaction and operational costs. Viewing the energy systems as a whole is also beneficial from both environmental and economic perspectives. However, implementation of this paradigm and improved coordination between different energy systems requires not only adoption of novel technologies, but also a reconsideration of policies and regulatory aspects. We believe that ESI can be achieved through innovative designs and incentives for network operators and consumers.

Agime Gerbeti

NEW SCENARIOS FOR LONG-TERM GREEN ELECTRICITY CONTRACTS AND THE ROLE OF GUARANTEES OF ORIGIN

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Overview

The present work aims to analyze novelties in energy production from renewable sources that are expected in the next few years in Italy. In particular, the introduction of Green Power Purchase Agreements (DM 4 July 2019) is analyzed to support the growing use of green energy in a context of environmental and economic sustainability. The development areas of this type of contract at national level are considered, even in the absence of direct state incentives such as, support schemes. The traceability of the origin of production from renewable sources takes place through guarantees of origin.
Furthermore, in this paper, it is assumed, that the green PPAs could be associated with an incentive form, guaranteeing an advantage over industrial production based on a high consumption of renewable sources through the application of Charge on added emissions within the VAT.

Results

The analysis shows that the nature of PPAs linked to renewables is even simpler than traditional PPAs but has a higher uncertainty. The promotion of production from renewable sources exclusively through the Green Power Purchase Agreements in the absence of government incentives for private companies is unlikely to be effective. This limit is connected to the fact that the private sector must have a direct interest and short returns to increase their share of consumption of energy produced from renewable sources. Instead, the stimulus resulting from paragraph 8 of the same art. 18 with reference to the green public procurements could be effective in the association with the Green Power Purchase Agreements. The context in which the public administration operates, the minimum levels and standards of the so called green procurements, will be decisive to understand if the potential to act as a support for this contractual form exists.

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Kristina Govorukha, Wolfgang Habla, Paul Kunz, Philip Mayer, Mathias Mier, Sebastian Voigt and Christoph Weissbart

ENVISIONING EUROPEAN POWER MARKETS IN 2050: INTEGRATING SOCIAL, ECONOMIC AND TECHNOLOGICAL DRIVERS

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Overview

Energy scenario analysis has proven to be an effective tool for evaluating and planning energy policy and supporting the political decision making process with quantitative assessments. Model-based energy scenarios provide a quantitative depiction of possible future developments within the energy system. Concurrently, the development of comprehensive scenario studies necessitates the consideration of the macro-economic framework. This can be achieved by linking electricity market models with macro-economic models. In recent years, other works have highlighted the significance of qualitative aspects that cannot directly be depicted by quantitative modelling frameworks (see Alcamo 2008, Schweizer&Kriegler 2012, Trutnevyte et al. 2014) Moreover, the systematic integration of those factors facilitates the process of soft-linking macro-economic models with electricity market models and ensures the consistency of the described context, the input parameters and, ultimately, the scenario study. While the benefits of the consideration of a broader context for the informative value of scenario analysis seem unambiguous, many studies tend to disregard certain context aspects, like changes in the social dimension (see e.g., Grubler et al. 2018). Thus, social attitudes, perceptions and acceptance should be included for an in-depth analysis of possible transition pathways of power systems (see e.g., Wüstenhagen et al. 2007).
Taking into account the macro-economic framework and a broad social and political context, the presented study delivers an extensive explorative scenario analysis of the European electricity market until 2050.

Methods

For finding the equilibrium in the European electricity market, this study applies the EU-REGEN model, an investment and dispatch model for the European power market that aims at finding the long-run, partial equilibrium (see Weissbart 2019). The economy-wide equilibrium is determined by the multi-sector and multi-region computable general equilibrium (CGE) model PACE (see Böhringer et al. 2006). For the construction of a consistent context and the soft-linking of the CGE and power market model, the cross-impact balance analysis (CIB) approach will be applied (see Weimer-Jehle 2006). The CIB is used to develop storylines, that, besides setting out a social context, provides both the CGE and the electricity market model with a consistent and interlinked set of input parameters.

Results

The methodology introduced in this work allows for a comprehensive analysis of consistent development trajectories. The scenario space consists of four scenarios describing possible futures of the European power market:

(1) Stagnation of the EU, (2) Dash for Gas, (3) Green Prosperity and (4) Renaissance of the nation state. Preliminary results indicate that the undertaken explorative approach reveals valuable insights on the interrelation of the techno- economic and the social sphere and their impacts on the equilibrium of the economy and the European power sector in particular.

Conclusions

The consideration of economic, technological, social, and political framework conditions facilitates the process of scenario studies and improves their informative value. While there is a general scientific consensus with respect to the value-added of a comprehensive approach applied to scenario development, studies still tend to neglect integration of a broader context. The current work aims to emphasise this aspect and highlights the possible gains for future scenario studies. In addition, it contributes to the discussion of methods for linking multiple and diverse models within the same scenario framework.

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TECHNO-ECONOMIC BENEFITS EVALUATION FOR BATTERY ENERGY STORAGE SYSTEMS

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The energy storage analytics team at the Pacific Northwest National Laboratory (PNNL) is currently evaluating energy storage systems with combined power and energy capacities of 26 MW and 104 MWh at 14 sites across the U.S. PNNL is evaluating lithium-ion and redox flow batteries in Washington, demand response programs in Hawaii, microgrids in Massachusetts, and pumped storage hydro systems in Washington, California, New York, and Hawaii. PNNL has developed analytical frameworks and tools for evaluating the economic benefits of storage systems, characterizing performance during economic operation, integrating storage into the distribution system, and developing real-time control systems in order to capture real-time value. These efforts have resulted in the development of a taxonomy and framework for evaluating the economic benefits of energy storage at multiple points in the grid, a storage valuation tool, self-learning non-linear models for predicting storage performance, state of health models, and a model for evaluating the performance of real-time dispatch control systems. This presentation will demonstrate how lessons from these engagements are being used to fill gaps in the industry knowledge base and will outline next steps in our research agenda.

As a case study, we discuss the case of a battery energy storage unit on Nantucket Island. Nantucket Island is located off the coast of Massachusetts in United States. It has a fairly small resident population of approximately 11,000. During summer months, however, the population on the island can swell to over 50,000, leading to significant constraints in the transmission grid serving the island. Nantucket's energy demand is being met by two submarine supply cables with a combined capacity of 71 megawatts (MW). To avoid an investment in a third transmission cable, which could cost the customers as much as $205 million, the utility, that supplies energy in the region, plans on adding a 6 MW / 48 megawatt-hours (MWh) Tesla lithium-ion battery energy storage system (BESS) and an on-island combustion turbine generator (CTG) with a varying capacity dependent on temperature (13.8 MW capacity during summer peaks). Pacific Northwest National Laboratory (PNNL) is evaluating the techno-economic benefits of the CTG and energy storage system, monetizing the value of ISO-NE market benefits and local benefits associated with outage mitigation, transmission deferral, and conservation voltage reduction. PNNL is conducting extensive distribution system modeling to support the analysis and is defining control strategies to operate the BESS in real-time. This presentation will present the results of this analysis, including those associated with the return on investment analysis, distribution system integration modeling and control system strategies and controller development.

Fernanda Guedes, Emmanuel Hache; Gondia Sokhna Seck

CRITICALITY OF RARE EARTH ELEMENTS AND THEIR ENVIRONMENTAL IMPACTS: EXPLORING DEEPER INTO THE ENERGY TRANSITION

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Overview

The Rare Earth Elements (REE) consist of a group of seventeen chemical elements with similar properties (Venås, 2015) represented in the periodic table by the fifteen lanthanides, plus scandium and yttrium. Despite their names, they are not so rare (Massari and Ruberti, 2013; Seaman, 2019). Occurrences of REEs are scattered around the globe (USGS, 2018). Nonetheless, many existing deposits may never reach the production stage due to issues such as labor costs, political instability, lack of infrastructure, environmental impact, social and political concerns and metallurgical extraction problems (APS, 2010). Nowadays, China is the world's largest producer (72%) and consumer (80%) of REEs (USGS, 2018) and, increasingly, the largest player in the value chain for key dependent products (Seaman, 2019). Over the last century, REEs have gained in importance due to their electrochemical, magnetic, luminescent and alloy strengthening characteristics, which are the basis for the manufacture of major low-carbon innovation technologies and modern electronics in general (APS, 2010; Massari and Ruberti, 2013; Ganguli and Cook, 2018). In a future driven by more stringent environmental constraints and economic growth, the crescent need of REEs of all decarbonisation and digital innovations (Seaman, 2019), particularly in the electronic, transport and power sectors, could hinder the diffusion of these technologies due to resource availability constraint (National Research Council, 2007). In addition to its potential criticality, REE production process is characterized by high levels of water consumption, energy inputs and chemicals use, resulting in significant environmental risks affecting water discharges (Haque et al., 2014; Charalampides et al., 2016). As already pinpointed by the World Resources Institute (WRI), many regions of the world would face exceptional water-related challenges for the foreseeable future (Luo et al., 2015). With a high water stress measured by the WRI [1] and the REE world's largest production, China could see water stress increase in some of its regions. Given all these factors in a context of climate crisis, the present article analyses the evolution of the REE criticality with the energy transition and their impact on the water consumption rate with the current water supply of rare earth production sites, through prospective climate scenarios (4°C and 2°C) run on TIAM-IFPEN (Times Integrated Assessment Model-IFPEN).

Methods

The methodology followed by this article consists, first, in the development of a consistent database with respect, among other data, to rare earth resources and production, measurement of the use of these elements in clean energy technologies (mainly wind turbines and electric

[1] Five levels of water stress have been considered by the WRI: Low, Low-Medium, Medium-High, High and Extremely high. Water stress measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available blue water. Higher values indicate more competition among users.

vehicles), estimating the energy and water consumption for REE production, and quantification of the water stress at rare earths production sites.
Then, in inputting the database information in TIAM-IFPEN[2] (Times Integrated Assessment Model-IFPEN), which is the first detailed global bottom-up energy model with an endogenous disaggregated life-cycle inventories. Finally, in running the climate scenarios (4°C and 2°C) over the period 2005-2050, to assess the impact on water demand caused by expected growths in rare earth production, and whether or not these impacts can be overcome by the current water supply at rare earths production sites. Regarding the climate scenarios, the 4°C scenario is consistent with limiting the expected global average temperature increase to 4°C above pre-industrial levels by 2100, while the 2°C scenario is more ambitious, translating the climate objectives of limiting global warming to 2°C by 2100.
The results show that the demand for rare earth elements follows an upward trend in both scenarios, being more pronounced in the 2°C scenario than in the 4°C scenario, as expected. By 2050 the major consuming countries remain China, followed by Japan, Europe and the United States. Due to the increasing demand for REEs, water requirements also tend to increase. In both scenarios, by 2050, water consumption of rare earth production becomes critical for countries who are already under water supply stress such as China. The other contribution of this study is the quantification of the water consumption rate for rare earth production as a function of its availability in a context of more constraining energy transition. Thus, the implementation of this water availability variable in a prospective energy system model will make it possible to analyse how it could affect the production of rare earths, and in fine, the roll-out and uptake of new digital and low-carbon innovations. The remaining question is: as water consumption and the development of decarbonizing technologies would certainly be closely intertwined in the future, could we continue to globally invest in low carbon innovations and alleviate water stress in REE production areas?

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[2] The TIAM-IFPEN (TIMES (The Integrated MARKAL-EFOM System) Integrated Assessment Model) model is a technology rich bottom- up cost optimization belonging to the MARKAL (MARKet Allocation model) family, that models energy supply, demand and market dynamics in order to represent energy dynamics over a long-term, multi-period time horizon at a local, national, multi-regional, or global level (Hache et al., 2019).Results and final remarks

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ASSESSING BATTERY MANAGEMENT FOR ENERGY COMMUNITIES: ECONOMIC EVALUATION OF A ARTIFICIAL INTELLIGENCE (AI) LED SYSTEM

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Overview

Electrification and distributed energy sources are central strategies for accelerating the green energy transition and still pose significant challenges to the existing energy systems, requiring a deep rethinking of the energy infrastructures, both under the point of view of resilience and economic sustainability. Indeed, smart grids and battery energy storage systems (BESS) are rising in importance both for technical and economical aspects as they enable a series of services such as active demand response, load peak reduction or mitigation, improved voltage stability etc. However, the economic viability of distributed generation coupled with storage systems is still being debated, as hidden costs associated to their use are complex to include in planning tools, especially when considering aging, and remain difficult to evaluate ex-ante, limiting the large scale penetration of BESS technologies. Here we present BRAINS (Balancing Responsive Artificial Intelligence Storage), a tool for planning and real time management of electrochemical storage systems based on a cross-disciplinary approach bridging Artificial Intelligence (AI), data science, and economics. BRAINS is used in the operation of a microgrid acting as a virtual power plant: the optimal sizing of the storage is determined according to the specific (and configurable) load characteristics, while the real-time management of the State of Charge (SoC) takes into account degradation costs while minimizing the total costs for the whole system.

We also show that by including the aging and cycle costs in the BESS management, the expected return of investment (ROI) is drastically reduced, and in some cases economic losses are observed. Furthermore, under the planning point of view we also show that storage sizing is critical, as we observe that the larger is not the better, while an optimal size must be computed for each specific application case.

Methods

The foundational concept of BRAInS is presented in *Figure* 1, there are two views mirroring each other: on the right side we find an infrastructural view, while the algorithmic and data processing view is on the left. We consider a microgrid operating as a virtual power plant (VPP) that has the objective to remain in balance (i.e. do not deviate) from a pre-declared position, that we can assume agreed with the Distribution System Operator. Under the economic point of view this means that the VPP neutrality is a mean to reduce costs associated to the energy required for balancing the fluctuations produced by the distributed generation, and represents a pre requisite for the participation of DER into the provision of ASM. The load of the VPP is continuously monitored and used as input for BRAInS, that controls the state of charge (SoC) of the battery. As output result, large fluctuations are effectively shaved depends on OF, while small and medium-sized fluctuations are partly reduced and partly left according the the current state of the battery, the degradation model, and the market conditions.

Going in greater detail, Figure 2 shows the block diagram of BRAInS, where the following modules can be found:

1. **Aging**: contains the aging model of the battery, where both calendar and cycle aging are considered
2. **Forecast**: A specific algorithm produces a forecast of the VPP load profile future values.
3. **Market**: introduces in BRAInS the regulatory and market conditions. By example it considers the pricing model for the fluctuations, electricity signal pricing, and demand response models.
4. **Infrastructural** constraints: introduces the physical characteristics of the grid and sets the constraints for the power flow operation.
5. **Genetic Optimisation**: computes the optimal charge/discharge profile according to the infrastructural, market, and battery conditions.

As input data BRAInS considers the load data of the VPP, the market information and the pre-defined position of the VPP. The incoming load data are used to build a real time a forecast of the future power balances of the network. According to the current BESS state, to the desired power profile, and to the forecast of the network balance, the GA module heuristically calculates the optimal power output of the BESS minimising the overall system cost. The system cost is computed and minimised by summing the battery degradation associated to the service provision, expressed in terms of amortization cost, and the market fees and fines, associated to the energy purchase (or sale) and the deviation from the agreed power profile. The resulting optimal BESS profile is then used and the procedure is then replicated in the following time step.

Results

BRAInS as planning tool: planning is performed by simulating the operation of the VPP for one year,
i.e we simulate the management of the VPP for one year considering different BESS size and different installation costs. In this particular case the forecast module is not used since no prediction is needed. Here we consider the following three cases:

1. No BESS installed: VPP load is free to fluctuate and pays the full amount of fines.
2. Use of BRAInS for managing the charge/discharge of the BESS
3. BESS used for its full capacity both in charge and in discharge.

Under the economic point of view, tables we can see that considering the optimal size, the net gain due to the use of BRAInS is between 5.52% (300 kWh, 1000 Eur/kWh installation cost) and 16.50% (500 kWh, 600 Eur/kWh installation cost), while considering the same BESS size without the use of BRAInS leads to an economic loss ranging between 11,32% (300 kWh, 1000 Eur/kWh installation cost) and 3,71% (500 kWh, 600 Eur/kWh installation cost), corresponding to a net loss of about 23000 and 7800 Euros per year respectively.

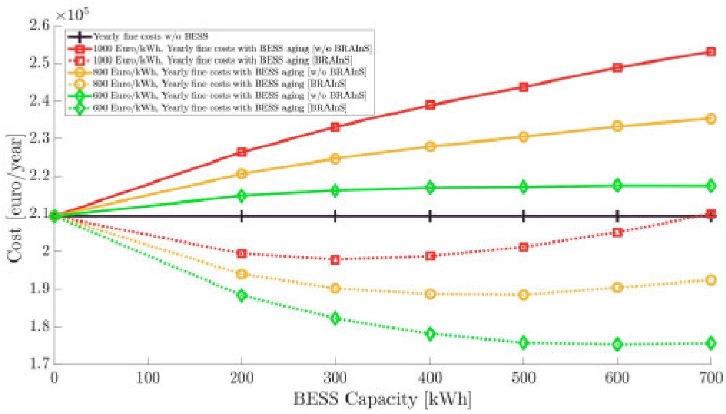

Figure 3, **The Yearly cost of the system with different size of BESS and 600** (green), **800** (orange) **and 1000** (red) **€ kWh installation cost**. Dashed lines refer to BRAInS, while continuous lines refer to the full capacity use of BESS. The fine cost and the total BESS aging costs are given as a sum for the year. The sum of yearly fine cost of the VPP without the BESS is given as a reference (black line)

Conclusion

We have introduced BRAInS a planning tool and a real time BESS management method that is flexible, fully configurable and adaptable to meet the technical and regulatory requirements of a wide range of installation conditions. This approach is relevant since it allows for the real time operation of storage systems, including nonlinear models of aging costs and real time energy markets conditions. We show that when including calendar aging and costs together with accurate nonlinear models of cycle aging, the correct sizing of the BESS becomes crucial and strongly dependent on the consumers behavior of the VPP, i.e. the sizing of the BESS must be specifically tailored for the typical load of the VPP, and that a solution found in the planning phase could not be suitable for other VPP with different load profiles and behaviours. Furthermore, total revenues depend on installation costs because of the lack of revenues deriving from the participation in ASM. Installation costs, including battery costs, impact directly on the system's overall costs and represent its main component. In this specific study, our results show that the proposed tool yields a profit even for installation cost of 1000€/kWh, while for a price of 600 Eur. kWh BRAInS showed significant advantages both under the technical and economic point of view. The aspect of self- consumed energy is particularly critical in view of the recent EC Directive 2019/944 on energymarkets and energy communities: as self consumption from renewable energy communities remains central, a careful management strategy is strictly required for the economic sustainability of VPP based on distributed generation and storage systems. Our study shows that at current installation costs, relying barely on self consumption might not suffice to provide positive ROI. Indeed the possibility of VPP to participate to the ASM is currently tested in a number of geographies with the possibility to to generate significant profits and reasonably affect VPPs budget, a considerable share of additional generation should be dispatched on the market, exceeding the share of internal consumption.

Such availability, indeed, can be provided at low marginal costs and therefore would represent a truly competitive participation to the potential ancillary markets.

The greater role that VPPs will play in the coming year is well documented by the increasing pilot projects developed almost everywhere in Europe and in the US 48. While the projects have different nature and characteristics, they all seems to confirm that the level of DSO's involvement in the System Operation and DSO's responsibility will be far larger than what happens today. This will require significant investments in monitoring and control systems, as well as higher level of expertise on DSO side (which can especially concern smaller DSO). Additionally, the so called "fit- and-forget" reinforcement policy (oversizing of networks in order not to have to deal with
network "problems", mainly congestions) which is, currently, often the basis of Distribution Network (DN) "operation" must be overtaken. These policies, in fact, may lead some DSOs to develop a resistance to consider flexibility as a value. Also, DSOs may underestimate the needs to invest in implementing monitoring and control system. Long term planning should also be extended to cover the whole DN as it already happens for Transmssion Networks. This implies that, apart from all the technological improvement needed, DSOs should also be able to extend their expertise, in particular having greater understanding, at local level, of the true costs associated with storage capacity and the system benefits provided by VPPs. AI offers the possibility to identify these costs and define and manage the operation of decentralised system with greater accuracy and efficiency.

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Nicola Sorrentino, Daniele Menniti and Anna Pinnarelli
SHARING ENERGY STORAGE SYSTEMS IN RENEWABLE ENERGY COMMUNITY

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Overview

Renewable energy communities involve groups of citizens, social entrepreneurs, public authorities and community organisations participating directly in the energy transition by jointly investing in, producing, selling and distributing renewable energy. Beyond the reduction of greenhouse gas emissions, there are many benefits for the communities involved, including economic development, the creation of new jobs, cheaper energy, self-sufficiency, community cohesion and energy security. Regional authorities can support the emergence of energy communities by providing financing, expertise and advice, and ensuring that regulatory issues can be easily understood and navigated. Community energy projects can involve renewable energy generation technologies alone, feeding into existing grids and networks, or can include community run management and ownership of distribution infrastructure, such as local smart grids, or heating networks. On the generation side, community energy schemes can use any of a number of technologies, with solar, wind or biomass sources being the most frequently used. Examples also exist of community run small hydropower plants, which have often involved restoring abandoned infrastructure and bringing it to modern environmental and safety standards.

Renewable energy projects can vary in scale, and larger scale installations require larger management and maintenance capacity. Larger systems will also require greater capital investment, but once investment is recovered, benefits are higher, and money saved (or even earned) through community energy can be reinvested in new community programmes and infrastructure. It is rarer for a community to run a utility-scale project, which are significantly more complicated and need greater expertise and capital investment. In particular, utility-scale projects will face tougher environmental and planning barriers.

Whilst the EU has strongly supported renewable energy generation, it had not made explicit reference to them until the recast of the Renewable Energy Directive (RED II), which will come into force by the end of 2018. RED II gives greater power to citizens for self-generation and consumption of electricity, with 'renewable energy communities' being defined for the first time and given new rights. The new RES Directive, for the first time, includes a definition of a 'renewable energy community'. The text defines it as:

"A legal entity: i) which, according to applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects owned and developed by that community; ii) whose shareholders or members are natural persons, local authorities, including municipalities, or SMEs; iii) whose primary purpose is to provide environmental, economic or social community benefits for its members or the local areas where it operates rather than financial profits".

Methods

As evidenced the advantages associated with an energy community are not only economic, but also social welfare and environmental issues have to be pursued. There is therefore the problem to exploit all the advantage of regulating energy exchange relationships within the community and to the outside such as DSO and TSO, which bring these advantages into account. The method that is proposed is to use a cryptocurrency that has validity of exchange of energy and services within the community. This cryptocurrency can be implemented by permissioned blockchain. Renewable Energy projects had offered a perfect growth industry for blockchain, to replace existing cumbersome, lengthy trading and clearing activities with a clean and efficient marketplace. Certificates, RIN credits, tax credits and other guarantees are all mechanisms whose complex data and the cash flows are dealt efficiently by blockchain. Storage has brought with it a potentially complex distribution of cash flows from “value stacking”, a perfect target application for a blockchain. The active participation in terms of efficient use of energy, the increase in self-consumption, the response to services requested by external operators allows us to have credits that can be used within the community for the use of other services, for example recharging of electric vehicles, energy efficiency interventions or any other service that allows the community to achieve its sustainability objectives.

Results

First results of some case studies, in simulation, carried out in the framework of some research projects will be illustrated

Conclusions

The development of renewable energy communities is the way to increase the share of energy produced by renewable sources, through the active and conscious role of the citizen. The benefits of the energy communities go beyond the economic aspects, but involve social and sustainability aspects of lifestyles, so a simple "economic remuneration" may not be adequate to "repay" the Citizen belonging to the community. For this reason, in the present work a first cryptocurrency experiment is presented for the members of the community to enhance their virtuous behavior and to be able to spend them to take advantage of community services

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Justine Barden, Emily Sandys and Erik Kreil,

ANALYZING GLOBAL PETROLEUM MARKET DISRUPTIONS

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Overview

Supply disruptions are an everyday occurrence in global petroleum markets. Throughout the globe, energy security is being put at risk as crude oil is continually being taken off markets by unplanned outages resulting from sanctions, political strife, labor strikes, military conflict, accidents, bad weather, and other events. Unless we move to a world without any of these events, supply disruptions will continue to be regular part of the market. How, then, do we assess the state of global energy security? What does that mean for the occurance of crude oil price shocks? The U.S. Energy Information Administration (EIA) developed several different approaches during its history to analyze the price impact of disruptiosn to crude oil supplies, including developing a Disruption Impact Simulator model following the Energy Crises of the 1970-1980's. Markets have changed signficiantly since its development, and EIA has moved on from this model. This presentation highlights how EIA currently analyzes global supply disruptsions.

Methods

Estimates based upon "one-size fits all" models using a price elasticity of demand have not proven reliable for assessing the market impact of global crude oil supply disruptions. EIA has learned through experience that similarly-sized supply disruptions can have very different impacts, depending upon market conditions. A small supply disruption in a tight market can have a very large impact on world oil prices, whereas large supply disruptions in a soft market may not have much of a price impact at all. As a result, EIA has found that relying too much on price elasticities can skew assessments of the impact of global oil market supply disruptions. Complicating this is the scarcity of data on truly large supply disruptions to use as a benchmark. Only a handful of supply disruptions have been large in magnitude, and the majority of these did not last more than a few months, making their use in regression-based models problematic.

EIA's approach is to develop monthly baselines of global supply/demand balances in its Short-Term Energy Outlook, and then combine them with key security indicators to assess the impact of supply disruptions. EIA makes and publishes estimates for a number of key indicators of energy security, including 1) monthly estimates of global oil supply disruption volumes (by country)[1]; 2) surplus production capacity in the OPEC countries[2], and 3) the volume of oil that could be disrupted in key transit chokepoints such as the Strait of Hormuz.[3]

Results and Conclusions

EIA's approach of assessing the state of markets first, then factoring in supply disruption events has proven to be much more reliable than solely using either elasticity-based estimates or a common alternative - expert judgment from long-time market watchers. As we entered the summer of 2019, the question arose as to when we could expect a price spike following the decision to not extend waivers for Iran sanctions.

Rather than expecting a "D-Day" for oil prices, as one analyst put it, the use of EIA's approach of assessing the state of markets first indicated that markets had built up very large stock cushions that would absorb the immediate impact of the waiver decision.

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François Benhmad

OIL AND THE DOLLAR COMOVEMENTS: IS SHALE OIL A GAME CHANGER?

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Abstract:
In this paper we explore the relationship between oil prices and US dollar before and after the shale revolution and its impacts on international oil markets.
As the two markets are linked through various channels which may have impacts at different frequencies, we should investigate this relationship from a time-frequency perspective. Indeed, the wavelet transform enables us to decompose oil and US dollar time series into their respective frequency components, and to run tests of Granger causality on these components on a time scale (frequency band) by time scale basis during two periods. The first period occurs before US shale revolution (2000-2007), the second one comes after this revolution and runs from 2008 to 2018.
Our main findings suggest that for to a time horizon running from 9 months to 64 months, representing approximately the business cycle frequency band, the Granger causality that was running from US dollar to Oil prices during the period 2000-2007 had switched its direction during the period 2008-2018. The US shale revolution was the main reason behind this switching according to its large effect on oil markets.

Keywords: Shale oil, Oil, US Dollar,Wavelet Granger causality JEL codes: E32, Q43

Giuseppe Dell'Olio

HEAT LEAKAGE THROUGH MASONRY: A DISTRIBUTED PARAMETERS METHOD

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Overview

In order to calculate heat leakage, external walls of buildings are usually simulated as lumped parametres systems (e.g. finite elements calculation method). This involves a significant discretization error.

In this paper we propose a calculation method that, more realistically, regards the wall as a distributed parameters system, which avoids discretization error. The method is based on equations which are formally identical to those commonly used for long electric lines. The wall is simulated by very few, cascade-connected double bipoles.

By Fast Fourier Transform, any air temperature variation, both fast and slow, can be simulated. Any climatic event can thus be simulated: daily temperature oscillations between day and night, as well as a sudden surge, caused, e.g. by a turn in the weather.

Methods

The method can be applied to any masonry element, irrespective of its orientation.

Let us consider, e.g., a horizontal surface crossed by a vertical, downward heat flux. This can be,.e.g., a roof hit by the sun.

Within the roof, let us consider an elementary layer E(x) of thickness dx.

E(x) is characterized by its thermal capacitance and by its thermal resistance. It can be represented by an equivalent electric circuit made up of a series resistance and a shunt capacitance.

This implies following thermal-electrical correspondance:

- electric resistance (R') corresponds to thermal resistance of one square meter's wall;
- electric capacitance (C') corresponds to thermal capacitance of one square meter's wall;
- electric current corresponds to heat flux through the wall;
- electric voltage corresponds to temperature; isothermal surfaces are planes.

R' and C' are ratioed to the roof thickness, and are therefore to be expressed "per unit length". Their calculation is straightforward: R' is the reciprocal of thermal conductivity; C' is specific heat times density (thermal conductivity, specific heat and density are usually declared by the Manufacturer.

The whole roof can be simulated by series-connecting infinite elementary circuits like the one above described. The outcome is a double bipole similar to those used to simulate long electric lines.

In turn, the doube bipole can be represented by means of four complex quantities A, B, C, D. If the roof is made up of multiple layers, each layer has its own double bipole: the whole roof can be simulated by cascade-connecting all the individual double bipoles.

Results

We applied the "double bipole method" to a real life case reported in literature: a building in Palermo, Italy, with a concrete, polyurethane-insulated roof; insulating slabs of different thicknesses (5 cm and 10 cm, respectively) were envisaged.

A know "sun-air temperature" was assumed to be acting on the outer surface of the roof, based on day-night succession: the resulting inner temperature temperature was calculated as a function of time. In both cases, temperature calculated by the double bipole method turned out to be in very good agreement with expected temperature, in amplitude, frequency and phase.

Conclusions

As compared to currently available methods, double bipole method yields following advantages:

- discretization uncertainty is avoided;
- no convergence problems arise;
- discontinuities between different layers are very easily addressed;
- calculation is limited to the surface of interest: internal planes within the insulating layer are not included. This enables to save a significant amount of time and of memory.

The last is probably the most important advantage. It is due to the extreme simplicity of the calculation method: calculation time is typically much less than 5 seconds.

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Charles Mason and Timothy Fitzgerald
PRODUCTIVITY EFFECTS OF HYDRAULIC FRACTURING

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Overview
Hydraulic fracturing has been cited as a transformative tech- nology for the oil and gas industry in North America [5, 8, 1, 7]. This new technology, along with other technologies such as horizontal drilling and multi- dimensional seismography, has facilitated substantial incremental ad- ditions of reserves of unconventional resources, yielding impressive extended projections of supply and downward pressure on domestic prices for natural gas. But despite the acknowledgment of the importance of fracturing, little or no work has been done to formally evaluate the incremental contribution of fracking to natural gas supply. Our paper rectifies this oversight. We quantify the contribution of hydraulic fracturing to well productivity, in par- ticular focusing on the productivity effects associated with various injectants. As some of the inject ants associated with fracking have raised concerns asso- ciated with groundwater contamination, our analysis can also be interpreted as offering estimates of the opportunity cost of prohibiting certain injectants.

Methods
Using data from wells drilled in two important U.S. gas fields from the state of Wyoming, we estimate a production function for hydraulic fracturing. Technical information about the completions was matched to monthly production reports; all of the data were provided by the Wyoming Oil and Gas Conservation Commission. In addition, we use disclosure data provided to FracFocus, a collaborative effort to divulge the chemicals and materials that are injected into fracked wells. We use detailed information about the completion techniques and each fracturing stage, including the specific ingredients in the fracturing fluid that are injected down the wellbore. By examining production records of hydraulically fractured oil and gas wells, we are able to estimate the marginal productivity of fracturing. This productivity can be measured in terms of the targeted natural gas and oil, but also for the production and flowback of injected water, which has been a central environmental concern about the process.

Results
We identify three different types of impacts. First, we observe how the physical characteristics of frac jobs change over our sample period, in terms of both scale and scope. This allows us to estimate the marginal production effects of hydraulic fracturing. Second, because we know the firms involved in each well, we can observe how firm behavior changes over the course of time. In particular, we are interested in how firms perceive the value of withholding disclosure of the ingredients in their frac jobs. We are also able to objectively assess the productivity of wells with differing levels of disclosure. These different measures allow us to characterize the strategic environment in which firms operate. Third, we observe differing levels of toxicity in various parts of the fracturing fluid, and we can assess trends in use of toxic ingredients. Because public concern about environmental risks has focused on the toxicity of injected fluids and produced water, an assessment of the role of toxic additives will help inform the policy debate.

Fracturing technology has been developed through “learning by doing," which our data allow us to observe. We expect that the marginal productivities have changed with more experience. Because the wells in our dataset were drilled and completed at different points in time, we use price variation to consider the value of marginal product. On the other hand, because we observe incomplete production histories due to continuing activity, our analysis is limited to the early stages of a well life.

Conclusions

Our analysis recognizes the heterogeneity of well completions and the use of fracturing, subtleties that are lost in the policy debate over expanded oil and gas production. These estimates benchmark the benefits for any benefit-cost analysis of “fracking,” the spread of which has increased concerns about the contamination of water resources [3, 6]. Regulation of fracking has been a contentious issue, particularly with respect to shale resources [2, 4]. Our estimates also explicitly include the flowback of injected water and the production of water after natural gas and oil production commence, and so can be used not just to consider effects on the supply of oil and natural gas, but also on the co-production of potentially harmful water byproducts.

These results allow us to back out the impact of various injected materials, and in particular to discuss the potential for substitution between inject ants that have the potential to contaminate groundwater and injectants that are relatively benign. In this way, our results provide the backdrop for a deeper discussion of the benefits and costs associated with tracking, and can serve as a springboard for a deeper discussion of potential regulatory approaches to fracking.

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Stefan Vögele, Lisa Hanna Broska, Sebastian Otte and Dirk Rübbelke

SOCIAL NORMS: JEOPARDIZING THE TRANSITION OF ENERGY SYSTEMS TOWARDS SUSTAINABILITY? THE EXAMPLE OF PRIVATE CAR PURCHASERS IN GERMANY

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Overview

The transport sector plays a key role when it comes to decarbonizing the energy system. In Germany, developments in the transport sector are characterized by an increasing use of cars running on new, environmentally friendly technologies (i.e. electric and hybrid electric vehicles). At the same time, sales of larger and heavier cars, such as sport utility vehicles (SUVs), are booming [2, 3]. Taking projections [4] of future SUV sales into consideration, the trend towards SUVs can be expected to continue. This trend in consumer preferences towards larger cars can be observed not just in Germany, but constitutes a worldwide phenomenon [5, 6]. Since these cars are linked with high demands for resources (needed for their manufacturing) and emissions, the trend runs counterintuitive to demands of sustainability. Thus, it shows a behavior change running contrary to goals of climate protection. In order to achieve those goals it is important to counter the trend towards ever larger and less fuel-efficient cars. But to do so, first requires an understanding of the trend and its underlying drivers. The trend to favor SUVs and other large vehicles in a car-buying decision is based on a complex collection of factors essentially driven by consumer preferences. This case study on Germany is a first concentrated effort to determine the share of social aspects in the development of consumer trends such as the rise of the SUV. We hypothesize that SUVs would not be bought in such large quantities if social aspects and particularly social norms were disregarded during the purchasing decision.

Methods

According to [1] there is a broad range of motives which determines the purchasing decision with respect to specific car categories, i.e. car segments. As most important criteria the price-performance ratio is listed, followed by comfort, safety, design, and many others. Most criteria contain both social aspects and aspects of self-interest to varying degrees. These criteria can be clustered according to their share of motives completely self-centered and motives generating a benefit for the individual through the influence of his/her social context. In principle, an assessment of the share of social aspects in the stated motives for buying a car of a particular car segment is difficult and linked to high uncertainties. A first guess for the shares of social aspects in the stated motives is presented in *Fig. 1*, assuming an uncertainty range of 25 %.

Furthermore, the list of motives as well as the individual motives' importance varies from actor to actor. For example, some actors might pay more attention to ecological impacts, while others give the car's design top priority.

Since social norms and their influence depends on the social group to which an actor belongs, we clustered actors using the so-called Sinus-Milieus [7], which identify ten groups for Germany, distinct from each other in terms of values, lifestyles, and attitudes: “Traditionals”, the “Precarious”, “Hedonists”, “Modern Mainstreamers”, “Adaptive Navigators”, “Social Ecologicals”, the “Established”, “Liberal Intellectuals”, “Performers”, and “Cosmopolitan Avant-gardes”.
Thus in a second step, we assess the importance of each motive in car-buying decisions from the different milieu’s point of view.

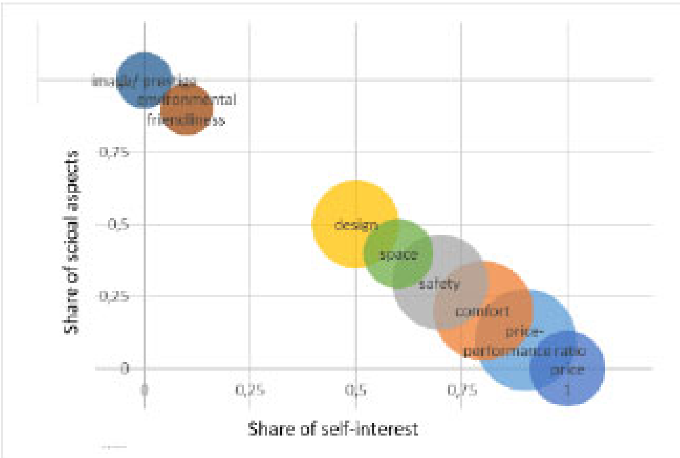

Figure 1. **Stated motives for buying a car of a particular car segment clustered according to their underlying share of self- interest and social aspects**
Source: Authors’ conception, own compilation based on [1]

Not only actors but also cars differ widely (e.g. with respect to costs, comfort, design, safety). For an appropriate assessment of changes in the car stock, the characteristics of cars need to be taken into consideration. We used a rating of car characteristics provided by the German Automobile Club ADAC [8] and chose an exemplary car model in each car segment for further calculations. Applying a multi-criteria decision analysis (MCDA) [9-11] we assess the decisions of private households to opt for a car of a certain segment by taking into account different milieus’ preferences as well as differing car characteristics. This approach is based on the assumption that a group of actors will opt for a particular car category if the category shows more advantages for the group of actors than any other category [12, 13]. In a second run of the MCDA social aspects are not factored in so as to evaluate their influence on the car-buying decision

Results
The results of the MCDA imply that social factors play a significant role in the trend toward large cars such as SUVs. We find that social aspects have differing effects within each milieu, which points to the influence of different social identities.

While in lower- and middle-class milieus the social influence seems to favor generally larger cars, the trend towards SUVs specifically seems to be a phenomenon of the upper-class milieus (Tab. 1). These results coincide with those of VuMA Touchpoints [14]. When social aspects were not factored in, smaller cars suddenly rise in ranking, becoming absolute favorites.

Conclusions

Table. 1: **Ranking of car segments showing the three most desirable car types for each Sinus-Milieu** (with and without "social aspects" included in the calculations)

	The three most desirable car segments for each Sinus-Milieu	
	With all motives included	**Without "social aspects"**
Traditionals	Medium cars; Large cars; Small cars	Small cars; Medium cars; Large cars
Precarious	Medium cars; Large cars; Small cars	Small cars; Medium cars; Large cars
Hedonists	Medium cars; Large cars; Small cars	Small cars; Medium cars; Large cars
Modern Mainstreamers	Large cars; Medium cars; Small cars	Small cars; Medium cars; Large cars
Adaptive Navigators	Large cars; Medium cars; SUVs	Small cars; Large cars; Medium cars
Social Ecologicals	Large cars; Medium cars; Small cars	Small cars; Medium cars; Large cars
Established	SUVs; Large cars; Medium cars	Large cars; Medium cars; Small cars
Liberal Intellectuals	Large cars; SUVs; Off-roa d vehicles	Large cars; Medium cars; Small cars
Performers	SUVs; Medium cars; Large cars	Large cars; Medium cars; Small cars
Cosmopolitan Avant-gardes	Medium cars; Large cars; SUVs	Large cars; Medium cars; Small cars

Our calculations seem to confirm our hypothesis that social norms play a significant role in the trend towards larger cars. It is a first concentrated effort to determine the share of social norms in the development of consumer trends such as the SUV. The approach applied here, can be developed further by determining the evaluation of car characteristics via surveys and discrete choice experiments among all Sinus-Milieus; it can also be used for other societal trends.

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Wojciech Drożdż

DEVELOPMENT OF ELECTROMOBILITY IN POLAND FROM PESPECTIVE OF YOUNG LOGISTICS.

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Overview

Along with economic progress there are many changes, connected with the continuous evolution of transport. An efficient process of energy transmission is a component of many factors that form the foundation of OSD activities. In the era of globalization and the modernized economy, it is impossible to imagine a world without a dense network of transmission connections. For several years, Poland has been ranked among the top countries in the world, recording continuous economic development. Nowadays, the power sector is the basis for the proper operation of the entire national economy, and its dynamic development is associated with a huge demand for energy, which is constantly increasing year by year. Both individual customers and various types of enterprises report increasing energy needs. Unfortunately, the Polish energy sector is still based on conventional fuels, ie hard coal and lignite, from which Poland draws up to 80 percent. energy. However, efforts to introduce environmentally friendly solutions that will allow to produce and distribute energy do not cease. Such is certainly the development of electromobility.

Methods

For the implementation of electromobility, not only financial support and non - financial incentives are needed, but also the creation of desirable consumer patterns. On the basis of own research on groups of over 200 students connected with logistics, the preferences of a young generation of Polish logistics specialists in the field of modern forms ofmobility will be presented.

Results

On the basis of research in the scientific community, proposals will be indicated for the development of electromobility in Poland, based on the needs of future managers replying for the transport and logistics sector.

Conclusions

Implementation of the plans included in the Act is connected with strong cooperation of Distribution Network Operators and local governments. On the basis of tests , the demand for energy can be registered at both local and regional levels. However, the development of electromobility is affected by many factors, both economic,
amd social. Emphasis on the development of electromobility at the regulatory level should provide a development impulse for the whole industry and allow for the intensive development of pioneers, giving them the opportunity to build new competitive advantages, over time distribution networks, brand recognition and new cooperative networks.

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Material collected on the basis of own research, conducted on a group of over 200 students of managerial majors.

Qixing Wang, Yuan Niu, Jie Wu and Chengliang Wang

LINK-BASED PRICING FOR AUTONOMOUS VEHICLE (AVS) SERVICES PERFORMANCE IMPROVEMENT

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Overview

As Autonomous Vehicles (AVs) become possible for the transportation services, especially when telecom companies start deploying next-generation wireless networks (known as 5G) , many new technologies may be applied in these vehicles. Dynamic-route-switching is one of these technologies, which could help vehicles find the best possible route based on real-time traffic information. However, allowing all AVs to choose their own optimal routes is not the best solution for a complex city network, since each vehicle ignores its negative effect on the road system due to the additional congestion it creates. As a result, with this system, some of the links may become over-congested, causing the whole road network system performance to degrade. Meanwhile, the travel time reliability, especially during the peak hours, is an essential factor to improve the customers' ride experience. Unfortunately, these two issues have received relatively less attention.

Method

In this paper, we design a link-based dynamic pricing model to improve the road network system and travel time reliability at the same time. In this approach, we assume that all links are eligible with the dynamic pricing, and AVs will be perfect informed with update traffic condition and follow the dynamic road pricing. A heuristic approach is developed to address this computationally difficult problem. The output includes link-based surcharge, new travel demand and traffic condition which would improve the system performance close to the System Optimal (SO) solution and maintain the travel time reliability.

Results

The method described above will be demonstrated in the well-known and well-studied 24 nodes, 76 links, and 360,600 total OD trips comprising the Sioux Fall network (assume all demands are running for the e-hailing services). While it has been noted that this network bears little physical sameness to Sioux Falls, South Dakota today, the network and its associated data have been widely used in variety of transportation network analysis studies.[1] With a 44.75% demand change, the total system travel time was reduced by 50.44% and each link travel time was reduced by 10.65%. The road became less congested with a v/c ratio 0.75, but travelers can expect an average 27.74% increase in cost to accomplish their trip.

Conclusions

In this research, we introduced an economical way to calculate the optimal surcharge rate in order to improve travel time reliability and system performance during peak travel hours. All link-based service congestion surcharges were calculated through a heuristic approach.

The results demonstrated that the principles of UE assignment were maintained in the travelers' path choice behavior while leveraging the relationship between SO and UE using the marginal cost function. At the same time, revenue received from this surcharge can be used in various ways, such as improving transit service quality or upgrading road infrastructure which could also advance road network performance. In all applications in this paper, demand saw a significant drop from its original level. Future work can explore alternate means of estimating demand response to surcharge levels and/or fine tune the existing function.

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Papers

BOOSTING RESIDENTIAL ROOFTOP SOLAR BY USING FINANCIAL INCENTIVES – A COMPARISON ANALYSIS. A CASE STUDY IN VIETNAM

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Abstract:
Finance policy plays an important role in establishing and promoting decentralized rooftop solar power market, where the estimated payback time is around ten years. This paper focuses on analyzing the relationship between finance decision-making and the market benefit by examining the market's reaction to different financial changes. The paper considers the newborn market in Vietnam with four different types and sizes of a PV system, four business models in the traditional financial supports including self-financed and debt-finance and new financial supports including leasing and crowdfunding. The results show the favour financial decision of all parties in all cases are the 70% support of total investment, where the total market benefit would increase by 10%, customer benefit increases an average of 20% and investor benefit increases average 7% compared with other types of financial support.

Keywords: *Rooftop solar market, Developing country, Promotion policy, Vietnam, Financial incentive*

1. Introduction

Solar energy is one of the key elements of sustainable development all over the aworld. Emerging countries have a chance to shorten the way to sustainable development by enhancing the contribution of solar energy in their energy supply. However, after ten to twenty years of effort, the governments and the public are struggling to encourage more solar energy use (Fernando and Siani 2016). The main and tautology problem is claimed for lacking capital, policy support and awareness (Gaëtan Masson, Jose Ignacio Briano, Maria Jesus Baez 2016). The promising potential of decentralized solar power is more and more obvious since the accelerating development of renewable energy technologies (RETs) recently reduces the amount of investment for solar power so that it is even cheaper than fossil fuel (International Renewable Energy Agency (IRENA) 2019, 2019). Therefore, a new window for creating a competitive market for rooftop solar becomes profitable in public views.

As one of the emerging countries, the Vietnamese government sets out an ambitious plan with bold targets for solar power by pushing residential solar energy usage increasing 26% by 2030. To actualize the target, the government has proposed new Feed-in-Tariffs (FiTs), detailed guidelines and requirements for rooftop solar projects in Vietnam in early 2019. In which, the government replaced the net metering payment mechanism for rooftop solar projects with a direct trading scheme under the regulation code 02/2019/QD-TTG. As a result, the state utility of Vietnam, which is Vietnam Electricity Corporation (EVN), is now eligible to pay directly for the electricity generating from rooftop solar. This scheme opens a way for household customers to directly purchase rooftop solar power and pay separately for the electricity they consume from the grid.

Under the Draft Decision, there are four business models for a rooftop solar project, which has a limited installed capacity of 1MWp or less. First of all, “Whole power selling business” or “Wholesale” model is an on-grid system, which can trade the generated electricity between the owner/investor and the state utility. “Consumption household” or “Consumer/Prosumer” model is a bi-directional metering system or prosumer system, which produces and consumes solar power directly from the solar system and sells the excess electricity to the state utility. “Direct power sale and purchase” or “Direct purchase” model is an off-grid model, in which the generated power is traded between the owner and consumer without using the serice and facility of the state utility. “Intermediary power sale and purchase” or IPSP model is an on-grid business model, where the owners sell their solar electricity to the customer through the state utility.

To understand the market operation and provide financial suggestions for the government in order to encourage household solar use, the paper will assess financial aspect of different sizes of PV system with different types of connection to the grid such as off-grid system with battery backup, and on-grid system without battery. Based on the current offers of providers in Vietnam, the paper attempts to calculate the change of payback period and internal rate of return (IRR) for all the systems when the government changes the financial incentives.

Since rooftop PV market in Vietnam is a newborn market, the government needs to encourage investment in various means. Learning from other pioneering countries in developing rooftop solar market is necessary. With this purpose, this paper aims to exams the benefit changes of each market's entity corresponding to different financial supports such as traditional financing instruments such as equity, debt financing and new financing instruments including leasing and crowdfunding.

2. Material and Methods

2.1 Determine business models

Figure 1 illustrates the cash and electricity flows for all business models of rooftop PV in Vietnam. There are three entities in the market including consumers, state utility and investors. Investors represent for the business company, which invests in installing a solar power system to generate electricity for trading without consuming. Consumers are residential customers, who are purchasing electricity for private use. Besides, state utility is the organization that provides and maintains the infrastructure for electricity use.

The responsibility for each party in the residential market is presented in table 1. In any business model, there are two parties negotiate a solar power contract and earn financially benefit from the contract. In the Wholesale model, the contract is signed between the investors and the utility. While in the Consumer model, the contract is between the customers and the utility. Customers in the Consumer model play both investor and consumer roles. PV system generates power can be easily directly consumed and the surplus power will be sold to the grid.

In the Direct purchase and IPSP model, the investors sign the electricity contract directly with their customers. However, in the Direct purchase model, the investors are responsible for all installation, operation, and transmission their PV system, while in the IPSP model, the Utility will take over the transmission responsible for them

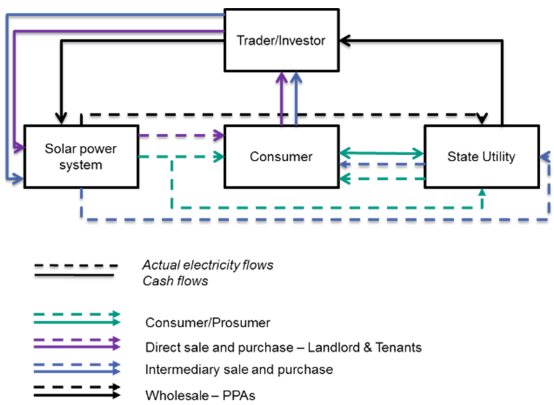


Figure 1. **Solar Power Models with actual electricity flows in dotted line and cash flows in bold lines.**

Table 1. **Responsibilities of stakeholders in the residential PV business model**

Business model (code)	Consumer	Trader/ Investor	Utility
Consumer (C)	Consume + Owner		Transmission & Payment
Direct sale and purchase (D)	Consume	Owner + Transmission + Payment	
Intermediary sale and purchase (I)	Consume	Owner + Payment	Transmission
Wholesale (W)		Owner	Transmission & Payment

2.2 Determine the system model

To calculate the correlation between each party's benefit with the government financial support changes, the paper investigates two typical PV systems are an off-grid and on-grid system at the residential scale. The off-grid system consists of PV generators, battery, converter, load regulator and switchboards, while the on-grid system includes PV generators, inverter, and meter (figure 2). Because the average household area in Vietnam is around 60m^2 (Vietnam Government Statistical Office – GSO, 2018), the available rooftop area is suitable for installing PV panel in such houses is around 1 to 5 kWp with total PV panel area from 6-32 m^2 (Appendix 1).

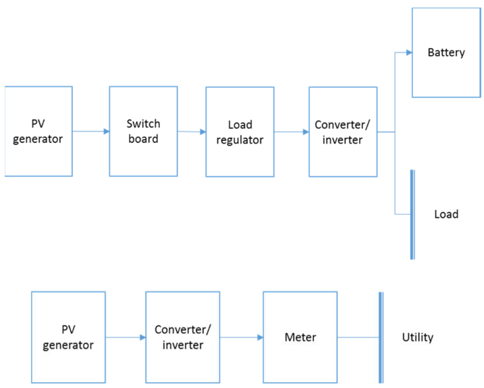


Figure 2. **On-grid PV solar system** (above figure) **and off-grid PV solar system** (below figure)

Table 2 shows the technical parameters and the estimated investment and annual cost for the sample PV systems (further information in appendix 3). The current investment and cost are calculated based on the current technology and market price and charge provided by the whole sales and retailed sales in the market. The system cost includes investment cost or capital expenditure and the annual operation and maintenance costs (O&M), which are cleaning, electrical checks, inverter replacement cost, the insurance cost. The price for the system is the initial cost or the investment cost includes equipment cost and labour cost. Since solar radiation in Vietnam is differed significantly along with the country from North to South, the capacity utilization factors are estimated based on the radiation characteristic of four zones. The rooftop solar price is also distinguished by four zones (see *Table 2*).

Table 2. **Technical parameters and cost of the sample PV systems**

	System 1-a	System 1-b	System 2-a	System 2-b
Technical parameters				
Type	Off-grid	Off-grid	On-grid	On-grid
System size (kWp)	1	5	1	5
Plantlife (year)	25	25	25	25
Degradation factor %/year	0.5	0.5	0.5	0.5
Performance ratio (%)	80	80	80	80
Required space (m^2)	6	32	6	32
Capacity Utilization factor (%)				
Zone 1	14.5	14.5	14.5	14.5
Zone 2	17	17	17	17
Zone 3	18.5	18.5	18.5	18.5
Zone 4	20	20	20	20
Cost and expenses				
Investment cost (Euro/kWp)	1200	1000	1000	600
O&M first year (%)	3	3	3	3
Annual O&M (%)	0.65	0.65	0.65	0.65

2.3 Determine the financial model

The paper considers traditional financial models are self-financing and debt financing, which is common in any investing project and compares them with the new financial models including leasing and crowdfunding models to investigate the specific advantage and disadvantage of each model. The consumers, in any case, will be benefited by saving electricity bill when replacing partly the electricity drawn from the utility and they are partly prevented from the increasing electricity cost over the years by using solar electricity. While the investors receive benefit from selling their generated solar power. The utility or state will benefit from reducing financial effort investing in building a new power plant.

The paper analyzes different cases of the debt-financing model including 30% and 70 % loans at 8% and 10% interest. The cases are built based on the government-financing program for the solar power project. This program has been prepared to approve for rooftop solar project at the end of 2019. To be convenient for reading results, the paper coded the different experimental models as shown in Table 3.

Table 3. **Code of different considered financial models**

Code	Explanation
D30_10	30% loan at 10% interest
D30_8	30% loan at 8% interest
D70_10	70% loan at 10% interest
D70_8	70% loan at 8% interest
S	Self-financing

To financially compare between different solar models and financial models, the paper uses the financial indicators including net present value (NPV), Internal rate of return (IRR), payback period. The savings and expenses of each PV system for each parties participating into the market are calculated by saving electricity cost based on rooftop solar Feed-in-tariff

(FiT) and grid tariff for the household customer (table 4 and 5). The escalation rate of the grid tariff is estimated at around 5% per year in the base case of Vietnam Master Plan VII for the electricity sector.

Table 4. **Rooftop solar power Feed-in-tariff by zone in Vietnam**
(Decision No. 02/2019/QD-TTG of the Prime Minister dated 8 January 2019)

Zone I		**Zone II**		**Zone III**		**Zone Vùng IV**	
Northern Vietnam (28 provinces)		Central (6 provinces)		Southern East Vietnam (23 provinces)		Southern West Vietnam (6 provinces)	
VNĐ/kWh	Euro cent/kWh	VNĐ/kWh	Euro cent/kWh	VNĐ/kWh	Euro cent/kWh	VNĐ/kWh	Euro cent/kWh
2.7346	10.31925	2.3529	8.878868	2.1076	7.953208	1.9833	7.484151

Table 5. **Retail electricity grid tariff for a household in Vietnam**
(Decision No. 4495/QĐ-BCT of the Prime Minister dated 30 November 2017)

	Grid tariff		**Consumed Capacity**	**Total pay**	**Cumulative consume**	**Cumulative bill**	**Average tariff**
	1000 Vnd/kWh	**cent/kWh**	**kWh**	**cent**	**kWh**	**cent**	**cent/kWh**
Step 1: 0 - 50 kWh	1.55	5.85	50.00	292.26	50.00	292.26	5.85
Step 2: 51 - 100 kWh	1.60	6.04	50.00	301.89	100.00	594.15	5.94
Step 3: 101 - 200 kWh	1.86	7.01	100.00	701.13	200.00	1295.28	6.48
Step 4: 201 - 300 kWh	2.34	8.83	100.00	883.02	300.00	2178.30	7.26
Step 5: 301 - 400 kWh	2.62	9.87	100.00	986.79	400.00	3165.09	7.91
Step 6: >401 kWh	2.70	10.19	100.00	1019.25	500.00	4184.34	8.37

The saving is calculated as shown in equation 1.

$$\sum_n B_s = \sum_n B_i = \sum_n E_i \times T_i \qquad \text{eq.1}$$

where:

- B_s is the benefit of the system in one year
- B_i is the benefit of party i in one year
- E_i is the consumed electricity of a party in one year
- T_i is electricity tariff by the party i in the year
- n is the lifetime of the solar PV system

The net benefit is calculated by

$$NPV = \sum_n \frac{B_n - C_n}{(1+r)^n} \qquad \text{eq.2}$$

where:

- B_n is the total benefit of the system ($B_n = \sum_n B_s$
- C_n is the cost of the system
- r is the discounted rate

Internal rate of return (IRR) is the discount rate that forces NPV to equal zero is calculated by

$$NPV = \sum_n \frac{CF}{(1+IRR)^n} \qquad \text{eq.3}$$

where:

- CF is the cash flow in one year

Payback period indicated to the time when the investment is paid off

$$Payback\ period = \frac{Initial\ Investment}{CF_n} \qquad \text{eq.4}$$

where: CF_n is the cash flow per period of n year

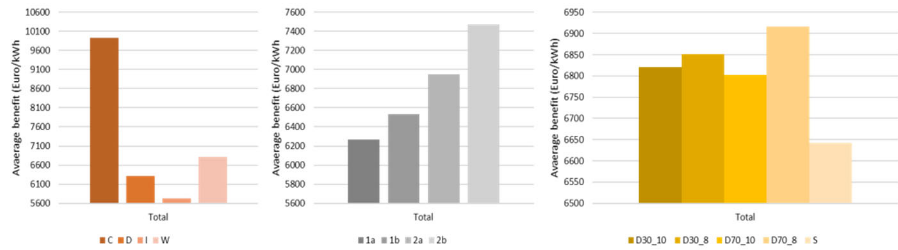
3. Results and Discussion

3.1 The traditional financing models

In the traditional financial models, the investors own the PV system, sell the generated electricity for the state utility and gain the benefit from solar electricity in the Wholesale model. While in the IPSP and Direct purchase models, the investors have to bargain the price with their customers. They can offer their electricity to the consumer at a lower price than the utility charges the consumer, thus the consumers will benefit by saving on the electricity bill, while their benefit will be the difference between their bargained price and the grid price. In the case of the Consumer model, the PV system generates power during the daytime while the consumer is working outside the house, this electricity can be easily exported to the grid. The consumer would draw electricity from the grid during the nighttime for their using purposes. Thereby, the customers will gain benefit from consuming their own generated electricity and from selling surplus electricity to the grid.

Total market benefit and government scheme

The paper compares the market benefit from different system models, business models, and financial models. The market benefit is the total market of every entity including the investors, the customers, and the utility. In general, the results show that market benefit reaches a maximum level in the Consumer model at around 10000 euro per kWh after 25 years, or 4000 euro/kWh/year (figure 3). However, it decreases significantly in the Wholesale, Direct purschaes and IPSP models by 31%, 36% and 42% respectively (Table 6). Comparing system case 1b and 2a shows, the on-grid model provides around 8% for the total market benefit than the off-grid model. By investing in a bigger PV, the whole market would increase its benefit to 0.23% per capacity increase for off-grid system and 0.2% per capacity increase for the on-grid system.
In case of financial support, if the government does not give any financial support to the market, the market could work at the favoured benefit of around 6650 Euro/kWh after 25 years, or 266 Euro/kWh/year. However, if the government could provide a loan scheme of at least 30% capital support at 10% interest the benefit of the whole market will increase by 10%. The increase in the loan from 30% to 70% at maximum as applied for the solar project would slightly benefit the whole market with 2%. However, of the government would tend to decrease the loan interest from 10% to 8%, which is the current lowest loan rate of the government support scheme for energy investment, the benefit would only be increased if the investors choose the package of 70% capacity support.



(a) (b) (c)

Figure 4. **Average market benefit by** *(a)* **business model,** *(b)* **system model and** *(c)* **financial cases after 25 years**

Table 6. **Comparing between different models by relative comparisons index**

Business model	Relative comparisons Index	System model	Relative comparisons Index	Financial cases	Relative comparisons Index
C	1.00	1a	1.00	S	1.00
D	0.64	1b	1.04	D30_10	1.09
I	0.58	2a	1.11	D30_8	1.09
W	0.69	2b	1.19	D70_10	1.08
				D70_8	1.11

Consumers and Investors choices

Figure 5 compares the benefit of each entity in the market with different considerations. First, in case of CH model, since the customers are the investors, their total benefit is estimated around 300 Euro/kWh/year after 25 years at 7% inflation rate and 5% electricity price escalation. The customers' benefit decreases while the investors' benefit increases in the Consumer, Direct purchase, IPSP and Wholesale models respectively. It shows that the most favourite business model for the customer in investing in solar PV is the Consumer model, while the most favourite model for the investor is the Wholesale model. However, they would both prefer the on-grid system and the 70% loan support scheme (figure 5).
Since the solar capacity performance and solar price are differentiated by four regions, the paper compares the benefit between them to assess the attraction of each market with the investors and the customers. The results show that the investors would slightly earn more at zone 1 market or northern part of Vietnam than the other part, while the customers gain much more benefit in the other zones than zone 1 (figure 6).

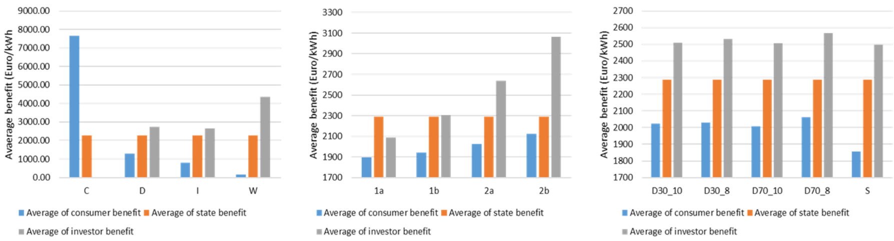


Figure 5. **Comparing the average benefit of each entity by**
(a) **business model,** (b) **system model and** (c) **financial cases after 25 years**

Bargain price in the Direct purchase and IPSP models

In the case of the Direct purchase and IPSP models, the investors have to bargain price with the customers. Therefore, the paper compares the benefit of the two parties at a different level of bargain price to find out the reasonable range, which brings benefit for both parties. Since the bargain price should be lower than the grid price to convince the customers to buy solar power instead of grid power, the paper examines the level of bargain price ranging from 30% to 90% of the average grid price. Figure 7 shows that at the end of the 25-year-period, the benefit of the investor increases from around 32 Euro/kWh/year to about 200 Euro/kWh/year by increasing the bargain rate from 30% to 90% of the average grid price. However, at the 30% rate, the investors would rather choose to save money in the bank rather than decide to invest in a solar project. Because the IRR at 30% is around 1%, which is lower than the bank interest at 7%. From the customers' perspective, their benefit from using solar power decreases from average 120 euro/kWh/year at 30% bargain rate to around 10 euro/kWh/year in average at 70% bargain rate. That would keep them still be interested in choosing power solar for consumption. However, at the higher rates, the customers will not choose to buy solar power instead of grid power. However, the bargain rate is different between different zones. In zone 1, the investors could negotiate from around 45% to a maximum of 76% of the grid price. While in zone 2, zone 3 and zone 4 the range covers from around 50% to 80% of the grid price.

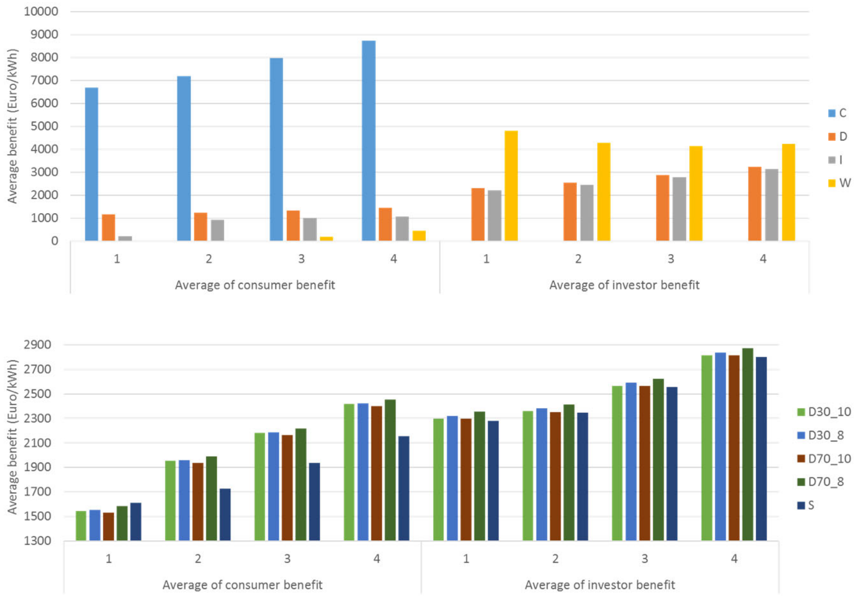


Figure 6. **Comparing customers and investors benefit from different zones after 25 years.**

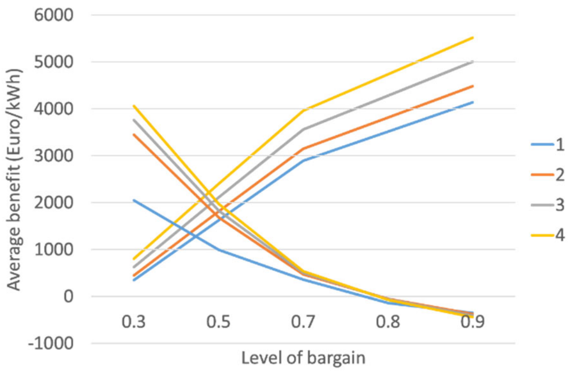


Figure 7. **The changes in each party's benefit when changing the level of bargain price after 25 years**

3.2 The new financing models

In the new financial models, the role of the entities in the market will be changed. There is a new role called the third party will appear in the market (*Table 7*). The third-party owns the PV system and pay onetime for the capital investment and the annual O&M charges. The third-party has the option of selling the electricity to the consumer at a lower price than the grid price or leases its PV system to the customer. The first case can be called double sell and purchase contract (row 1 *Table 7*), in which the customers save their electricity bill according to the arrangement between them and the third party, while the third party earn benefit from price difference of the contract with customer (S&PC 1) and the contract with the utility (S&PC 2). In the second case or leasing contract case (row 2 *Table 7*), the consumers benefit from the electricity bill to the utility based on net consumption (export-import) of electricity and the leasing fee but avoid large upfront capital investment and are free from maintaining the system.

Solar crowding funding is another new financial model. It works as a platform investment for small investors to join and receive interests by investing in a common solar system. This mechanism covers the financing gap of projects, which have difficulties to get bank credit. The crowdfunding contract can be combined easily with other types of financial model (*Table 7*). The crowding funding model is suitable for the installation of PV systems in residential customers, especially in the scale of multi-family.

Table 7. **Responsibilities of stakeholders in the new financial models**

New financial model	Consumer	Third-party	Utility
Double sell and purchase contract	S&PC 1	- S&PC 1 - S&PC 2 - (Crowdfunding contract)	S&PC 2
Leasing contract	- Leasing contract, - S&PC - (Crowdfunding contract)	Leasing contract	S&PC
Crowdfunding contract	- Crowdfunding contract, - S&PC		S&PC

Acronyms: S&PC is selling and purchase contract

The leasing and crowdfunding models can be simple or complicated depends on the government procedure. Since Vietnam has not introduced these models to the market, the paper tends to test the simple case of the two markets. In which, the leasing and crowdfunding are considered separately. A leasing contract is established between the third party and the consumers or the system's owners. The third-party will supply electricity at 90% of the grid price. The consumer in this case still gains benefit at around 30 euro/kWh/year. It is higher than in the case of Direct purchase and IPSP models, in which the investors could not bargain at 90% rate. However, the IRR results show that the third party would not be favoured by investing in off-grid (table 8).

By using crowdfunding with three investors, the IRR would slightly decrease compared with the Consumer model. However, since the investors do not take the whole risk of investment and operation cost, they will gain less benefit. The PV rooftop seems still very attractive since the IRR results shown at the high interest of nearly 17% to 25.5% depending on the system (table 8).

Table 8. **Financial calculation in case of simple leasing and crowdfunding models**

Row Labels	Average of consumer benefit	Average of third party benefit	Average of IRR	Average of Payback
Leasing	**29.96**	**130.00**	**13.53%**	**10.02**
1a	29.87	109.24	4.91%	13.21
1b	29.92	119.63	9.60%	11.05
2a	29.98	135.40	11.95%	10.00
2b	30.09	155.72	27.65%	5.81
Crowding	**156.08**	**87.37**	**27.87%**	**7.33**
1a	144.00	77.43	16.95%	10.25
1b	149.67	82.42	18.82%	7.41
2a	159.67	89.82	18.18%	7.41
2b	170.99	99.81	25.53%	4.25

4. Conclusion

Because of the limited land for building centralized solar, the decentralized market could be a solution for a developing country like Vietnam. Moreover, the development of decentralized solar PV would help to diversify the national economy in the ongoing transition process by avoiding additional cost for investing in utility for solar plants. Following the pioneering countries in developing solar power, Vietnam should put more effort in designing financial attractions for solar energy development to attract more investment that is public. Financial attractions involve the transfer of funds in investing in rooftop solar and promises of future return. Specifically, the policymakers should make up financial schemes for rooftop solar funds individually instead of combining with other renewables and transforming risk schemes to increase the public will.

The paper assesses the financial analysis and comparison to different system models, business models in different financial cases to find a suggestion for the government in encouraging household solar power aspect of the four types of the solar system. Based on the current market status and the government plan by 2030, the paper calculated the change of payback period and internal rate of return (IRR) and benefit of each participant in the market when the government's financial subsidies change.

The results show that if the government would support rooftop solar project in a household with a loan program of 30% to 70% total capacity investment, the total market benefit would increase by at least 10%. If the government would consider applying new financial models such as leasing or crowdfunding it would help to scale up the residential solar market. Because the solar leasing would offer financing for customers to own or have access to solar systems requiring monthly instalments and no upfront cost. The third-party in this case would benefit at IRR of nearly 17% to 25.5% depending on the system. It also allows providers to benefit from customers through a combination of access to financing, operations, and maintenance (O&M) service, and performance guarantee.

Appendix

Appendix 1. **Summary of solar PV system packages for a household customer in Vietnam**

On-grid

Capacity (kWp)	area (m^2)	Price(1000 Vnd)	Price (euro)	price (euro/kWp)
1	6	25000	943.39	943.39
2	12	37000	1396.22	698.11
3	20	50000	1886.79	628.93
5	32	75000	2830.18	566.03
10	56	162000	6113.20	611.32

Off-grid

Capacity (kWp)	area (m^2)	Price (1000 Vnd)	Price (euro)	price (euro/kWp)
1	6	28000	1056.60	1056.60
2	12	55000	2075.47	1037.73
3	20	75000	2830.18	943.39
5	32	127000	4792.45	958.49
10	56	240000	9056.60	905.66

Source: in the links below. Last accessed 19 March 2019
https://solarstore.vn/he-thong-dien-mat-troi-hoa-luoi/kinh-te/
https://hethongtudong.vn/vn/bao-gia-mainmenu-155/bao-gia-he-thong-dien-mat-troi-menu-165.html
https://gpsolar.vn/bao-gia-dien-mat-troi.html
https://solarpower.vn/he-thong-dien-mat-troi-gia-bao-nhieu/
https://congnghexanhvn.com/bao-gia-lap-dat-pin-nang-luong-mat-troi-re-nhat-2019/
https://congnghexanhvn.com/chi-phi-lap-dat-dien-nang-mat-troi-2019-tai-ha-noi/
http://solarachau.com/du-an-thi-cong/bao-gia-lap-dat-he-thong-dien-mat-troi-nam-2018-cua-solar-a-chau.html

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RETHINKING REGIONAL COOPERATION – A NEW LAYER IN THE EUROPEAN ENERGY GOVERNANCE

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1. Introduction

A substantial literature has been produced to investigate on the design specifics regional market [0]. Fewer contributions, however, focus on the energy governance and infrastructure investment implications that take account of energy transition challenges in both national and regional context. This paper aims to identify variables that specify and affect the interaction patterns and outcomes for the regionalization in European energy governance. Two important questions are explored: What factors foster cross-border energy cooperation? What makes Member States take divergent paths in energy transition? The answer comes by investigating the elements that motivate and shape the region boundary of effective cross-border cooperation in the European energy arena: scenario and technology uncertainties, externality and energy security. Among the three factors that shape cross-border cooperation dynamics, scenario and technology uncertainties as well as externality reflect the benefits of coordinating energy market and investments in vast geographical area. The divergent energy security perceptions may give incentives for countries to seek a smaller number of partners for converged cross-border cooperation.

Section 2 comprises the sources of scenario and technology uncertainties for infrastructure planning and long-term energy strategy making. It shed lights on the long-term forecasts from major energy agencies, which the cross-border energy infrastructure planning in Europe has often referenced. These scenarios have showed various outcomes projecting future energy transition path and energy mix. The technology uncertainties in energy mix are analysed in two dimensions: the current versus next generation technology and cross-border cooperation complexity. Cost reduction for current renewable technologies are mainly based on the deployment learning curve. A closer look at cross border aspect shows that a pan European agreement on the same set of technology choices will incur extremely high political cost, given the large number of countries and players.

Section 3 discusses unexpected challenge brought by loop flows to the cross-border coordination. Current market design using zonal or uniform pricing does not reflect accurately the network externality by pricing and lead to separation of market and technical operation. On the interconnection investment, different perceptions for costs and benefits of interconnection projects make the incentives asymmetry, compounded by the fact that national regulation and financing schemes for developing cross-border network are not aligned without an effective higher -level decision making structure. To address the externality, not only market design needs to be improved, but also involves the coordination in renewable and transmission network investment.

Section 4 comprises three selected elements of energy security demonstrate that differences among them make countries take divergent positions in energy transition: 1) desired change of fossil fuel trade flow; 2) affordability; 3) relative position in the race of renewable technology. The desired flow change for fossil fuel import is influenced by the geopolitical perceptions of the countries that are interconnected. Socioeconomic factors matter for energy transition path in the national context. This analysis calculates the energy affordability index to represent the

economic development differences for countries and renewable energy technology patent as proxy to represent industry policy in clean technology. The combination of these three aspects of energy security has major implication for a country to position itself in energy transition strategy, its preferred technologies paths and timing.
To offer a proper governance model, arrangements would need to accommodate increased diversity amongst players, while avoiding requiring the same levels of commitment from participating countries. In a nutshell, a regional layer in European energy governance that aims for deeper cooperation should bundle countries that share similar attitudes towards uncertainty, common externality problem and energy security perceptions.

2. Scenario and technology uncertainties

2.1 Scenario uncertainties

Policies to tackle climate change represent the fundamental transformations of the energy, land and economic systems over the 21st century. Energy transition is one of the most important corner stones in the battle against climate change. As Christopher Clark put it, the climate disaster provides a narrative for terminal of temporality [2]. The incapability of the current national economic systems to tackle climate change problems are being challenged by the young generations worldwide. The temporal awareness for long-term consequence as a result of the future ecological threat raises appeal to collective actions. There is, however, not much discussion on how to deal with long term scenario uncertainties resulting from market and technology paradigm shift and guide the transition strategy and infrastructure investments.
Some input variables for European long-term energy planning come from forecast reports from major energy agencies. While the climate objective is defined by Paris Agreement, there is no universal story to achieve it. The IPCC literature review shows the diversity of potential scenarios to reach the climate target. For instance, in the 85 available 1.5 degrees pathways investigated in the IPCC report, the share of renewable energy in primary energy sources all increases. Among its four envisioned scenarios, the share of renewable energy sources in electricity ranges from 25% to 60% in 2030 [0]. Table 1 illustrates the 2050 scenarios from two major energy agencies and one company. These forecasting agencies take different positions on the path and energy mix to reach the climate target. The REMap from IRENA depicts the scenario that mainly bases on deployment of renewable energy and energy efficiency to limit the global temperature rise to 2 degrees above pre-industrial level[0]. The IEA depicts a scenario in which an array of policies are implemented in the energy sector to follow a trajectory of greenhouse gas emission that limits the rise of global average temperature with a 66% probability to well below 2°C from pre-industrial levels [0]. The Shell Sky illustrates the technical, industrial and economic route envisioned by Shell that limits the global average temperature rise to well below 2°C from pre-industrial levels [0]. Among the three, IRENA REMap case represents the most positive scenario in terms of the renewable energy share in the future energy system. In IRENA REMap, renewable energy accounts for 63% in the total primary energy supply as opposed to 46% by IEA and 43% by Shell. At the same time, the energy efficiency improvement including the electrification in REMap characterises the major contribution among abatement options that accounts for 53% of the total abatement. The Shell Sky scenario forecasts a much higher total consumption. In particular, this Sky scenario assumes that accelerated contributions take off after 2028 global stocktake, which represents another important element departing from others: the balance between policy implementation timeline and technology innovation.

Table 1. Comparison of major agency and company scenarios [0]

Energy agencies and company	IRENA	IEA	Shell
Scenario in 2050	**REMap Case**	**2 Degrees**	**Sky**
Total primary energy supply [EJ/yr]	550	586	828
Total final consumption [EJ/yr]	386	398	548
Renewable energy share in total primary energy supply [%]	63	46	43
Fossil fuel CO_2 emission in 2050			
Baseline [Gt/yr]	37	37	
Emission in 2050 [Gt/yr]	9.7	9	18
Contribution of abatement options			
Renewable energy [%]	41	37	
Energy efficiency (including electrification) [%]	53	35	
Others	6	28	
Energy intensity improvement[%/yr]	2.8	2.9	2
Electric mobility in transport [%]	31	n/a	21
Total biomass demand [EJ/yr]	128	147	55

The scenario evaluation performed by Aurora focusing on the forecast history of IEA shows there are three major mistakes made by IEA in the 30 years [0]. In 1983 the oil price is overpredicted and essentially IEA failed to foresee the price falls in the mid-1980s. In the gas sector, the gas price forecast in 2008 for the US market was to reach $14/MBtu in 2010, which turned out to be $4.6 that year. The coal price forecasts by IEA had largely underestimated the potential impact of China's accession to the World Trade Organization (WTO) and did not foresee the financial stimulus package by the Chinese central bank during the global financial crisis. It stated in 2007 that coal price would hover around $64 per tonne in the foreseeable future and it turned to be exceed $125.

2.2 Technology uncertainties

2.2.1 Cross-border dimension

In the EU, Lisbon Treaty states that energy is a joint competence between EU and Member States. Each Member State retains its right to maintain energy mix based on its own institutional history and philosophy. The choice for energy mix is national but the energy technology industry is global. For individual market investors, sheer chance plays a substantial role in picking winner from innovations and determining the economic technical viability of certain technology. From the perspective of a technology adopting country, experimenting the energy transition with policies betting on the wrong technologies for the next generation can be very costly for a single country. From the lessons learned in supporting current generation of renewable energies, a patchwork of national policies to support clean technology deployments are not only more costly system wide, it also creates uncertainties for cross-border cooperation. For instance, when renewable support schemes and grid connection rules are made national, joint projects or joint support schemes that supply consumers outside the producing country becomes difficult to agree on due to domestic political pressures. Furthermore, stakeholders from at least two countries need to agree on a common set of cost and benefit measurement to support certain technologies and the resulting cost allocations. Consequently, few joint projects or joint support schemes have been set up in Europe.

Information gap is another issue in forming accurate assessment for priority preferences in European energy development planning following a top down approach. Although in the advent of digitalization, the means and costs of obtaining such information become more available. The information that reveals different preference from the cities, states or customer groups in terms of costs, sustainability and security remains difficult to obtain and to feed back into a European wide decision making. At European level, agreeing on the deployment of the same set of technology preferences may be impossible due to the large number of stakeholders. In contrast, a regional approach provides the mid-way between flexibility and efficiency.

2.2.2 Deployment VS Innovation

In the past decade, current generation renewable technology such as solar and wind has showed continued cost reduction and performance improvement. Global weighted average levelized cost of energy (LCOE) for utility scale solar PV projects has dropped 73% between 2010 and 2017. The global weighed average LCOE for onshore wind has dropped 23% during the same period [0]. IRENA summarizes the reasons for the cost reduction against the backdrop of increasing deployment and growth of markets for solar and wind: 1) increasing economics of scale in manufacturing; 2) manufacturing process improvement; 3) more competitive and optimized global supply chain; 4) technology improvement that increases the capacity factor and 5) standardization of the project development; 6) improved O&M practices and the use of real time data for better predictive maintenance; 7) low entry barriers and a large number of developers competing for medium to large scale projects [0].

Nordhaus proves that the usual practice of modelling learning by doing effect in energy and climate models neglects the interactions of exogenous technological change, demand elasticity and output growth. This simplification brings upward bias in estimating learning coefficients of current technologies. Consequently, the model may wrongly recommend the type of technologies with high learning rate to devote resources for research and development while it comes from upward biased estimate [0]. Under the current planning and investment practices, the renewable technologies that have been initially promoted for historical reasons will likely to be deployed in the future auctions to achieve the renewable target, as long as their cost advantage is kept by continuing large scale deployment.

While large scale deployment of current renewable technologies maximizes the benefits of learning by doing, the two main technologies share two major drawbacks: 1) they are intermittent and require backup; 2) the installation of wind turbines raise Not In My Back Yard (NIMBY) resistance from communities and current solar power plant is low density and requires large amount of land [0]. To address these inherent drawbacks, Europe is in need of innovation and commercialization of next generation technologies.

The investment prospect in a low carbon technology can be seen as self-fulfilling prophecy. The more players invest in a certain technology, the faster the technology investment and financing costs fall. The whole market grows and attracts further investments. The consistent framework created by policy makers is thus essential in managing investor expectation and risk perception [0]. However, without some level of commitments and stepping-stone policy actions, the next generation technology is unlikely to be mature and cost competitive. Acting now or later and whether such technology decision can be jointly implemented at EU are difficult questions for policy makers.

While the European wide cross-border cooperation substantially lowers the overall costs for reaching the EU renewable energy target, each national system has its own energy mix, value and institutional history in setting the energy transition agenda. A regional approach has the benefit of allowing neighbouring countries the flexibility to choose their preferred technology paths and timelines. Trial and error can be allowed within different regions in Europe to increase the chance of finding the optimal combination of institutions, technologies and rules. The joint investments to scale up novel technologies should be left to regional level consensus or bilateral cooperation at its initial phase when the costs and performance uncertainties are too high. A cost threshold can be set up to include novel technologies into the joint regional planning. At the same time, an important lesson for the European cross-border infrastructure investment planning is to focus on the more matured technologies with more cost uncertainties. The drastic cost reduction of selected technologies by means of large-scale deployment means that transmission network investment planning in anticipation of long-term technology development is likely to deviate from future reality and incur asset stranding risk. One way to mitigate scenario uncertainties for investments is to incorporate the cross-border renewable and grid cooperation into the National Energy and Climate Plans (NECPs) with specified renewable energy site location, capacity and timing up to 2030.

3. Externality

The form and geographical boundary for cross-border cooperation of electricity transmission may be increasingly linked with the energy supply choices and market operation in the neighbouring countries. Common pool resource is characterised by the difficulty to exclude players and may be subject to freeriding since resource is diminished for others if one uses it. The network use, if not designed properly, may be subject to a prisoner's dilemma where the individual interest may diminish the welfare of the others. In light of the increasing integration of intermittent renewable electricity, new challenges such as loop flows are on the rise. In general, there are two types of unscheduled flows: loop flow and transit flow [0]. The unscheduled flow is defined as the deviation between scheduled flow and physical flow in the host area. Loop flow is defined as the physical flow incurred in neighbouring area, stemming from internal energy transfers within one bidding zone. Transit flow is defined as the incurred flow on the host area, as a consequence from transactions between two or more bidding zones.

The flow-based market coupling takes into account the grid constraints in the auctioning by using the simplified grid architecture to approximate the relation between commercial flow and physical flow between different bidding zones. The zonal pricing implemented in the market coupling, largely neglects intrazonal transmission limits in the market clearing. The bidding zones that are mostly configured to conform with national borders make it difficult to accurately take into account the impact of domestic commercial transactions on neighbouring systems. Meanwhile, large scale integration of intermittent renewable energy sources such as wind and solar complicates the loop flow estimation. Due to the intermittency and the forecast errors of the renewable energy, the real flow deviates from power flow estimation made by the TSOs prior to market clearing according to historical patterns.

To address the externality problem, not only market design needs to be improved, but also it involves the coordination in transmission network investment. The need for coordinated expansion of interconnector is probably nowhere more visible than the case between Polish and German border. Following the Fukushima accident in 2011, Germany responded by phasing out nuclear energy and accelerating the renewable integration. This unilateral decision has a major implication on the neighbouring countries. The German energy transition has featured a stable policy framework and financial incentive to integrate renewable electricity and led to rapid growth of wind and solar capacity. The wind farms mostly located in the Northern part of the country while the load centre is in the South.

Germany and Austria have been designated as one bidding zone until very recently. Where the internal transaction takes place, for instance the transaction from North Germany to South Germany, the network constraints between North and South Germany are neglected. In the market model, it goes from North to South Germany as if there is no constraint. In reality, the unscheduled physical flow will take two parallel paths. The western path flows from northern Germany, the Netherlands, Belgium, France and south Germany, while the eastern path flows from northern Germany, Poland, Czech Republic, and Austria to southern Germany [0]. ACER report shows a significant increase of unscheduled flow in central eastern Europe from 60TWh in 2014 to 75TWh in 2015 [0]. At the same time, Poland has a weak grid in its northern western part of the country.

There are two existing interconnectors between Germany and Poland. A third interconnector has been included in the national development plan of the TSOs and the ENTSO-E Ten Year Network Development Plan (TYNDP). However, the progress of constructing a new interconnection has been very slow and results in the locked in situation. The German-Polish interconnection case shows that phase out of certain energy technology in one European country can have important impacts on its neighbouring countries. In this circumstance, current congestion management method and interconnection investment governance need careful examination to address the loop flow problem together and reduce the risk of blackouts.

> Puka and Szulecki discuss the reasons behind the slow progress in interconnection development between Germany and Poland: divergent interest between stakeholders, governance and administrative problems, trust and security perceptions [0].
>
> Firstly, from the angle of stakeholder incentives, Puka and Szulecki pointed out the difference between Polish and German TSOs. While the Polish stakeholders including the Polish TSO are deeply concerned about the loop flow problem, the German side exhibits less interests in the new interconnector construction. They argue an important reason behind the scene is that there was no punishment mechanism on the German TSO for not building the interconnector. It leads to the important question of monitoring and rule enforcement in cross-border coordination when dealing with free-riding problems. An interesting observation on German Polish interconnector development is that the energy exchanges on both sides have the incentive to increase the trade volume across borders. However, they have limited role in the infrastructure development.
>
> Secondly, the governance challenge is not limited to the difference between German and Polish legislatures in streamlining the planning and permitting procedures for transmission network. It involves the communication from highest governance level to the local community, as well as addressing the criticism from NGOs regarding the legitimacy for some network investments. A major challenge for the German energy governance is the asymmetrical perception of the costs and benefits. The perceived costs, i.e the impact on landscape, nature incur at local level while the benefits such as grid stability and renewable energy integration accrue in other places. This poses challenges to the participatory German model.
>
> Thirdly, the fundamental difference of energy security perception and insufficient trust among the two neighbouring countries contributed to the slow progress. While the German stakeholders perceive the electricity trade as economic activities, the Polish counterparts see electricity imports as a loss of energy independence that may hamper the energy security.

The loop flow problem, with its asymmetric impact, tests the effectiveness of current national based energy governance structure in dealing with externality. Following the large blackout in 2006, national TSOs established voluntary Regional Security Coordination Initiatives (RSCIs) such as CORESO and TSC. The RSCI plays an advisory role and leaves the decision making in the hands of national TSO. In 2017, these Regional Security Coordination Initiatives have been transformed to Regional Security Coordinators as a form of mandated cooperation among national TSOs by the network code. The main tasks of CORESO[1] currently involve: 1) merging the individual grid models to common grid model in 2 day ahead, day ahead and intra-day time frames; 2) coordinated security analysis that includes identifying operational risks that may violate security limit and proposing remedial actions; 3) based on common grid model, compute parameters that define the available capacity and propose improvements; 4) perform a regional review of short/medium term active power adequacy analysis based on local adequacy inputs and network capacity for cross-border exchange and produce recommendations on remedial actions; 5) identify outage incompatibility between grid assets that have a cross-border impact and propose solutions.

In the next phase of energy transition with higher share renewables, the need for strengthened regional cooperation in market and technical operation is widely recognized. Regional Operational Centre (ROC) proposed in the Clean Energy Package represents the effort to step up regional cooperation with delineated competences between ROCs and the national TSOs. In the envisioned set-up of ROCs, decision making responsibility in the market facilitation tasks and for the planning phase of system operation fall under ROC, while the real time operation responsibility lies within national TSOs [0]. Controversies around setting up regional coordination entity for short term flow management are mainly about what operational decision power to be transferred from TSO to a central entity and whether such order from regional level should be advisory or obligatory. A core question is how independent these regional entities would become. The evolution from RSC to ROC reflects a clear trend of regional operation as an interim step towards Pan-European Internal Energy Market.

The electricity system comprises market, investment, regulations and institutions. So far, the liberalization of electricity market target at European level while the infrastructure regulation and remuneration for renewable energies and remuneration for transmission network remains largely national. On the interconnection investment, different perceptions for costs and benefits of interconnection projects make the incentives asymmetry, compounded by the fact that incentives of stakeholders at national local level are not aligned for cross-border coordination. To address the externality, not only market design needs to be improved, but also involves the coordination in renewable and transmission network investment. The governance in electricity interconnection need to be based on mutual trust within a number of directly interconnected neighbour countries by long term commitment tools. A joint commitment tool can take the form of a joint asset base on interconnection investments and cross-border renewable projects. Essential for the success of a cross-border commitment tool is the careful craft of the stakeholder interactions from public and private sectors that value the interest of those who benefit or lose and feed the valuations into decision making structure in new investments.

4 Energy Security under climate policies

The EU energy triangle contains three objectives that are not mutually compatible: competitiveness, sustainability and security. There is no commonly agreed hierarchy for these objectives, given the differences of national specifics in energy mix and market development. The most irreconcilable among the three is probably energy security. To date, there is no concrete definition for energy security made by European Commission. There is no consensus about what the concept energy security entails in the academic literature. Boersma finds one element that is common in all literature for energy security discussions is sufficient availability

[1] www.coreso.eu

of affordable energy supplies. Other studies touch upon the gas infrastructure investment and market liberalization as pillars of energy security [0].
This research combines the elements from energy security discussions from major energy agencies to present different perspectives. In its energy supply security 2014 report, IEA gives a definition: uninterrupted availability of energy sources at an affordable price [0]. Under this definition, reliability and economic sustainability constitute the main criteria. IRENA has mapped two main aspects in the power shift of different countries in the world along the renewable energy transition: 1) change of fossil fuel trade flow; 2) the commercial race to be renewable technology leader [0].
With a perspective on seeking partners for strengthened cross-border cooperation to reach a decarbonised energy and transport system, the energy security variables from IRENA conceptualization is extended with the dimension of economic affordability. By examining the role of gas under climate policies, this paper directs additional attention to the transitional phase with the discussion of divergent consideration for transitional fuel. Furthermore, a narrative is constructed with case studies from Germany and Poland to show energy security implications on the regional cooperation.

4.1 Chang of fossil fuel trade flow in the sector coupling trend

Two questions embedded in the variable of change of fossil fuel trade flow are explored in the case study: 1) which fossil fuel to consider? 2) which direction of the trade flow is preferred? The case studies from Germany and Poland are chosen to illustrate the divergence in pace and preference of energy transition.

Under the European energy governance, transition path and the fuel mix are increasingly shaped by climate policies. The market based mechanism, European Emission Trading Scheme (EU ETS), sends the economic signal for market operation and low carbon investments [0]. When the transition expands towards heating and transportation, sector coupling becomes a key pillar for energy transition. The notion of sector coupling reflects different degrees of interaction between the electricity and gas sector: co-production, combined use, conversion and substitution of electricity, heat and fuels [0]. In essence, sector coupling in infrastructure investment means that differences in energy security perception in particular regarding gas import may create the momentum to identify which players are likely to move towards deeper intra-regional cooperation in the electricity sector as well.
The sector coupling concept has been translated into the joint scenario development in the pan European cross-border infrastructure planning: Ten Year Network Development Plan (TYNDP)[2]. In the 2018 TYNDP, ENTSO-E and ENTSO-G cooperated for the first time to establish joint electricity and gas scenarios. The 2018 TYNDP reflects an interesting trend to jointly the assess the use of infrastructure in electricity, gas and heating.

The role of gas and hydrogen in the transition attracts attention and generates heated discussion at the time being. An important question revolving the energy pathway in the long term is whether transitional fuel is needed. In the absence of large-scale storage technology, gas is debated as the transitional fuel for energy transition. The advocates emphasize two advantages of natural gas [0]. Firstly, to deal with the intermittency from renewable energies i.e. when the wind is not blowing or the sun is not shining, fast starting back-up thermal generations are needed to balance the system, together with other measures such as demand side management or short term network management. At the same time, gas emits around half the carbon dioxide as coal when producing the same energy, which contributes to emission reduction in the short term. The economics and rationality of transitional fuel are challenged

[2] https://tyndp.entsoe.eu/

by many. On one hand, when the transitional period comes to an end, the system needs to switch once more to renewable dominated energy mix. Due to the lock in effect and the potential technology path inertia, the late deployment of renewable energy may create the windfall for fossil fuels and postpone the time to reach the renewable future as transition fuels is likely to stay longer. On the other hand, the acceptance of gas as transitional fuel is strongly influenced by energy security perception. The different acceptance is explained in the German and Polish case studies.

a) ***Germany***

As Westphal notes, the energy policy in Germany is in general guided by market-based principle [0]. Security of supply is first and foremost the responsibility of private utilities and companies active in the market. The role of government is mainly to guarantee a stable regulatory framework that guides functioning market. The strategic position in cross-border energy trading relies on its central geographic location and persuasive power to promote energy transition in EU and globally. Since the liberalization, there are 4 electricity TSOs and a variety of players involved in the renewable energy projects. By the end of 2016, around 40 percent of the total renewable energy investments are owned by citizens. The decentralized renewable ownership gives citizens and communities the autonomy to determine their own energy system. Therefore, citizen groups are also actively involved in energy agenda setting, together with NGOs and think tanks [0].
The Fukushima accident in 2010 made a U turn for the German nuclear power. Afterwards, Energiewende has been promoted by German government as a flagship energy and economic project towards sustainable transition. So far, the German energy transition has mainly featured large scale integration of renewable electricity and the nuclear exit. The year 2022 will witness the closure of the last nuclear power plant in Germany.

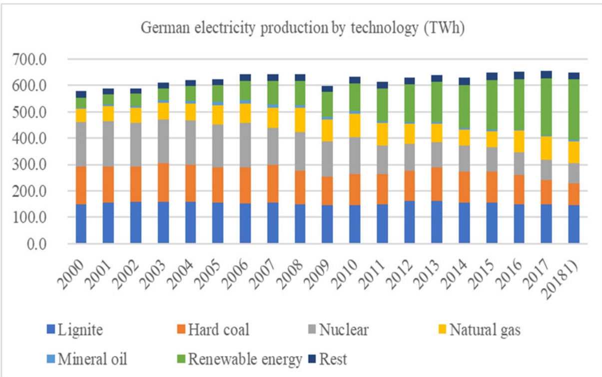

Figure 1.: **Electricity production by technology type in Germany**

Source: Own illustration based on data from AG Energiebilanzen website[3]

Due to the loophole in the EU ETS design, the renewable integration does not effectively impact the emission cap setting. After the financial crisis, the oversupply in global coal market as a result of the previous overestimation in demand brought down coal price. The combined effect of low carbon and low coal price had led a golden age for the coal fired power

[3] https://www.ag-energiebilanzen.de/

plant. Between 2000 and 2015, 7.3 GW new investment was made in hard coal fired power plant and 5.5 GW in lignite power plant. As Helm points out, the emission savings made by the renewables are counterbalanced by the additional emission from coal fired power plant [0]. The increased use of coal in German Energiewende has incurred criticism and raised pressure domestically. At the end of January in 2019, the government appointed coal exit commission announced that they had reached agreement in a deadline for the closure of coal fired power plants in Germany. As a result, stable level of natural gas demand in Germany is expected in the next decade. In 2015, the German federal office for export control abandoned the practice of counting import fuels by country [0]. The demand in Germany as the share of Russian export to Europe increased slightly from 45.2 to 48.5 percent between 2015 and 2017 [0].

b) ***Poland***

In Poland, a more statist perspective is taken for energy policy making in contrast with the market centred approach in Germany [0]. After unbundling, the largest four generation companies account for 65 percent of the total electricity production and there is one nationwide transmission system operator. The state is the majority shareholder for most power companies and the nationwide transmission system operator is owned by the treasury [0].

The Polish energy strategy is included in the national responsible development plan [0]. In this plan, energy objectives in cultivating efficient state are described as: security, availability and price [0]. Coal accounts for 80 percent of the power supply and half of the total energy supply in Poland. Energy security is tied to the notion of energy independence from the use of domestic coal. As stated in the responsible development plan, the modernization of the energy system in the Polish context may mean the modernization of coal sector. Also high in the energy agenda is safeguarding citizens and Polish industries from high energy cost [0].

The emphasize on energy security reflects the difference of perceptions in geopolitical risk and climate policies. Poland challenged the recent reform in the EU ETS to include Market Stability Reserve (MSR) in court. The Polish government argued that adjustment of auctioned allowance by MSR interferes the sovereignty of Member States to determine its energy mix and leads to significantly increased use of natural gas [0]. Figure 2 shows a clear trend and preference of reducing the gas flown from Eastern direction in three years between 2016 and 2018.

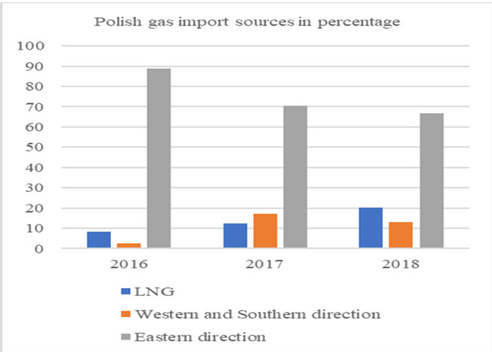

Figure 2: **Gas import by means and directions in Poland**

Source: Own illustration with data from PGNiG[4]

[4] http://en.pgnig.pl/news/-/news-list/id/pgnig-2018-another-year-of-declining-gas-import-volumes-from-russia-and-growing-lng-imports/newsGroupId/1910852

Based on the reflection that a major supply disruption may directly or indirectly affect several Member States, a regional approach is taken in the revised Gas Security of Supply Regulation [0]. The regional cooperation is encouraged within group of limited size. The defined area for joint work in regional group is regional risk assessment and preparation of emergency planning on risk mitigation. This bottom up cooperation to safeguard security of supply is not confined to gas sector in emergency situation. The mutual trust built upon such cooperation can also shape future cross-border cooperation in long term investment.

4.2 Socioeconomic factors

a) ***Affordability***

At present, there is no regulation or directive targeting at energy affordability or energy poverty problem at EU level. The measures to tackle energy poverty remain national issues [0]. Since the industrial energy price is mainly based on bilateral power purchase agreement, there is no uniform national industrial price. In this research, household energy affordability is investigated to reflect the social aspect of the energy transition.

The share of energy expenditure including electricity, gas and other fuels in the total household expenditure is used to assess energy affordability. The Eurostat data[5] used to compute energy affordability in Figure 3 exist only in five-year time span in Member States and are limited to central estimate. It is available for Germany over a longer period, for Poland available only in the year 2005, 2010 and 2015. Figure 3 shows that the proportion of household expenditure devoted to energy consumption is significantly higher in Poland than in Germany. On average, Deller shows that the new Member States that joined EU in 2004 that joined EU in 2004 spend a much higher share of their total household expenditure than the EU15 Member States to pay the energy bills [0].

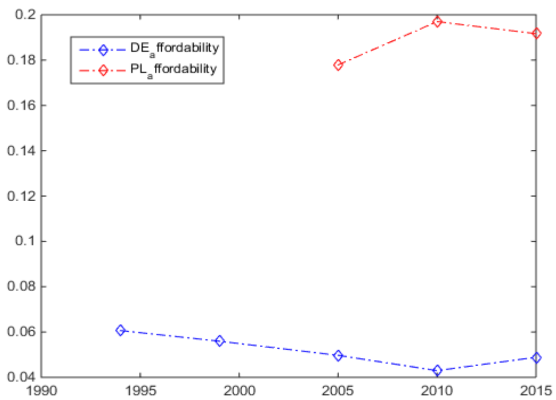

Figure 3: **Energy affordability index in Germany and Poland**

Source: Own illustration with data from Eurostat

[5] https://ec.europa.eu/eurostat/web/household-budget-surveys/database?p_p_id=NavTreeportletprod_WAR_NavTreeportletprod_INSTANCE_JvzEu7FSH6aI&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=2

In Germany, the Feed-In Tariff (FIT) scheme had been given credit to bring down financial cost and facilitate widespread renewable investment. High investment cost is partially justified domestically by the technical and business innovation. At the same time, German support scheme on renewable energies such as wind and solar has contributed significantly to the cost reduction in the global market. However, continuously rising cost to subsidize renewables raised pressure and reforms have been made to introduce competition for renewables in electricity market and auctions for renewable investments. The electricity price paid by households has increased steadily and gas prices fluctuates. German household electricity is the most expensive in Europe in 2017 that exceeds 0.3 €/KWh [0]. There is no official definition for energy poverty in Germany and it is only perceived as a minor problem. Not only the overall energy expenses as a share of household expenditures is low, but also the percentage of households not able to pay their bills on time had been lower than 5% between 2007 and 2014 [0].

According to interviews conducted by Szulecki and Kusznir, most interviewees claim that renewable energies are still perceived to be too expensive for Polish society [0]. Absent of a national definition for energy poverty in Poland, measures taken in Poland are incomplete, mainly concentrating on the tax reduction and protection of customer from energy disconnection. The highest share of households that are unable to keep house sufficiently warm concentrates in the countries that joined EU in 2004. Several reasons are identified: the eastern Member States have a common problem of poor housing stock, inefficient heating technologies based on electricity and lower income level [0]. During the COP24 hosted in Katowitz, the concept of just transition was promoted by the Polish government. The just transition is a concept of making equitable and inclusive transition towards the low carbon economy, transition that ensures job security and social protection for vulnerable sectors and households.

In light of the diversity of income differences and national specific circumstances, no common definition for energy poverty has been drawn at European level. In the Revised Gas Security of Supply, as a step towards strengthened regional cooperation, protected customers that include all household customers and the district social heating are defined for cross-border supply in emergency situation [0].

b) ***Comparison of renewable energy patents***

Innovation will play a determinant role in the pace and strategy of national based energy transition. The access to innovative technology shapes 'power shift' of countries in the future with high shares of renewable energies [0]. Not only the R&D input matters, but also the value chain that integrates research and manufacture acts as catalyst to foster innovation. Although the highest number of patents does not necessarily translate into the most innovative country, it gives a quantitative measurement to a country capacity to absorb and produce knowledge. Research shows that at country level, the absorptive capacity dictates the utilization of new knowledge. The countries that are near the knowledge frontier will be likely to continue benefiting from further knowledge advancement [0]. In this research, the number of renewable energy patents in a country is used as indicator to assess the relative position of a country in the commercial race towards renewable energy technology. According to the IRENA renewable patent database, from the year 2009 to 2013, there were 1000 renewable energy patents filed in Poland, while the total number in the same period reached 14088 in Germany. The breakdown of patented technology types and year are shown in *Figure 4* and *Figure 5*.

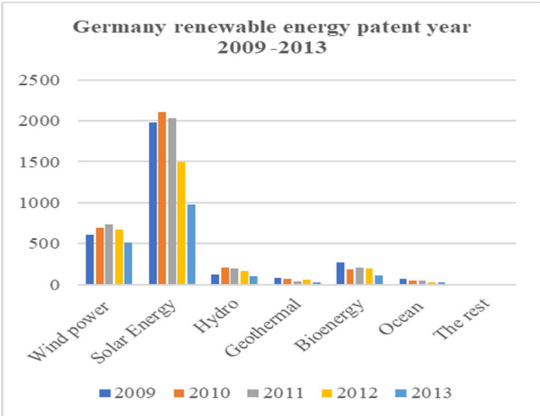

Figure. 4. **Renewable technology patents in Germany between 2009 and 2013**
Source: Own illustration based on IRENA data[6]

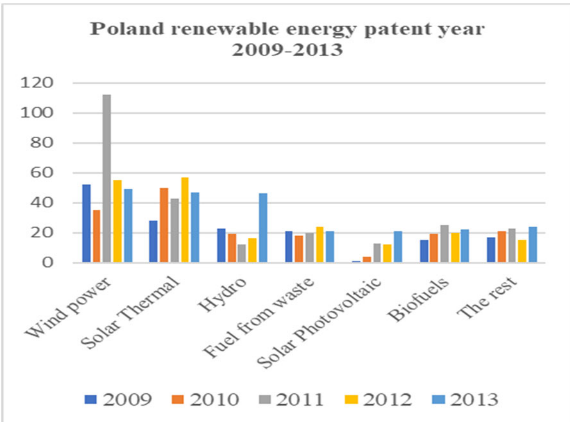

Figure 5. **Renewable technology patents in Poland between 2009 and 2013**
Source: Own illustration based on IRENA data

Accelerated decarbonization calls for emission reduction in transportation and heating sectors. Hydrogen is perceived by some as a potential fuel that interlinks the electricity, heating and transportation. By the time of writing, there are 229 hydrogen projects in Europe. However, they predominantly locate in Western European countries. Germany has 40 hydrogen projects, while there is none available in Poland[7].

Strong policy intervention can assist the novel technology to create market by:1) creating utility; 2) pricing; 3) fostering adaptation of social economic behaviour. Examples of policy led drastic cost reduction abound for renewable technologies such as wind and solar [0]. Aghion finds empirical evidence that the firm's inclination to continue innovation on clean

[6] inspire.irena.org/
[7] https://hydrogeneurope.eu/projects

technology correlates positively with their stock of clean technology patents and is strongly influenced by the country's monetary and industrial practices [0]. At country level, however, it remains an open question whether the innovation in clean technologies in the frontier countries will stimulate investments in less developed countries to develop the absorptive capacity.

For economies that have relied on fossil fuels, the initial cost to break the path dependence from the original economy model can be very high. In addition, there is system cost incurred for integrating renewables. The fact that energy transition cost in Germany is high and total amount far from clear raised concerns for some countries to follow. In the Polish context, large deployment of renewable energy source is perceived with scepticism by some in Poland as a form of dependence on technology, knowhow and materials [0]. Zenghelis argues that once the political barrier is overcome and initial high costs paid, given the positive spill over to the rest of economy of clean technologies, the positive feedback loop will kick in and changes will accelerate [0]. Countries already at the vanguard of the clean technology innovation process are more likely to accelerate easily. Consequently, different strategies and paces will be likely to emerge between Member States in adopting renewable technology, whether to subsidize in innovation or early deployment phase or to deploy in commercially competitive phase.

The case studies show that different aspects of energy security have major implications for a country to position itself in the energy transition, its preferred technology paths and timing. Coincident with the absence of national player, the competitive market is at the centre to ensure security of supply for energy transition in Germany. Fast deployment of renewables provides alternative to import energy by domestic production and is perceived as an effective long term means to improve energy security. At the same time, sector coupling, in particular the potential for hydrogen, provides an opportunity to decarbonise heating and transport from renewable electricity and to take on leading position in technology innovation. In the Polish narrative, the main policy objective is on changing direction of gas import. The high affordability index suggests that the burden for vulnerable consumers will need to be addressed carefully in the energy transition process.

5. Conclusion

The institutional approach employed in this analysis shows that the current decision-making structure in the European energy governance is not adequate to address the energy transition challenges or to foster effective cross-border cooperation. In international agreement negotiations, coalition stability can be pursued in two forms, a broad but shallow or a narrow but deep cooperation [0]. For instance, the European energy governance is applicable to actions that benefit from wide participation and thus reduce transaction costs such as market-based EU ETS. The narrow but deep cooperation can be better achieved within a few countries where the number of players is smaller and those with directly connect networks and shared energy security perceptions to cooperate with each other in the long term.
In face of scenario and technology uncertainties, adaptation on new technological strategy and market reality is faster with a smaller number of countries and stakeholders. When there is no given optimal solution for energy transition, trial and error can be allowed within different regions in Europe to increase the chance of finding the suitable combination of institutions, technologies and rules. The network externality illustrates that market coordination that has been pursued in the European Internal Electricity Market is only part of the solution. Not only improvements on market coupling mechanism is required, it is also important to coordinate on infrastructure investment across border. The narrow but deep cooperation in infrastructure

asset investment at regional level will require joint commitment tool. The divergent energy security perceptions may give incentives for countries to seek a smaller number of partners for close cross-border cooperation. The socioeconomic factors of a country are also at work depending on their: 1) capability of clean technology innovation and national strategy to take on leader or follower position on renewable technology front; 2) economic development level that has impact on consumer affordability.

The long-term scenario uncertainties imply implementation ambiguity on:1) how much to invest on different technologies; 2) where to locate network infrastructure. Given the fact that cost reduction for current renewable technologies are mainly driven by the deployment learning curve, stepping-stone policy and consensus building to spur the research and development of next generation technology should be promoted at regional level or by intergovernmental agreements. Important for the cross-border infrastructure investment planning is to focus on the more matured technologies with cost certainties. One way to mitigate scenario uncertainties for investments is to incorporate the cross-border renewable and grid investment planning into the National Energy and Climate Plans with specified renewable energy site location, capacity and timing up to 2030.

The forecast errors and intermittency of renewable energy has exacerbated the externality problem as a consequence of zonal pricing that conforms to national border. To address loop flow problem and align investment incentives for stakeholders at national and local levels across borders, the next phase of energy transition calls for improvements on market and system operation mechanism at regional level. Furthermore, the physical reality of interlinked network implies need to move towards deeper cooperation with a joint commitment tools such as a joint asset base on interconnections and cross-border renewable projects at regional level. Driven by climate policies in Europe, the trend to move towards sector coupling may change the narrative of energy security when electricity and gas sector closely interact in market operation and investment planning. This may create the momentum for a country to identify which players are likely to move towards deeper cooperation in the entire energy system.

In short, while an organic regionalization process different in pace and technology preference in the energy transition is emerging in Europe, the regional governance model that features joint commitment tool on infrastructure assets and technological strategies should be targeted to form deeply interwoven and economically efficient cross-border energy cooperation.

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THE ENERGY UNION GOVERNANCE

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Regulation (EU) 2018/1999 of 11 December 2018 shapes the architecture of the Energy Union's[1] governance by outlining its regulatory framework on the basis of two guidelines: on the one hand, the simplification and integration of planning obligations, communication and monitoring in energy and climate[2] sectors; on the other hand, the construction of a framework of rules for the comparison between Member States and the European Commission, with the involvement of other European institutions, aimed at ensuring the constant pursuit of objectives of the Energy Union as well as the long-term goals relating to greenhouse gas emissions, in line with the Paris Agreement[3].

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[1] On the issue of the Energy Union governance there are numerous essays relating its elaboration phase. Among them: L. Ammannati, The Governance of the Energy Union: An 'Intricate System' for the European Union Common Goals, at www.ogel.org; Id. Una nuova governance per la transizione energetica dell'Unione europea. Soluzioni ambigue in un contesto conflittuale, in Id. (a cured di) La transizione energetica, Torino, 2018, 3 ss.; M. Vandendriessche – A. Saz-Carranza – J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, EUI Working Paper RSCAS 2017/51; M. Duwe – N. Meyer-Ohlendorf – K. Umpfenbach, Governance of the Energy Union. Assessment of the Commission Proposal for a Governance Regulation, in Ecologic Institute, 2 February 2017; M. Ringel – M. Knodt, The governance of the European Energy Union: Efficiency, effectiveness and acceptance of the Winter Package 2016, in Energy Policy, 2018, 209 ss.; K. Szulecki – S. Fischer – A.T. Gullberg - O M. Keay – O. Sartor, Shaping the 'Energy Union': between national positions and governance innovation in EU energy and climate policy, in Climate Policy, 2016, 548 ss.; D. Buchan, Europe's Energy Union: a problem of governance, in The Oxford Institute For Energy Studies, November 2015.

[2] Already with the Communication of 25 February 2015 COM (2015) 80 final, the Commission indicated the need for an integrated governance mechanism to ensure that actions related to energy - at EU, regional, national and local level - all contributed to the achievement of the Energy Union objectives thus extending to all the five dimensions that characterize the scope of governance, beyond the 2030 framework for climate and energy.

[3] The literature on the Paris Agreement is vast. Noteworthy, without any pretense of completeness: Z. Savaşan, Paris Climate Agreement: A Deal for Better Compliance?, cit., 2019; D. Klein – M.P. Carazo – M. Doelle – J.B. Andrew (Eds) The Paris Agreement on Climate Change: Analysis and Commentary, Oxford, 2017; M. Montini, Riflessioni critiche sull'Accordo di Parigi sui cambiamenti climatici, in Rivista di diritto internazionale, 3/2017, 719 ss.; L. Aristei, L'Accordo di Parigi: obiettivi e disciplina, in RQDA n. 3/2017; J. Vinuales, The Paris Agreement on Climate Change: Less il More, in German Yearbook of International Law, 2017; A.L. Garín, Novedades del Sistema de Protección Internacional de Cambio Climático: el Acuerdo de París, in Estudios Internationales, 2017, 137 ss.; M. Gervasi, Rilievi critici sull'accordo di Parigi: le sue potenzialità e il suo ruolo nell'evoluzione dell'azione internazionale di contrasto al cambiamento climatico, in La comunità internazionale, 2016, 21 ss.; F. Romanin Jacur, L'accordo di Parigi e i passi avanti della cooperazione multilaterale sul clima, in sidiblog.org, 13 January 2016; R. Falkner, The Paris Agreement and the New Logic of International Comate Politics, in International Affairs, 92(5), September 2016, 1107 ss.; D. Bodansky, The Legal Character of the Paris Agreement, in Review of European, Comparative and International Environmental Law, vol. 25, July 2016, 142 ss.; D. Bodansky, The Paris Climate Change Agreement: A New Hope?, in The American Journal of International Law, vol. 110, 2016, 288 ss.; V. Voigt, The Compliance and Implementation Mechanism of the Paris Agreement, in Review of European, Comparative and International Environmental Law, vol. 25, luglio 2016, 161 ss.; H. van Asselt, International Climate Change Law in a Botton-Up World, in Questions of International Law, vol. 26, 2016, 5 ss.; E. Burleson, Paris Agreement and Consensus to Address Climate Challenge, in www.asil.org, 29 March 2016; S. NESPOR, La lunga marcia per un accordo globale sul clima: dal Protocollo di Kyoto all'Accordo di Parigi, in Rivista trimestrale di diritto pubblico, 2016, 81 ss..; A. Savaresi, The Paris Agreement: A New Beginning, Edimburgh School of Law Resarch Paper No 2016/08, in papers.ssrn.com and F. Scalia, L'Accordo di Parigi e i «paradossi»

As highlighted in the document that accompanied the proposal, the main objective of governance is to ensure that «*policies and measures at various levels are coherent, complementary and sufficiently ambitious*»[4].

The choice of the Commission on the legislative instrument of the regulation - mandatory in all its elements and directly applicable[5] - is indicative of the desire to govern the implementation process within legal systems of Member States of these union legislative measures on energy and climate, favoring the collaboration between countries and the coherence of interventions according to the achievement of European targets[6]. Moreover, this choice is functional to ensuring governance that allows uniforming the model of drafting national plans[7], so as to make them comparable and indicate common procedures and timing, in order to achieve the objectives of the Union[8].

The legal basis of the Regulation is Article 194 TFEU[9], marked by a close interrelation of competences between the Union and Member States, such as imposing a model of allocation of these competences that guarantees the pursuit of European objectives while fully respecting the freedom of Member States to establish their own energy mix. However, this freedom - again on the basis of article 194, par, 2 TFEU, which recalls article 192, par. 2, lett. c), on environmental matters - must be compatible with the achievement of European climate and energy objectives and with the gradual transition to a low-carbon sustainable economy[10].

The Regulation establishes a governance mechanism functional to implement strategies and measures aimed at achieving objectives and goals of the Energy Union and the long-term objectives related to greenhouse gas emissions; encouraging cooperation between Member States, including at regional level, to achieve these goals; ensuring the timeliness, transparency, accuracy, consistency, comparability and completeness of the information communicated by the Union and Member States to the Secretariat of the UNFCC Convention and of the Paris Agreement[11] and to ensure greater regulatory certainty for investors and to

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delle politiche dell'Europa su clima ed energia, in Rivista di diritto e giurisprudenza agraria, alimentare e dell'ambiente n. 6–2016 www.rivistadga.it. Inoltre, per un'analisi di diversi possibili scenari sulla base degli INDCs proposti dalle Parti, si veda H.L. van Soest – H.S. de Boer – M. Roelfsema – M.G.J. den Elzen – A. Admiraal – D.P. van Vuuren – A.F. Hof – M. van den Berg – M.J.H.M. Hamsen – D.E.H.J. Gernaat – N. Forsell, Early action on Paris Agreement allows for more time to change energy sistems, in Springer International Publishing, 2017.

[4] Cfr. COM(2016) 759 final del 30 novembre 2016.

[5] Article. 288, par. 2, TFUE.

[6] In particular, the objectives of the 2030 framework for climate and energy, in greenhouse gas emissions reduction, renewable energy sources and energy efficiency, objectives that cannot be separated, none of which can be considered secondary to others (see Recital (18) Regulation (EU) 2018/1999.

[7] On this point, see the Communication from the Commission, State of the Energy Union - Annex 2 Guidelines for Member States on national energy and climate plans in the context of the Energy Union governance, (COM (2015) 572 final), 2.

[8] This need for uniformity was underlined by the report that accompanied the proposed regulation (COM (2016) 759 final of 30 November 2016), which defines the regulation dedicated to governance «a toolbox», which allows «optimization, to simplify and increase the coherence of the various policies, giving homogeneity to the relations between the different levels of government. On this point, see L. Ammannati, Una nuova governance per la transizione energetica dell'Unione europea. Soluzioni ambigue in un contesto conflittuale, cit,, 11 ss

[9] In relation with articles 191 and 192 TFEU concerning environment.

[10]See the Recital (18) of the regulation, which indicates as limits to the national policies flexibility, beyond the objectives mentioned, also the further integration of the market and the intensification of competition.

[11] M. Vandendriessche - A. Saz-Carranza - J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit., 14-15, highlight how, on the one hand, the chronology of the obligations of Member States established by the Regulation is functional to the respect of terms prescribed to the Parties by the Paris Agreement, on the other hand, "the Energy Union's GHG inventory reporting provisions specifically geared towards UNFCCC requirements".

take full advantage of opportunities for economic development, investment promotion, job creation and social cohesion[12].

The Governance covers all five dimensions of the Energy Union, namely energy security, internal energy market, energy efficiency, decarbonisation, research, innovation and competitiveness[13], to be considered as closely related[14]. These dimensions represent, in fact, objectives that are inseparable from each other, of equal importance and find in the sectoral legislation the specific methods of implementation, improvement and monitoring. Member States should have the flexibly to choose internal policies in compliance with national preferences and their energy mix, providing - as already highlighted – that such flexibility is compatible with market integration, intensification of competition and the transition to a low-carbon economy.

The governance structure is a complex mechanism of planning, communication and monitoring, based on two pillars: the first is the national integrated plan for energy and climate, the biennial communication on state of implementation and monitoring of progress; the second is a set of communication and monitoring forecasts linked to projections of greenhouse gas emissions[15].

Indeed, the most significant innovation - in line with the Paris Agreement[16] - seems to be the requirement for Member States to define their commitments, in terms of objectives and measures, in the national and integrated plans for energy and climate with a medium-long term perspective. This determines the overcoming of sectorial planning on the subject, resulting from distinct normative acts adopted at different times, which have led to redundancy, overlaps and an insufficient consideration of synergies and interactions between various sectors of intervention and, above all, the failure of integration between energy and climate policies[17].

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[12] See Article 1, paragraph 1 of the Regulation.

[13] In line with the five dimensions of energy that the Union aims to pursue, in addition to the Regulation on governance, the EU has developed an entire "Clean Energy Package", with interventions in the field of renewable sources, energy efficiency (in particular in the buildings) and electricity markets, addressing, among others, the issue of energy poverty and promoting fair competition in the internal market. Already in the Communication on a framework strategy for a resilient Energy Union, accompanied by a forward-looking climate change policy of 25 February 2015, the Commission referred to the need for an integrated governance mechanism to ensure that related actions to energy - at Union, regional, national and local level - they all contribute to achieving the objectives of the Energy Union, thus extending to all the five dimensions that characterize the scope of governance, beyond the 2030 framework for climate and energy.

[14] Already the Communication on the Energy Union - COM (2015) 80 final - defined the five dimensions "closely interconnected and mutually reinforcing, aimed at improving the security, sustainability and competitiveness of energy supply".

[15] Thus L. Ammannati Una nuova governance per la transizione energetica dell'Unione europea. Soluzioni ambigue in un contesto conflittuale, cit,, 13.

[16] M. Vandendriessche - A. Saz-Carranza - J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit., 7, observe that the integrated energy and climate plans « [i]n a way, they are comparable to the (Intended) Nationally Determined Contribution ((I) NDCs) in the UNFCCC's Paris process, in that they are plans designed and submitted by individual member states in fulfillment of a collective goal, in a bottom-up type process. However, the NECPs differ from the (I)NDCs in that they cover far more policy ground and in that the requirements in terms of their content and the procedure to develop them are more precisely defined»..

[17]See recital (24). The Communication COM (2019) 570 final, which accompanied the proposal, highlighted how «[g] the current obligations of planning and communication (both for the Commission and for Member States) in the energy and climate sectors offer advantages in terms of detailed information on specific areas of intervention and encourage the implementation of sectoral legislation. However, these obligations are contained in a wide range of distinct legislative acts adopted at different times, which has given rise to redundancy, inconsistency and overlap, as well as the lack of integration between energy and climate policies. Furthermore, some of the current obligations have been defined in consideration of the achievement of the corresponding objectives set for 2020 and therefore do not lend themselves to favoring

The “integrated national energy and climate plans” are ten-year planning documents, detailed in their structure by article 3 and by annex 1 of the Regulation[18] to guarantee the uniformity. They must provide a picture of the current[19] energy system and planning framework, with projections in the decade under current legislation, establishing national objectives for each of the five dimensions of the Energy Union[20] as well as policies and measures aimed at achieving them, respecting their mutual interrelations and the principle “energy efficiency first” [21]. They also describe the impact of measures envisaged, for the duration of the plan, on the development of the energy system, of greenhouse gas emissions and of absorption, from a macroeconomic point of view and, to the extent possible for health and environment[22].

The plans also provide a general overview of the investments needed to achieve the set goals, as well as an assessment of sources of such investments.

Plans should pay particular attention to energy poverty[23], taking into account all relevant policies and the level of household energy services needed to guarantee a basic standard of living in the respective national context[24].

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the realization of the 2030 framework for energy and climate, nor are they synchronized with the obligations regarding planning and communication required by the Paris agreement”.

[18] According to the article. 3, par. 2, the plans must contain: an overview of the procedure followed for their adoption, with a summary and a description of the public consultation and involvement of stakeholders and their results, and of regional cooperation with other Member States in preparing the plan; a general overview of the investment needed to meet the corresponding objectives, targets and contributions; a description of the current situation of the five dimensions of the Energy Union, including with regard to the energy system and greenhouse gas emissions and removals as well as projections with regard to the objectives with already existing policies and measures; an assessment of the impacts of the planned policies and measures to meet the objectives referred to in point (b), including their consistency with the long-term greenhouse gas emission reduction objectives under the Paris Agreement and the long-term strategies as referred to in Article 15,

as well as a general assessment of the impacts of the planned policies and measures on competitiveness linked to the five dimensions of the Energy Union; an annex defining the methodologies and measures to be applied by the Member State to achieve the expected energy saving obligations, drafted in compliance with the requirements set out in Annex III of the Regulation.

[19] Article. 8 states that Member States shall describe the current situation for each of the five dimensions of the Energy Union

[20] Consistent with the objectives set by European legislation: for the «decarbonisation» dimension the regulations (EU) 841 and 842 of 2018; for “renewable energy”, the binding target of the EU at 2030 of at least 32% of its share in the energy mix set by Directive (EU) 2018/2001; for “energy efficiency”, the equally binding target of the EU at 2030 of at least 32.5% set by Directive 2018/2002/EU and the objectives for long-term restructuring of the national residential buildings and non-residential, public and private, set by directive 2018/844/EU; for “energy security”, the objective of increasing the diversification of energy sources of the related supplies from third countries, with a view to reducing dependence on energy imports, increasing the flexibility of the national energy system and addressing limitations or interruptions supply, with a view to increasing the resilience of regional and national energy systems; for the “internal energy market”, the minimum goal of 15% interconnection by 2030; increasing the flexibility of the system, integration and coupling of markets, in order to increase the exchangeable capacity of existing interconnections, smart grids, aggregation, demand management, storage, distributed generation, the dispatching, redispatching and production reduction mechanisms, as well as real-time price signals; for the “research, innovation and competitiveness” dimension.

[21]The definition of the principle of energy efficiency first is given by Article 2 “Definitions” of the Regulation: “means taking utmost account in energy planning, and in policy and investment decisions, of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient, in particular by means of cost-effective end-use energy savings, demand response initiatives and more efficient conversion, transmission and distribution of energy, whilst still achieving the objectives of those decisions “.

[22] This is foreseen in Article 8, paragraph 2 of the Regulation.

[23] According to the Climate Action Tracker between 50 and 125 million of European citizens are in conditions of energy poverty. See, Scaling up climate action European Union of 6 December 2018 at

Each Member State notifies the Commission of its integrated national energy and climate plan by 31 December 2019, subsequently by 1 January 2029 and always to follow every ten years[25]. Since this is a program that affects environmental protection, the regulation requires public consultation[26] on the proposal and making available to the public the plan presented to the Commission[27], in compliance with Directive 2001/42/EC, concerning the assessment of effects on plans and environmental programs, and the Århus Convention[28].

Regional cooperation between Member States for the drafting of integrated national energy and climate plans[29] implies the consultation (at least) [30] between neighboring States and may involve, on a voluntary basis, the joint definition of parts of the integrated national plans, for aspects of common interest to several States[31]. But States should, in drafting their plans, also consider existing regional[32] cooperation forums and cooperate with signatories to the Energy Community, with third countries that are members of the European Economic Area and, as appropriate, with other relevant third countries.

https://climateactiontracker.org. More generally on energy poverty, see A. Maestroni, Povertà energetica e strumenti di tutela: solidarietà e fratellanza, in E. Bruti Liberati – M. De Focatiis – A. Travi, Esperienze regolatorie europee a confronto nel settore dell'energia – Atti del convegno AIDEN Milano, 3 dicembre 2015, Milanofiori Assago, 2017. The author, criticizing the recent habit of the Italian Legislator to use the English language to adequately describe phenomena (and sometimes better) definable with the Italian language, distinguishes in the category of energy poverty or fuel poverty (both expressions used to indicate energy poverty, although in English law they identify different situations, the second referring to the lack of fuel for heating) the "energy poverty", as a flaw of means to be allocated to heating or electric costs, and the "energy misery", defined as above. Well, according to a study conducted in 2015 for the Bank of Italy, in Italy there would be 2,065,063 families in conditions of energy poverty: connected to the network, but in conditions of being eligible to access the social bonus as "vulnerable customers".

[24] Member States, as foreseen in Article 3, paragraph 3, if they encounter the presence of a high number of families in energy poverty, outline in their integrated national plans for energy and climate policies and appropriate measures to address it.

[25] Paragraph 1 of Article 3 of the Regulation clarifies that "the first plan shall cover the period from 2021 to 2030, taking into account the longer term perspective. The subsequent plans shall cover the ten-year period immediately following the end of the period covered by the previous plan ".

[26] According to the art. 11 of the Regulation, Member States establish a permanent multi-level dialogue on energy that brings together local authorities, civil society organizations, entrepreneurs and all other interested parties; this dialogue is at the basis of the elaboration of the individual integrated national energy and climate plans.

[27] Member States must attach to the integrated national plans notified to the Commission a summary of the comments from the public or of the provisional observations and that guarantee the periodic information to the public, so that it participates in and expresses its views, as provided for in Article 10.

[28] Convention of the United Nations Economic Commission for Europe (UNECE) on access to information, public participation in decision-making processes and access to justice in environmental matters.

[29] Provided by Article 12, which says that Member States cooperate with each other, taking into account all existing and potential forms of regional cooperation, to effectively achieve the objectives, goals and contributions defined in their respective plans. Article 42, on the other hand, governs cooperation between Member States and the Union.

[30] If the Member State issuing the plan considers it appropriate, it may also consult other Member States or third countries that have expressed an interest.

[31] At the request of two or more Member States, the Commission facilitates this exercise, pursuant to Article 12 (3).

[32] Such as: the Baltic energy market interconnection plan (BEMIP), the interconnection in central and south-eastern Europe (CESEC), the energy market of the central western region (CWREM), the offshore network initiative of the countries of the seas of north (NSCOGI), the Pentalateral Energy Forum, interconnections for south-western Europe and the Euro-Mediterranean partnership).

The process of drafting integrated national plans is long and complex to the point that, the Regulation imposes to member States to send the draft versions by the end of the year 2019 preceding that of their adoption[33].
The Commission receives the proposals for integrated national plans from Member States, evaluates them and if necessary - within six months of the deadline for their presentation in the final version - makes recommendations concerning, in particular, the level of ambition of objectives, goals and contributions aimed at the collective achievement of objectives of the Energy Union, policies and measures in relation to objectives both at the level of each State and of the Union and other policies and measures of cross-border importance, any additional policies and measures that may prove to be necessary in the national plans and, finally, interactions and the coherence between the policies and measures in force and those foreseen included in the national integrated plan for energy and climate within a single dimension and among different dimensions of the Union of energy[34]. Member States must take due account of Commission' recommendations in the final version of their integrated national energy and climate plans, to such an extent that if they decide to deviate from them they are obliged to justify their decision by publishing the motivation[35].
The integrated plans, due to their ten-year perspective, are subject to updating procedures within a defined time frame[36]. The updating of plans must represent an increase in ambition compared to what has already been defined[37] in analogy with the ratcheting mechanism outlined by the Paris Agreement[38].

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[33] Article 9 par. 1: "By 31 December 2018, and subsequently by 1 January 2028 and every ten years thereafter, each Member State shall prepare and submit to the Commission a draft of the integrated national energy and climate plan in accordance with Article 3(1) and Annex I."
[34] Article 9, par. 2. The rule is difficult to coordinate with the following article. 31, which states that if, on the basis of its assessment of the draft integrated national energy and climate plans or assessment of the draft updates of the final plans as part of the iterative process, the Commission concludes that the objectives, targets and contributions of the Member States are insufficient for the collective achievement of the Energy Union objectives and in particular, for the first ten-year period, for the Union's binding 2030 target for renewable energy and the Union's 2030 target for energy efficiency, it shall — as regards the Union's target for renewable energy — and may — as regards the other Energy Union objectives — issue recommendations to Member States whose contributions it deems insufficient to increase their ambition in order to ensure a sufficient level of collective ambition. It must be assumed that the mere faculty to formulate recommendations for objectives other than that relating to renewable energy concerns exclusively the proposals for updating the plans, applying the most rigorous provision of the article 9 for the proposed plan. And in any case, is useful to highlight the unfortunate formulation of the article 31, according to the letter of which, only the EU 2030 objective in the field of renewable energy, not even that related to energy efficiency, would be binding.
[35] Article. 9, par. 4.
[36] Pursuant to Article 14, paragraph 1 of the Regulation, By 30 June 2023, and subsequently by 1 January 2033 and every 10 years thereafter, each Member State shall submit to the Commission a draft update of the latest notified integrated national energy and climate plan or shall provide the Commission with reasons justifying why the plan does not require updating . The update proposal is followed, according to the provisions of paragraph 2 below, the presentation to the Commission of the definitive updating of the plans by Member States by June 30, 2024, then by January 1, 2034 and subsequently every 10 years, unless have motivated the Commission that the plan does not need updating.
[37] Pursuant to Article 14, paragraphs 3, 4 and 5.
[38] In fact, the agreement is not limited in accepting the unilateral commitments of the individual States, but takes them into an international system characterized by transparency and accountability, guaranteed by binding procedural rules, which leads to the periodic upward updating (ratcheting mechanism) of objectives. See on the point D. Bodansky, The Paris Climate Change Agreement: A New Hope?, 323: «Since parties' NDCs are not legally binding, the Paris Agreement's transparency framework is the main mechanism to hold states accountable for doing what they say.». Sul ruolo cruciale di un sistema di credibile ed effettiva trasparenza si veda H.D. Jacoby – Y.H Henry Chen – B.P. Flannery, Trasparency in the Paris Agreement, Report 308 February 2017 del MIT Joint Program on the Science and Policy of

The integrated energy and climate plan is not the only programming tool envisaged by the new energy governance, as the regulation requires Commission and Member States to also adopt a thirty-year horizon plan: the so called long term strategy[39].
The tools of the new governance - in addition to the described planning and programming acts - include means of communication and monitoring of policies and objectives pursued, such as integrated national interim reports on energy and climate, the report on the state of the Union of energy[40] and a complex system of "communications", including those relating to energy efficiency[41].
In particular, by 15 March 2023 and every two years thereafter, each Member State shall notify the Commission of the state of implementation of its integrated national plan through interim reports concerning all five dimensions of the Energy Union[42]. With regard to energy efficiency, Member States must provide information with these reports regarding the implementation of trajectories outline in the plans[43] and of the planned policies and measures[44].

Global Change, in core.ac.uk. e H. van Asselt – P. Pauw – H Sælen, Assessment and Review under a 2015 Climate Change Agreement, Nordic Council of Ministers, Copenhagen K, 2015.

[39]According to the provisions of Article 15, paragraph 1: "By 1 January 2020, and subsequently by 1 January 2029 and every 10 years thereafter, each Member State shall prepare and submit to the Commission its long-term strategy with a perspective of at least 30 years. Member States should, where necessary, update those strategies every five years ". Paragraph 2 also states that the Commission shall, by 1 April 2019, adopt a proposal for a Union long-term strategy for greenhouse gas emissions reduction in accordance with the Paris Agreement, taking into account the Member States' draft integrated national energy and climate plans, paying particular attention to the scenario given by the net zero greenhouse gas emissions within the Union by 2050 and negative emissions and the consequent implications on the budget of the global carbon.

[40] The detailed time schedule of the report is contained in Article 35 of the Regulation.

[41] As provided for in very detailed articles 18 - 25 of the Regulation, the system includes: integrated communications on policies and measures relating to greenhouse gases and projections, communications of national adaptation actions, financial and technological support provided to developing countries and the use of proceeds from auctioning, integrated communications related to renewable energy, communications on energy efficiency and those on energy security, communications on the internal energy market, those on poverty energy and those on research, innovation and competitiveness. Added to the "communications" are the annual reports requested from the Member States by 15 March 2021, pursuant to Article 26, and the reports on the 2020 objectives, to be presented by 30 April 2022 by each Member State in line with article 27.

[42] According to the art. 17, par. 2, the integrated national energy and climate progress report shall cover the following elements: a) information on the progress accomplished towards reaching the objectives, targets and contributions set out in the integrated national energy and climate plan, and towards financing and implementing the policies and measures necessary to meet them, including a review of actual investment against initial investment assumptions, b) where applicable, information on the progress in establishing the dialogue referred to in Article 11; c) the information referred to in Articles 20 to 25 and, where appropriate, updates on policies and measures, in accordance with those articles; d) information on adaptation in accordance with point (a)(1) of Article 4; e) as far as possible quantification of the impact of the policies and measures in the integrated national energy and climate plan on air quality and on emissions of air pollutants.

[43] Specifically, pursuant to art. 21, par. 1, lett. a): 1) the indicative trajectory for primary and final annual energy consumption from 2021 to 2030 as the national energy savings contribution to achieving the Union-level 2030 target, including the underlying methodology; 2) the indicative milestones of the long-term strategy for the renovation of the national stock of residential and non-residential buildings, both public and private, and the contributions to the Union's energy efficiency targets pursuant to Directive 2012/27/EU in accordance with Article 2a of Directive 2010/31/EU; 3) where applicable, an update of other national objectives set out in the national plan.

[44] According to the article 21, par. 1, let. b): 1) implemented, adopted and planned policies, measures and programmes to achieve the indicative national energy efficiency contribution for 2030 as well as other objectives referred to in Article 6, including planned measures and instruments (also of a financial nature)

The Regulation provides for a double proof of objectives and measures: both at national level (verification for each country) and at European level (assessment of the countries' aggregate commitment).
By October 31, 2021 and every two years thereafter, the Commission, on the basis of the interim reports and communications received from States, evaluates the progress of both at EU level and that of each individual Member State together with the overall impact of measures adopted by Countries in the five dimensions of energy[45], with different parameters in sectors of renewable energy[46], energy efficiency[47] and the internal energy market[48].
The Commission, if based on the evaluation of the national plans and the respective updates, reaches the conclusion that objectives, targets, contributions included in them are insufficient to collectively achieve the goals of the Energy Union[49] "proposes measures and exercises its powers at a Union level" in order to ensure the collective achievement of these objectives[50]. If, on the other hand, the judgment of inadequacy concerns the progress made by individual Member States, subject to a two-year evaluation, pursuant to article 29 of the Regulation, the Commission makes recommendations to them. If, on the basis of the aggregated evaluation of the national interim reports, the Commission concludes that there is a risk of not achieving the Energy Union goals, in addition to make recommendations to all[51] Member States, proposes

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to promote the energy performance of buildings, measures to utilize energy efficiency potentials of gas and electricity infrastructure and other measures to promote energy efficiency; 2) where applicable, market-based instruments that incentivize energy efficiency improvements, including but not limited to energy taxes, levies and allowances; 3) national energy efficiency obligation scheme and alternative measures pursuant to Article 7a and 7b of Directive 2012/27/EU and in accordance with Annex III to this Regulation; 4)long-term renovation strategies in accordance with Article 2a of Directive 2010/31/EU; 5) policy and measures to promote energy services in the public sector and measures to remove regulatory and non-regulatory barriers that impede the uptake of energy performance contracting and other energy efficiency service models; 6) regional cooperation in the area of energy efficiency, where applicable; 7) without prejudice to Articles 107 and 108 TFEU, financing measures, including Union support and the use of Union funds, in the area of energy efficiency at national level, where applicable.

[45] Article 29 of the Regulation, in paragraph 1, identifies the specific areas of evaluation taken into consideration by the Commission, concerning: progress made at the Union level relative to the goals set for 2030, progress made by individual States, the global repercussions of the world air transport sector, including those due to emissions or effects of substances other than CO_2, the overall impact of integrated national energy and climate policy on the functioning of EU climate and energy policy measures , the overall impact of the policies included in the integrated national plans on the functioning of the EU emission allowance trading system and on the balance between demand and supply of allowances in the European carbon market.

[46] Article 29 paragraph 2 provides that in the area of renewable energy, as part of its assessment referred to in paragraph 1, the Commission shall assess the progress made in the share of energy from renewable sources in the Union's gross final consumption on the basis of an indicative Union trajectory that starts from 20 % in 2020, reaches reference points of at least 18 % in 2022, 43 % in 2025 and 65 % in 2027 of the total increase in the share of energy from renewable sources between the Union's 2020 renewable energy target and the Union's 2030 renewable energy target, and reaches the Union's 2030 renewable energy target of at least 32 % in 2030.

[47] In the field of energy efficiency, pursuant to paragraph 3 of Article 29, the Commission shall assess progress towards collectively achieving a maximum energy consumption at Union level of 1 273 Mtoe of primary energy and 956 Mtoe of final energy in 2030 examining whether has been achieved the maximum EU thresholds set in 2020 and assessing whether the progress of Member States is consistent with the Union's objective.

[48] The Commission assesses the progress made in achieving the level of electrical interconnectivity that Member State intends to achieve in 2030, as required by paragraph 4 of the aforementioned Article 29.

[49] In particular, in the first decade, to achieve the Union's 2030 targets on renewable energy and energy efficiency.

[50] Article. 31, par. 3.

[51] Article. 32, par. 1.

measures and exercises its own powers at Union level to ensure the achievement of the 2030 goals on the renewable energy and energy efficiency fronts[52], being able in this last sector to also propose additional measures with respect to those envisaged by the relevant directives (2010/31/EU and 2012/27/EU) in order to guarantee the achievement of the target set for 2030[53]. The regulation also rules a particular monitoring regime with reference to greenhouse gas emissions and absorption from sinks[54].

In its complex activity, the Commission is assisted by the European Environment Agency, the Climate Change Committee and the Energy Union Committee[55]. The first one assists the Commission in activities carried out for the decarbonisation and energy efficiency[56] dimensions. The Committee on Climate Change[57] intervenes in relation to the execution in the areas of structure, format and procedures for the transmission of some information required by the Regulation[58] and for the definition of timing and procedure for the complete revision of national stocktakes on the final greenhouse gas data, transmitted by the Member States each year to the Secretariat of the UNFCC Convention, and to ensure consultation of the same with respect to conclusions of the revisions[59].

The Energy Union Committee, on the other hand, assists the Commission in the adoption of implementing acts to define the structure, format, technical specifications and procedure of the information contained in the biennial[60] intermediate national reports and to define necessary

[52] Article. 32, par. 2. In the field of energy efficiency, additional measures may relate, in particular to products, in accordance with Directive 2009/125 / EC and Regulation (EU) 2017/1369, buildings, in accordance with Directives 2010/31/EU and 2012/27/EU and transport (see article 32, paragraph 2, letters a), b) and c).

[53] See art. 32, par. 3. In the area of renewable energy the additional measures are implemented within one year following the date of reception of the Commission's assessment in order to cover the gap compared to their national reference point, such as: a) national measures to increase deployment of renewable energy; b) adjusting the share of renewable energy in the heating and cooling sector set out in Article 23(1) of Directive (EU) 2018/2001; c) adjusting the share of renewable energy in the transport sector set out in Article 25(1) of Directive (EU) 2018/2001; d) making a voluntary financial payment to the Union renewable energy financing mechanism set up at Union level, contributing to renewable energy projects and managed directly or indirectly by the Commission as set out in Article 33; e) using cooperation mechanisms set out in Directive (EU) 2018/2001.

[54]According to very detailed provisions of articles 37 and 38 of the Regulation.

[55] The first Committee assists the Commission mainly in areas of communications and inventory management, the second in the areas of adopting implementing acts following the evaluation of the national intermediate reports on energy and climate, as provided for by the Article 44.

[56] Article. 42, par. 1.

[57] This replaces the one established pursuant to article. 26 of the regulation (EU) n. 525/2013, governing the mechanism for monitoring and communicating greenhouse gas emissions and for communicating other information on climate change.

[58] The information communicated by the Member States concerning national adaptation actions, the financial and technological support provided to developing countries and the use of revenues from the auctioning of allowances, in line with article 19, par. 5; emissions greenhouse gas stocktake laid down by article 26, par. 2 and 3, and removals of greenhouse gases accounted for in accordance with Articles 5 and 14 of Regulation (EU) 2018/841, pursuant to article 26 par. 7 (the text in Italian of the regulation erroneously on the point indicates the “energy union committee referred to in article 44, paragraph 1, letter a)”, while the text in English indicates the “Climate Change Committee”); information on national inventory systems and the requirements concerning the establishment, management and operation of national inventory systems, pursuant to art. 37 paragraph 6; information on national and EU policy regimes, measures and projections regarding anthropogenic emissions by source and the absorption of greenhouse gas wells, pursuant to Article 39, par. 3.

[59] According to the Article. 38, par. 3.

[60] Article 17, par. 4.

provisions for the establishment and functioning of the Union financing mechanism for renewable energy[61].

Finally, article 45 of the Regulation contemplates the political phase of the complex governance procedural structure - the so called review - providing that within six months of each overall budget referred to in Article 14 of the Paris Agreement, the Commission shall present a report to the European Parliament and the Council on the application of the Regulation, on its contribution to the Energy Union governance, on its contribution to the long-term objectives of the Paris agreement, on the progress made towards achieving the goals set for 2030 on the subject of climate and energy and on additional objectives of the Energy Union as well as on the compliance with provisions on planning, communication and monitoring of the regulation to Union law or decisions relating to the UNFCC and the Paris Agreement. Reports of the Commission, which, as seen, include the entire spectrum of Union actions on energy and climate, can be accompanied by legislative proposals, evidently functional to adapt the European legal system to needs highlighted by the process of implementation of the approved plans and communication and monitoring activities.

Follows: Compliance system outlined by the Regulation.

As seen, the Commission has several opportunities to intervene in case it finds that programming of individual Member States or its implementation puts at risk the achievement of union's objectives in the five dimensions, with particular attention to those of renewable energy and energy efficiency. The Commission intervenes in the evaluation phase of individual plans proposals and the related updates, making specific recommendations for each Member State[62]; it also makes specific recommendations in the context of the European Semester[63] which Countries must take into account in formulating updates immediately following their plans[64]; when assessing national plans and their respective updates[65], proposes measures and exercises its powers at Union level in order to ensure the collective achievement of the Energy Union objectives; formulates recommendations in the assessment of Member States' two-year interim reports[66], i.e. exercises its powers at Union level and, also proposes specific additional measures to ensure achievement of the 2030 targets on renewable energy and energy efficiency[67].

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[61] Foreseen and regulated in Art. 33.

[62] Article. 9, par. 2 e 31, par. 1.

[63] This is a cycle of coordination of economic and budgetary policies within the EU which is concentrated in the first six months of the year, during which Member States align their economic and budgetary policies with the agreed objectives and standards at the Union level. The progress of the Member States in the renewable energy and energy efficiency sectors with reference to the targets set for 2020 was also (and still is) monitored in the framework of the European Semester. For the 2030 objectives, the soil of the European Semester will change, focusing on issues of macroeconomic and structural reform, while the governance of the Energy Union will focus on the energy issue and climate change. However, the Commission may make climate and energy recommendations in both systems as they are "where energy and climate specific policy issues are relevant for macroeconomic or structural reforms, they could still be addressed by the Country Specific Recommendations in the European Semester Process" (European Commission, New Energy Union governance to deliver common goals, 30 November 2016, in ec.europa.eu).

[64] Article. 14, par. 5.

[65] Article. 31, par. 3.

[66] Article. 32, par. 1.

[67] Article. 32, par. 2, 3 e 6.

Therefore, the compliance system is based on "recommendations" of the Commission to Member States and on, not well defined, "measures" and "powers" that Commission proposes and exercises at Union's level[68].
Well, "recommendations" are, pursuant to article 288, par. 5, TFEU, non-binding legal acts and the Regulation does not clarify what happens if a State decides not to be in line with them[69], limiting itself in providing that they are immediately made available by the Commission and that the recipient takes them into due account[70] in a spirit of solidarity with other Member States and the Union specifying, in the national interim report drafted in the following year, how it has adapted them or motivating its decision of no-compliance.
The absence of binding national objectives, the nature of the legal instrument identified by the Regulation for the dialogue between the Commission and Member States and the vagueness of measures that the Commission could adopt to bring Member States back to pursuing the union objective, are the main reasons for criticisms raised in doctrine to the governance of the Energy Union[71].
On this point we can grasp a similarity with the doctrine divisions on effectiveness degree of the Paris agreement[72]. The paradigm shift with respect to the top down approach, proper to the Kyoto Protocol, with binding objectives, negotiated at international level, fixed within the treaty itself and supervised by a compliance system is in fact, subject of conflicting judgments. Against those who point out the recommended character of measures and the wide margin of discretion granted to the Parties in the determination of their contributions, as a weakness of the agreement, expressing perplexity about effectiveness of mechanisms for controlling the implementation of commitments[73] and of those who refer to lights and shadows[74], another part

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[68] M. Vandendriessche – A. Saz-Carranza – J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit, 7, observe that these measures, not better described "effectively keeping the door for a range of policy options".
[69] See. M. Duwe - N. Meyer, - K. Umpfenbach, Governance of the Energy Union. Assessment of the Commission Proposal for a Governance Regulation, 2017, in www.ecologic.eu/de.
[70] In the proposal Regulation of the Commission was referring to an "utmost consideration" ("Member States shall take utmost account of any recommendations from the Commission"). The attenuation of the term in the final text ("due accounts") seems to be read as an underlining of the merely recommended character of the instrument.
[71] See, in addition to last cit., L. Ammannati, Una nuova governance per la transizione energetica dell'Unione europea. Soluzioni ambigue in un contesto conflittuale, cit., spec. 16-18; Id. The Governance of the Energy Union: An 'Intricate System' Unable to Achieve the European Union Common Goals, cit.; M. Vandendriessche – A. Saz-Carranza – J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit.. More articulated is the judgment of M. Ringel – M. Knodt, The governance of the European Energy Union: Efficiency, effectiveness and acceptance of the Winter Package 2016, cit., 219, even they agree on «the soft governance modes are not expected to deliver high compliance», note, on the other hand, that «the Commission has inserted a strong tool into the regulation to ensure the effective use of soft coordination. Its "blank check" to go directly for additional legislation at European level that the Commission inserted in the event of insufficient ambition on the part of Member States seems to be harder tool than those used in other OMC applications».
[72] Take the similarity M. Vandendriessche – A. Saz-Carranza – J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit observing that «[t]he unique and idiosyncratic project of governance of the Energy Union is mainly a response to the 2030 renewables and energy efficiency targets which are not nationally binding. In this way, the new proposed governance model resembles the design of the Paris Agreement mechanisms to some degree».
[73] M. Gervasi, Rilievi critici sull'accordo di Parigi: le sue potenzialità e il suo ruolo nell'evoluzione dell'azione internazionale di contrasto al cambiamento climatico, spec. 42-46; H. van Asselt, International Climate Change Law in a Botton-Up World, in Questions of International Law, cit,, 8-11; R. Falk, Voluntary International Law and the Paris Agreement, in https://richardfalk.wordpress.com e A.M. Slaughter, The Paris Approach to Global Governance, Project Syndicate, 28 December 2015, in https://scholar.princeton.edu e in www.project-syndicate.org. According to the last writer, former

of doctrine suspends the judgment[75] believing that the new approach may represent the reason for the possible success, as well as the "Achilles heel" of the agreement[76].
Also the Energy Union governance requires a paradigm shift: from national binding targets - although only for renewable energy - to voluntary contributions outlined in the integrated plans aiming at reaching union binding objectives - in a constant dialogue and in an iterative process between the Commission and Member States[77].
Regarding tools of the Energy Union governance, perplexities of the doctrine have focused in particular on the degree of effectiveness of recommendations, due to the non-exciting results of specific recommendations to Member States (Country Specific Recommendations) formulated in the European Semester[78]. This, since the Regulation does not foresee particular consequences for States that disregard recommendations of the Commission[79], except for the duty to motivate in their subsequent interim reports - in a time frame that can reach up to two years,[80] - so reasoning their decision.

President of American Society of International Law, Paris Agreement is "essentially a statement of good intentions".

[74] M. Montini, Riflessioni critiche sull'accordo di Parigi sui cambiamenti climatici, cit., 720 e 750-752. For the Author the positive elements are represented by the factual overcoming (if not of law) of the rigid distinction between Countries of Annex I of the Framework Convention and those not included in the Annex and by the establishment of a regulatory framework of duration potentially infinite, since it provides for a periodic review system. The negative elements, on the other hand, are represented by the fact that the achievement of the general objective is entrusted to the respect of national contributions determined by the contracting parties on a completely voluntary basis and by the lack of an effective system of monitoring and verification of compliance with the obligations to be met by the parties. Furthermore, according to the Author, although it is characterized by lights and shadows, the Paris Agreement must be assessed as a tool potentially capable of meeting the challenge of climate change in the coming decades, within the framework of a common will of the parties, but respecting their respective circumstances and needs.

[75] D. Bodansky, The legal character of the Paris agreement, cit., 150: «One cannot definitively say how much the legally binding character of the Paris agreement and its various provisions matters. Making a provision legally binding may provide a greater signal of commitment and greater assurance of compliance. But transparency, accountability and precision can make a significant difference, and legal bindingness can be a double-edged sword, if it leads States not to participate or to make less ambitious commitments. Thus, the issue of legal character, tough important, is only one factor in assessing the significance of the Paris outcome».

[76] J.E. Viñuales, El Acuerdo de París sobre cambio climático y su talón Sino-Americano, cit.: «Se ha redistribuido el esfuerzo en materia de lucha contra el cambio climático entre todos los países, incluyéndose a las grandes economías emergentes. Pero no es ed Acuerdo de París el que efectúa la parte esencial de dicha redistribución; de modo mas modesto, el Acuerdo se limita a organizar los compromisos que los Estados decidan asumir unilateralmente a nivel nacional. Es esa la gran ventaja del Acuerdo del París, así como su talón de Aquiles».

[77] M. Vandendriessche – A. Saz-Carranza – J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit., 18 but they note that « [a] key difference with Paris is that the Energy Union governance will require states to report on their plans through detailed templates, and that the Commission can take measures (some stronger than others) in case it sees the collective goal will not be met».

[78] C. Adolf - J. Nix, observe in The effectiveness of the European semester from a governance perspective, 2016, in green.budget.eu, that none of the specific recommendations, related to energy and climate, formulated by the Commission on the occasion of the European Semesters of the 2012-2014 period was completely implemented by the recipient States: only some progress was made in 53% of cases, none in the remaining 43%.

[79]See M. Duwe - N. Ohlendorf - K. Umpfenbach, Governance of the Energy Union. Assessment of the Commission Proposal for a Governance Regulation, 2 February 2017, in ecologic.eu, and the solutions suggested therein ensuring greater effectiveness of the recommendations.

[80] M. Duwe - N. Ohlendorf - K. Umpfenbach, Governance of the Energy Union, 2017, cit., 15 suggested on the point that "[r]eporting on recommendations must be annual".

Otherwise the Union level measures, being not appropriately detailed, open up to the Commission a wide range of possibilities for intervention. However, should they require the ordinary legislative procedure, must come to terms with the political consensus of Member States[81].
Greater concreteness is instead, recognized to the additional measures that the Commission can adopt in the field of renewable energy and energy efficiency[82].
In my opinion, the governance defined in the Regulation is set in the wake of the "new open method of coordination" inaugurated by the European Council in Lisbon on 23 and 24 March 2000[83], designed to assist Member States in the progressive elaboration of their policies in order to guarantee convergence towards the main aims of the EU[84].
This method creates a system of coordination between the definition of central objectives and decentralized responsibilities for their implementation[85], through the determination of quantitative and qualitative indicators and benchmarks, commensurate with needs of different Member States and sectors, and the transposition of European guidelines in national and regional policies by setting specific objectives and adopting measures that take into account the relative diversities, with periodic performance of monitoring, verification and peer review activities, organized with the function of mutual learning processes. It is not surprising, therefore, that criticisms that are put forward today about the Energy Union governance follow those that have drawn on the new open method of coordination, relative to its scarce efficacy as it is not guarded by sanctions and not structured on the relationship hierarchy[86].
Indeed, the intensity of the Union's powers depends on the subjects in which they are exercised based on competences entrusted to it by the treaties. The degree varies from the subjects in which the Union exercises its ordinary legislation, being able to adopt legally binding decisions for Member States, on areas that they have an exclusive competence, for which the Union will be able to carry out a coordinating action depending on the pursuit of common goals only with the consent and voluntary participation of these.

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[81] See M. Vandendriessche - A. Saz-Carranza - J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit. 10: "for these types of measures, political limitations will likely persist: implementing new Union-level measures would presumably require the ordinary legislative procedure and, hence, political (member state) consent. In other words, this hardly seems like a flexible tool in the Commission's hands ».

[82]See again, in this sense, M. Vandendriessche - A. Saz-Carranza - J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap?, cit. 11.

[83] Lisbon European Council 23 and 24 march 2000. Presidency Conclusions, par. 37, in europarl.europa.eu: «Implementation of the strategic goal will be facilitated by applying a new open method of coordination as the means of spreading best practice and achieving greater convergence towards the main EU goals. This method, which is designed to help Member States to progressively develop their own policies, involves: fixing guidelines for the Union combined with specific timetables for achieving the goals which they set in the short, medium and long terms; establishing, where appropriate, quantitative and qualitative indicators and benchmarks against the best in the world and tailored to the needs of different Member States and sectors as a means of comparing best practice; translating these European guidelines into national and regional policies by setting specific targets and adopting measures, taking into account national and regional differences; periodic monitoring, evaluation and peer review organized as mutual learning processes».

[84] See in this sense Ringel - M. Knodt, The governance of the European Energy Union: Efficiency, effectiveness and acceptance of the Winter Package 2016, cit., 210-211.

[85] See. G. Schmid – S. Kull, Die Europäische Beschäftigungsstrategie. Perspektiven der Offenen Methode der Koordinierung, in H. Kaelble – G. Schmid (Hrsg), Das europäische Sozialmodell. Auf dem Weg zum transnationalen Sozialstaat, Berlin, 2004, 317 ss.

[86] See I. Linsenmann – C. Meyer, Dritter Weg, Übergang oder Teststrecke? Theoretische Konzeption und Praxis der offenen Politikkoordinierung, in Integration, 4/25, 2002, 285 ss.

The governance of the Stability and Growth Pact is also based on the open method of coordination model, but it makes use of particularly effective tools for the areas it refers to[87]. The same recommendations - as mentioned, non-binding legal instruments - reveal in this context the maximum degree of effectiveness, being preparatory to possible application of sanctions, according to article 126 TFEU.
Well, the article 194, par. 2, TFEU assigns energy to the ordinary legislation of Parliament and the Council[88], but with the limit that Member States determine conditions of use of its energy sources, the choice between various sources and the general structure of supply. This limit can only be broken by a special legislative procedure, which requires unanimous deliberation by the Council and prior consultation of the European Parliament, the Economic and Social Committee and the Committee of the Regions[89]. Therefore, even the dissent of a single Member State[90] can prevent legislating with binding effects in this matter. Moreover, the same special legislative procedure is required by article 192, par. 2, TFEU, again in the field of the environment, when the EU adopts provisions of a fiscal nature and measures that affect the territorial planning, the management of water resources or the destination of the land: areas of intervention strictly related to energy policies and climate.
In conclusion, the Energy Union governance designs a procedural scheme that is very detailed in structure and binding in the form, but essentially open to the possible different outcomes that the dialogue and the iterative process between the European institutions and Member States can favor[91]. The hope is that, as for the Paris Agreement[92], the ambition of each

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[87] Budgetary policies are decided by individual Member States, but they are a matter of common interest which they undertake to coordinate within the Council through three different coordination instruments: (i) definition of broad guidelines for Member States' economic policies and for those of the Union (Article 121, paragraph 2 TFEU); (ii) surveillance procedures on the economic development of each of the Member States and the Union (Article 121, paragraphs 3-4, TFEU); (iii) prohibition of excessive public deficits and related control procedures and, possibly, sanctions (Article 126 TFEU).

[88] The Lisbon Treaty establishes that the decision-making rule in the Union is the ordinary legislative procedure, by virtue of which legislative acts are adopted, on a proposal from the Commission, by the European Parliament and the Council acting by qualified majority.

[89] Article. 194, par. 2, lett. c). this standard has thus introduced a so called. special "passerelle" clause, which allows the transition to the ordinary legislative procedure, and therefore, to qualified majority voting, in the matters indicated by the first paragraph of the same paragraph. Article. 48, par. 7 of the TEU instead regulates in a general way, as a simplified revision procedure of the TFEU and of Title V of the TEU, the so called "passerelle" standard, providing that what these provide that the Council must decide unanimously in a specific sector or case, the Council itself may adopt a decision - acting unanimously after approval by a majority of the members of the European Parliament - that the allows a majority to be deliberated, except for decisions that have military implications or fall within the defense sector. The same can happen when the TFEU provides for the Council to adopt acts in accordance with the special legislative procedure; also in this case the same council - with the same procedure - can adopt a decision that allows the passage to the ordinary legislative procedure. The initiative in this sense is transmitted to the national parliaments, which have six months to oppose it. If this were to happen even by a single Parliament, the decision could not be taken. The Commission, with Communication COM (2019) final dated 9 April 2019, "A more efficient and democratic decision-making process in the EU energy and climate policy", proposed the adoption of the bridging clause for tax decisions on the subject environmental.

[90] The resistance of the Vise grad group countries (Poland, Hungary, Slovakia and the Czech Republic) is known with respect to binding national targets and more generally on the timing and modalities of the energy transition, although the group's compactness can be undermined by the diversity of energy mixes of the four countries. See on M. Dufour, How to get the Vise grad Group to sign up to the EU's Clean Energy Package, in Energy Post, 6 March 2017.

[91]See M. Vandendriessche - A. Saz-Carranza - J.M. Glachant, The Governance of the EU's Energy Union: Bridging the Gap ?, cit., 11: «It is strong on formal processes and procedures, but very much open-ended on substance – and particularly enforcement rules».

Member State “can be increased through a process of naming and shaming” [93], according to the approach indicated by Elinor Ostrom[94] and favored by the Regulation’s provision of the establishment of a multi-level dialogue on climate and energy within each state, among all the so-called non-state actors[95].

[92] Which has created a platform for enhanced cooperation between States on which it will be played according to shared and transparent rules. See, F. Romanin Jacur, L’Accordo di Parigi e i passi avanti della cooperazione multilaterale sul clima, cit. D. Bodansky, observes in The Paris Climate Change Agreement: A new Hope? , cit., 2, “[t]he Paris Agreement seeks Goldilocks solution that is neither too strong (and hence unacceptable to key states) nor too weak (and hence ineffective). To safeguard national decision-making, it adopts a bottom-up approach, in which the Agreement “reflects rather than drives national policy.” But to promote stronger action, states’ “nationally-determined contributions” (or NDCs, for short) are complemented by international norms to ensure transparency and accountability and to prod states to progressively ratchet up their efforts». On the other hand, H. van Asselt, International climate change law in a bottom-up world, cit. 9, observes that “it remain unclear what kind of incentives the transparency framework will offer for Parties to ratchet up implementation”, clarifying «such incentives need not be limited to ‘sticks’ (e.g. financial penalties or other sanctions), but may also be in the form of ‘carrots’ (e.g. financial support)”.

[93] R. Falkner, The Paris Agreement and the New Logic of International Climate Politics, cit.

[94] See. E. Ostrom, Polycentric systems for coping with collective action and global environmental change, in Global Environmental Change, 2010, 550 ss.

[95] Article 11: Each Member State establishes a multi-level dialogue on climate and energy, in which local authorities, civil society organizations, the business community, investors and other interested parties as well as the public are able to participate actively and discuss the various scenarios envisaged for energy and climate policies, including in the long term, and review their progress.

BLOCKCHAIN TECHNOLOGIES FOR ELECTRICITY TRADING REGULATION

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Abstract

Nowadays, there is an increasing interest in the adoption of Blockchain technologies within the energy sector, especially for peer-to-peer trading applications. However, the application of Blockchain technologies and its principles are often transposed in the energy sector without focusing on the particular advantages or disadvantages that different platforms may bring. In particular, it is currently missing to our knowledge a focus on how Blockchain platforms applied to the energy sector may concretely affect energy market regulation. Above all, it is not clear yet whether and how it could guarantee that new form of interaction between regulators, citizens, and industries often emphasized by literature (Aste et al., 2017). Usually, when analyzing the relationship between Blockchain technologies and regulation, the starting point is the technology itself, and regulation is at most considered as a possible unidirectional incentive or disincentive driver of technology adoption. The present work aims to revert this relationship, namely analyzing how Blockchain technology might affect the regulatory mechanisms and the need for public intervention in the electricity market. In particular, the underlying question is twofold: how could Blockchain platforms affect electricity trading regulation? And, more generally, what are the possible interactions between Blockchain Code and Conventional Law?

Keywords: *Blockchain technologies; peer to peer trading; regulation; circular economy; energy decentralization; energy transition; prosumer; renewable energy.*

1. Introduction

The recent approval of the so-called "Clean Energy Package"[1] (also known as "Winter Package"), aims to meet opposing needs. On the one hand, it intuitively represents another step in the liberalization process towards the full completion of the Energy Union, also recognizing that some public interventions – like subsidies, capacity markets, and more generally price interventions – cause market distortions; but, on the other, it still allows these market distortion mechanisms. As an example, considering the Directive (EU) 2019/944, such contradiction is evident by comparing the original formulation of article 5 contained in the European Commission's initial proposal, with the text as finally approved. The article in question, entitled "market-based supply prices", ended up introducing a broad derogation regime, basically continuing to allow Member States to apply public interventions in the price setting for the supply of electricity. Because of growing concerns over energy security, environmental sustainability, and energy access – the so-called energy trilemma – public policy support for renewable energy has increased dramatically in the last few years, while the ambition to deliver an internal electricity market for EU consumers has not been realized yet. (Pepermans, 2019).

At the same time, the 2030 climate & energy framework increasingly requires the integration of contiguous policies, also through the contextual achievement of targets on emissions

[1] The eight main legislative files are Energy Performance of Buildings Directive (EU) 2018/844; Renewable Energy Directive (EU) 2018/2001; Energy Efficiency Directive (EU) 2018/2002; Governance of the Energy Union and Climate Action Regulation (EU) 2018/1999; Electricity Regulation (EU) 2019/943; Electricity Directive (EU) 2019/944; Regulation on Risk-Preparedness in the Electricity Sector (EU) 2019/941; and Regulation on the European Union Agency for the Cooperation of Energy Regulators (EU) 2019/942.

reduction, renewable energy, and energy efficiency[2]. Therefore, the close link between energy and climate policies also affects public intervention modalities, suggesting to find new solutions in the technological and digital evolution. In particular, the present electricity sector is to be deeply shaken by a "3D revolution" (Dobbeni et al., 2017), where the keywords are digitalization, decarbonization, and decentralization, and the first one is the instrument to reach the two other aims. For the first time, new technologies are creating ample opportunities for European citizens to participate and benefit from the energy markets, allowing them to actively take part in the clean energy transition and so putting them at the heart of the Energy Union. For example, the Winter Package recognizes that new technology developments facilitate consumers ability to consume, store and sell self-generated electricity to the market and to participate in all electricity markets by providing flexibility to the system, for instance through energy storage, such as using electric vehicles, by demand response or through energy efficiency schemes[3].

2. Consumer empowerment through peer-to-peer electricity trading

2.1 Peer-to-peer electricity trading in the Clean Energy Package

In this sense, one of the most significant innovations introduced by the Winter Package is represented by the so-called "peer-to-peer trading", even though only a few and fleeting references have been dedicated to it. As specified by the Renewable Energy Directive (EU) 2018/2001, Member States shall ensure that renewables self-consumers, individually or through aggregators, are entitled to store and sell their excess production of renewable electricity, including through peer-to-peer trading arrangements[4]. The Directive defines "peer-to-peer trading" of renewable energy as "the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator. The right to conduct peer-to-peer trading shall be without prejudice to the rights and obligations of the parties involved as final customers, producers, suppliers or aggregators". At any rate, under the recently approved Directive, new types of interactions start to emerge in the energy market, allowing consumers to become more active[5] and exchange energy peer-to-peer, both individually and jointly, acting as Citizen Energy Communities (CECs)[6]. Even if peer-to-peer

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[2] Key targets for 2030 are: at least 40% cuts in greenhouse gas emissions (from 1990 levels); at least 32% share for renewable energy; at least 32.5% improvement in energy efficiency.

[3] See Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU, "Whereas" No. 42.

[4] See Article 21.

[5] The Directive (EU) 2019/944 has set up the definition of the '"active customer", that is to say "a final customer, or a group of jointly acting final customers, who consumes or stores electricity generated within its premises located within confined boundaries or, where permitted by a Member State, within other premises, or who sells self-generated electricity or participates in flexibility or energy efficiency schemes, provided that those activities do not constitute its primary commercial or professional activity." This definition should be coordinated with the Directive (EU) 2018/2001, which introduced the concepts of "renewables self-consumer" – defined as "a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a non-household renewables self-consumer, those activities do not constitute its primary commercial or professional activity" (Article 2(14)), and "jointly acting renewables self-consumers", i.e. "a group of at least two jointly acting renewables self-consumers in accordance with point (14) who are located in the same building or multi-apartment block" (Article 2(15)).

[6] Defined as a "Legal entity that: (a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises; (b) has for its primary purpose to provide environmental, economic or social

electricity trading is still in its infancy, it seems to be possible to conceive a future where the energy could be sold between consumers/prosumers without the intervention of a traditional utility, even with a majority of autonomous off-grid and self-sufficient agents (Lavrijssen and Carrillo Parra, 2017). In particular, some literature (Andoni et al., 2019; Diestelmeier, 2019; Brilliantova et al., 2019) argue that blockchain technologies could be the critical factor in deploying this alternative market organization, generically named "consumer-centric electricity market" (Sousa et al., 2019). Before analyzing the potential of Blockchain for electricity trading regulation, it seems necessary to provide a general overview of this emerging digital technology.

2.2 Blockchain: key features

In brief, Blockchain is a distributed ledger technology (DLT) which can securely and publicly store digital transactions without using a central point of authority. It sees its theorization in a nine-page paper published in 2008, entitled "Bitcoin: A Peer-to-Peer Electronic Cash System": it is, in fact, the core technology of Bitcoin, the first electronic payment system based on a decentralized peer-to-peer network. It finds its ideological origins in the so-called «Cyberpunk Manifesto»[7]: the idea behind its creation is to allow trustless transactions, which can be automatically verified and recorded by the nodes of the network through cryptographic algorithms, thus eliminating the need for control and regulation by centralized authorities. So, basically, through the innovative combination of already existing IT technologies, such as cryptography, proof of work, and hash functions, its prerequisite is the elimination of the so-called middleman, although it often actually gave birth to the creation of new intermediaries, such as digital wallet service providers, initially operating in a sort of "regulatory disconnection" (Butenko, 2016)[8]. Furthermore, it even risks replacing trust in institutions with the one in software developers (Walch, 2019). Literally, Blockchain is a set of data blocks, which are linked together to form a sequential, temporally marked "chain." Each block, which constitutes the fundamental units, contains information referring to a specific number of transactions. It represents a sort of archive, from which it is possible to reconstruct "block by block" every single transaction that has affected a certain flow of value, in a way similar to what happens in civil law with the institution of transcription. Once entered into the register, the transactions become substantially immutable, being able to be modified only with the approval of the majority of the network nodes since it is shared among all peers. To validate a transaction and add a block to the Blockchain, a specific consensus mechanism is used, distributed on all the nodes of the network, which replaces the classic concept of "trust" characterizing the relationship with institutions and more general among users. It is a network system, where each computer (and therefore each subject owning it) becomes a node, following a mechanism that replicates the functioning of the Internet: in fact, for some authors (Tapscott and Tapscott, 2016), "Blockchain represents the second era of the internet". In other words, every member of the platform holds a copy of the ledger, having access to the historical log of the system and so being able to verify the validity of transactions, enabling a high level of transparency and cybersecurity. More specifically, the computational power of the PCs that are part of the network is used to solve complex algorithms and mathematical problems: an incentive is provided for the resolution of this calculation. To avoid double spending, each operation is validated through an electronic signature system with asymmetric cryptography,

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community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and (c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders".

[7] For more information, see: http://project.cyberpunk.ru/idb/cyberpunk_manifesto.html.

[8] Hovever, the fifth EU Anti-Money Laundering Directive has recently intervened by establishing obligations also for these operators.

created by means of a specific hash function used to enclose all the transactions contained in a block and summarize them in a data string, unique and unchangeable, which allows validators to verify the actual ownership and availability of the amount of Bitcoin that they intend to exchange with another person on the platform. In summary, therefore, Blockchain combines the values of transparency and distributed consent with those of cybersecurity. If it is true that each node on the network can exercise a form of control over the information stored and exchanged within the platform, it is also true that no one is able to independently modify or corrupt the network. Therefore, it is believed that the process of decentralization creates a more secure system and prevents easy access for cyber-criminals and potential fraud.

2.3. Smart contracts and the law of private entities

In light of the success achieved by the Bitcoin platform, new Distributed Ledger Technologies were created, like Ethereum, Monero, and Hyperledger. The idea of using DLT platforms not only for cryptocurrencies but in the most different traditional markets, such as the energy one, has started to spread since Blockchain promises transparent, tamper-proof and secure systems that can enable novel decentralized applications (dApps)[9]. However, unlike the financial sector, electricity requires a network infrastructure to be transported (Tapscott and Tapscott, 2016). In particular, according to the UK Government Office for Science[10], the real potential of blockchain technologies can be realized only when combined with smart contracts, i.e. computer protocols "which formalize the elements of a relationship and automatically execute the terms therein encoded once pre-defined conditions are met", following the scheme "if x, then y" (Cuccuru, 2017).

Therefore, smart contract seems to constitute the most actual concretization of the so-called "exchanges without arrangements" theorized long ago by the Italian doctrine (Irti, 1998), in which the agreement is the result of a combination of two unilateral juridical acts, often through a conduct implying intent, without any possibility to constitute a fully-fledged consent in any way[11]. For partly similar reasons, even the latest American doctrine (Werbach and Cornell, 2017) believes that smart contracts are by default unilateral contracts. However, even without getting into the heart of this doctrinal debate, smart contracts seem to guarantee the maximum expression of trade disintermediation, or at least a new form of exchanges "control" by individuals. When distributed consensus is reached by the nodes of the network, the DLT becomes the "guarantor of the contract" and performs the conditions that are predefined into the smart contract, which is saved permanently and unalterably within the Blockchain, thus becoming independent from the subsequent will of the parties. Once combined, smart contracts can form an interconnected system of "technically enforced" relations (De Filippi, Wright, 2018), which collectively define the rules of a Decentralized Autonomous Organizations (DAO), allowing individuals to carry out transactions on a peer to peer basis.

Smart contracts seem then to represent the most current realization of the "law of private entities" described by Cesarini Sforza, being not state-originated, and therefore being different from private law (that is always decreed by the State), since it is introduced only by the effective interaction between private entities.

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[9] That is to say digital applications or programs that exist and run on a blockchain or P2P network of computers instead of a single computer, and are outside the purview and control of a single authority

[10]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf.

[11] For a recent discussion on this point, see also Damiani, E. (2019) "Difficulties in adapting the general discipline of the agreement to the phenomenon of the completion through automatised systems in the civil law before and after the codification of 1942", in *Comparazione e Diritto Civile*, p. 6, available at the link: http://www.comparazionedirittocivile.it/prova/files/damiani_difficulties.pdf.

2.3 Blockchain: a new Institution?

Also for these reasons, from a legal point of view, some doctrine (De Filippi, Wright, 2018) tends to associate Blockchain with the concept of Rule of Code and in particular with the rise of the so-called "lex cryptographica", which clashes with the Rule of Law in an "emerging battle for supremacy" (Yeung, 2019). In fact, this last author cites just peer-to-peer energy systems as an example to illustrate the dilemma faced by conventional lawmakers in responding to them, resulting in a relationship of "mutual suspicion and uneasy co-existence" between these two regulatory modalities.

At the same time, some authors in the area of neo-institutional economy (Davidson et al., 2017; Berg et al., 2018; Potts et al., 2016) claim that blockchains are an instance of institutional evolution, which «adds an additional category to the suite of Williamson's (1985) "economic institutions of capitalism" – viz. markets, hierarchies, and relational contracting – with a new type of economic order: a Decentralized Collaborative Organization (DCO)» (Davidson et al., 2018)[12].

So, Blockchain has been defined as a technology of decentralization, which offers an alternative way to coordinating economic activity (Davidson et al., 2018), representing a spontaneous organization different from the Market, nevertheless having typical properties of the Market itself; at the same time, its role is to encourage transactions more efficiently than hierarchies (being smart contracts self-executable) and traditional contracts, which require the existence of trust between the parties. If so, maybe this new technology could also affect the so-called "State-Market pendulum" with new marked swings.

Thus, trying to synthesize the current state of the art, when the literature considers the relationship between Blockchain and regulation, it normally adopts a unilateral perspective, in the sense that it investigates the need to regulate this kind of technology and not vice versa. In this viewpoint, it also considers Blockchain as a normative system, which competes and contrasts with the legitimate one. In my investigation, I aim to revert this relationship: so, fundamentally, to explore if Blockchain could also be an innovative means of regulating the energy transition, in at least two ways. First of all, if the "Blockchain Code" could also be an innovative tool of public intervention in the society that evolves and becomes more and more complex. Secondly, by adopting a more radical perspective, whether the Blockchain can itself become a source of regulation of renewable energy exchanges and, if so, what impact it has on the public intervention in the energy market. In other words, could Blockchain application in the energy market help to solve some of those regulatory criticalities that emerge from the current regulatory framework? Or, even more radically, could it force a rethinking of the actual need for regulation in the electricity market?

2.4 Blockchain technologies for peer-to-peer electricity trading

Many research initiatives indicate that Blockchain technology could be an instrument for the "3D revolution" mentioned before. As it has already been observed in the literature (Andoni et al., 2019) thanks to the review of more than 140 blockchain research projects, "blockchains could potentially provide solutions across the energy trilemma: they could reduce costs by optimizing energy processes, improve energy security in terms of cybersecurity but also act as

[12] In particular, "A DCO is a self-governing organization with the coordination properties of a market, the governance properties of a commons, and the constitutional, legal, and monetary properties of a nation state. It is an organization, but it is not hierarchical. It has the coordination properties of a market through the token systems that coordinate distributed action, but it is not a market because the predominant activity is production, not exchange. And it has the unanimous constitutional properties of a rule-of-law governed nation state, by complicit agreement of all "citizens" who opt-in to such a Decentralized Collaborative Organization, and the automatic execution of the rules of that DCO through smart contract enforcement".

a supporting technology that could improve security of supply, and finally promote sustainability by facilitating renewable generation and low-carbon solutions". The active participation of consumers seems to be guaranteed by the presence of immutable, transparent, and tamper-proof smart contracts, exchanged in a platform that records transactions, at the same time providing almost real-time price signals and information on energy costs for users, as required by the Winter Package.

Moreover, if we compare the definition of "peer-to-peer trading" contained in the Winter Package with the features of smart contracts, it is quite clear that the "contract with pre-determined conditions governing the automated execution and settlement of the transaction" refers to a smart contract.

As mentioned before, many energy projects are currently being developed all around the world using blockchain platforms to enable people to generate, sell, and buy energy directly to and from each other. The most famous one is the so-called "Brooklyn Microgrid" project run by Transactive Grid, which is a partnership between LO3 Energy, Consensys, Siemens, and Centrica. In summary, prosumers can sell their energy surplus directly to their neighbors using Ethereum-based smart contracts, creating a decentralized "community microgrid" that allows direct sales of solar energy. Energy surplus is measured by specially designed smart-meters that can handle physical energy measurements and data, and sequentially transformed in equivalent energy tokens tradable in the local marketplace. Tokens indicate that a certain amount of energy was produced from the solar panels and can be transferred from a prosumer's smart meter wallet to end-consumers by use of blockchain technology, being deleted by the consumer's smart metering device when purchased energy is used in the house. Microgrid users interact with the platform by specifying their individual price preferences in the form of willingness to pay or sell electricity.

Moreover, the platform can display location-specific and real-time energy prices. The ledger records and crystallizes in an immutable way the contract terms, transacting parties, volumes of energy injected and consumed as measured by metering devices, keeping track of the chronological order of transactions. Besides, every member of the community can have access to all historical transactions in the ledger and verify transactions for themselves.

From these aspects, the potential in terms of user "consumer empowerment" clearly emerges, and it seems to be more significant not only than what is guaranteed by the current regulatory framework but also considering other ICT technologies. In particular, while AI and IoT stand as "inevitable and automated intermediaries" (Di Porto, 2016), thus replacing human activity, on the contrary, Blockchain allows dis-intermediated and peer to peer transactions (therefore among peers) between private subjects, strengthening, rather than diminishing, the individual's self-determination ability, as the same is equipped with cognitive tools to make their own choices and obtain a personalized offer[13]. In this context then, the "hyperconnected consumer" seems to free himself from the problem of "excess of intermediation", fully automatic, detected by doctrine (Di Porto, 2016), with reference to other ICT technologies. Total automation only indirectly concerns Blockchain technology, which arises with the main aim of allowing greater autonomy for its user. Therefore, even the passive consumer can become an active and aware protagonist of the energy transition. The integration between DLT and other forms of emerging technologies promises the most significant innovations, making possible exchanges that (at least, in theory) do not even require the centralized, top-down power grid. Let's think to the example of an active customer who owns a photovoltaic system and a column for the private recharge of electric vehicles: the same could coordinate (perhaps through DApps) with other consumers, exchanging self-produced renewable electricity through the charging column and crystallizing the supply contract, in the form of a smart contract, within the Blockchain, thus also guaranteeing immutability, transparency and

[13] For an in-depth legal analysis of cognitive biases that afflict the consumer, see Rangone, N. (2017) "Tools for effective law: a focus on nudge and empowerment", in *Concorrenza e mercato*, 25: 195-214.

probative value. Besides, in a perspective of real diffusion of self-driving electric cars, these supply contracts could take place automatically thanks to the integration between Blockchain, AI and IoT, so allowing the same vehicle to supply in turn other electric cars (V2V) the infrastructure (V2I) and the network (V2G).

Summing up, Blockchain technology seems to provide some benefits for both passive and active consumers. For example, the passive consumer has the flexibility to choose his supplier, making transactions in very short timescales. At the same time, this is an opportunity for prosumers, because it allows them to no longer just feed their excess energy into the grid against payment of a fixed fee, but to sell it individually. Moreover, consumers would have a more extensive choice of payment methods: they can use also can use tokens and cryptocurrencies, while cash payments become more transparent because the transaction is crystallized in the smart contract. So, if combined with smart metering, Blockchain seems to allow greater traceability, since it makes it possible to clearly verify and record the source of the electricity supplied, for example in terms of the sharing of renewable energy.

In this regard, even the European legislator seems to recognize these benefits. For example, the European Parliament resolution of 3 October 2018 *on distributed ledger technologies and blockchains: building trust with disintermediation* underscores that DLT can transform and democratize the energy markets by allowing households to produce environment-friendly energy and exchange it on a peer-to-peer basis, stressing that such technologies provide scalability and flexibility for plant operators, suppliers, and consumers. Moreover, it underlines that DLT can support the production and consumption of green energy and could improve the efficiency of energy exchanges, transforming the grid operation and allowing communities and individuals to provide grid services as well as to integrate renewable resources more efficiently. Even more significantly, it emphasizes that blockchain technology can create alternatives to state-sponsored renewable investment schemes, at the same time facilitating the energy transmission and distribution infrastructure and creating a new transaction ecosystem surrounding electric vehicles.

Particular emphasis is paid to the possibility of using DLT technologies to improve energy reporting, for their ability to enabling accurate tracking of renewable or carbon certificates.

Finally, the resolution stresses that Blockchain platform can support the electrification of poor rural communities through alternative payment and donation mechanisms, bringing new opportunities to the circular economy by incentivizing recycling and enabling real-time trust and reputation systems. Particularly, it seems interesting to note that technology could become not only a means of making transactions more efficient but also a social promotion tool, managed by the local institution. Significant in this sense is the project underlying the creation of NRGCoin (Mihaylov et al., 2014), a cryptocurrency that aims to encourage the production and – above all – the consumption of renewable electricity at the local level. Furthermore, in the United Kingdom, the city of Hull has created a social cryptocurrency, HullCoin, and reinvested all the profits derived from it in its social policy to reduce poverty in the territory. This currency is also used to promote the social integration of citizens: subjects in conditions of vulnerability who carry out voluntary activities are paid in HullCoins, which they can then exchange for hot meals at the local food bank.

In general, it is possible to favor bottom-up initiatives, solidarity actions that start from individuals. The consumer could really become an active protagonist of social policies, for example by providing for free self-produced electricity (which, having a marginal cost of zero, if not consumed or "stored" would still be dispersed) in favor of the community. Therefore, it is possible to attribute a new value to the local dimensions through "incentive mechanisms" that reward virtuous consumption, translating simple "peer-to-peer" exchanges into real relationships, encouraged and guided by municipalities and energy communities.

However, Blockchain is not a panacea. For example, it should not to be forgotten that the option between a centralized database and a distributed register is not always so obvious, since the same concept of decentralization has to be balanced with other needs, like privacy and data protection, also because a too transparent market could facilitate collusion (Schepel, 2019). Therefore, the real opportunity to use a blockchain platform for peer-to-peer trading must be critically evaluated on a case-by-case analysis. Since there are different types of blockchain, specific features of the platform to implement should be agreed. Regarding this point, considering the literature on this subject, it could be noted that many times the features of the Bitcoin platform are generally transposed in the energy sector, forgetting that such a model loses many of its advantages when applied to different and more specific contexts. As an example, a Blockchain implemented for a microgrid to guarantee secure peer to peer exchanges between private individuals (like in the Bitcoin platform) should also consider that microgrid refers typically to a network that is composed only by few nodes. So, there is not the same high level of cybersecurity that characterize a global, public blockchain like the Bitcoin system; therefore, the so-called "51% attack" becomes more feasible.

3. Blockchain technologies as a mean of regulation

In any case, at least theoretically, although Blockchain has been created on the impulse of the so-called crypto-anarchists movement, it does not configure a necessary alternative to the role of institutions, also being able to set a public regulation tool: not only in the meaning attributed to it by the European resolution but also in a more innovative way.

For example, it has already been pointed out the possibility, recognized by the resolution, of using DLT technologies to improve energy reporting, for their ability in enabling accurate tracking of renewable or carbon certificates; at the same time, they could "create alternatives to state-sponsored renewable investment schemes", thus helping to solve market distortion mechanisms.

Moreover, some authors (Gerbeti and Catino, 2019) have rightly observed that blockchain technology is "perhaps the best enabling tool to guarantee the certified, unambiguous, safe and transparent traceability of product supply chain emissions", following the path of CO_2 contained in the various goods through all the industrial and commercial steps that took place in the global market, thus reducing the competitive asymmetry created by the environmental obligations imposed on industries located in the European territory and of which those outside Europe are exempt.

It is evident that in the European emissions trading discipline, although currently structured on a "Cap and Trade" system that has replaced the previous "Command and Control" model, the top-down regulatory momentum still assumes dominant importance. There is, in fact, a substantial regulatory intervention, which consists of the strict regulation of the exchange activity. The latter is not left to the free market dynamics but constitutes an administrative discipline that aims to regulate the functioning of a market created *ad hoc*, by imposing charges and costs.

In other words, the trading system is not only organized and regulated by law, but it also originates from a normative and non-factual source: it is, therefore, a fictitious market, created *ex lege*, certainly not by the free deployment of economic forces. In this context, moreover, public intervention does not only concern the creation of the market but also its functioning and control. Therefore, despite the abandonment of the "Command and Control" system, the pre-eminent public interests underlying the protection of the environment justify the persistence of an incisive public intervention, without which it would not be possible to start, operate and control a such an articulated system. In any case, this regulation of emissions trading continues to give rise to significant critical issues, as demonstrated, for example, by the many regulatory interventions on the EU Emission Trading System (EU ETS), which took place in a limited time[14]. The aforementioned regulatory asymmetry problems between EU and non-EU countries must also be considered. Furthermore, even at the European level, the EU ETS system excludes sectors – such as transport, construction, and agriculture – which represent around 60% of the EU's internal emissions. These are instead regulated by the Effort Sharing Regulation[15], which contains more properly Command and Control measures. But it is also the Cap and Trade system that, to date, has not produced the expected results. Also due to the economic crisis, in the last decade, the European market has been characterized by a chronic excess of supply (equal to around two billion shares) which has led to a price level that is too low to stimulate the energy sector and industrial sector and invest in measures to effectively reduce emissions.

Therefore, given the inefficiencies of the EU ETS regulation, it is interesting to investigate whether it is possible to use Blockchain technology not only to trace already existing certificates and so "administrative titles", created *ad hoc* by the legislator (as suggested by the European resolution), but, more radically, to *replace the need* of this kind of certificates that represent an artificial market.

In light of the characteristics described above, Blockchain technology appears suitable to automatically trace all the individual "passages" of electricity, from its generation from a renewable source to its exchange and consumption, thus favoring control of the origin of the electricity that is more effective and direct also towards the final consumer.

The Blockchain, integrated with other technologies (such as smart metering), could even wholly replace the current certification systems, allowing the market itself, when the electricity transactions take place, to quantify and qualify the origin of the electricity exchanged, as well as any related CO_2 emission, providing more precise and real information also concerning the Guarantees of Origin (GOs). In fact, this type of reasoning can also be applied to other certificates like GO, which is a tracking instrument introduced by article 15 of the European Directive 2009/28/EC to provide information to electricity customers on the renewable source of their energy. However, in practice, they only show the annual average of renewable energy, not being so precise in indicating the exact origin of the energy consumed at that time by that specific consumer: so "we know they don't have much value as they show the average of energy over the year".[16]

Summing up, with Blockchain technologies, it could be the same market that, when the peer-to-peer electricity transactions take place, makes it possible to trace the renewable energy and the carbon emissions. This conclusion sounds to be quite interesting, because in a well functioning peer-to-peer market, where individuals exchange renewable energy, the production of renewable energy is incentivized with truly market mechanisms, by the fact that the active consumer can earn from the sale of self-produced energy, while the passive consumer has more choice.

4. Smart contracts as an "entry point" for regulators

Therefore, considering at least a speculative point of view, future implementations of Blockchain technology for peer-to-peer trading could impose a rethinking of some specific forms of energy market regulation, and could even replace the need for them. Nevertheless, at the same time – and probably this is the most innovative aspect – they could allow a new form of public interventions in the market, which is currently not possible.

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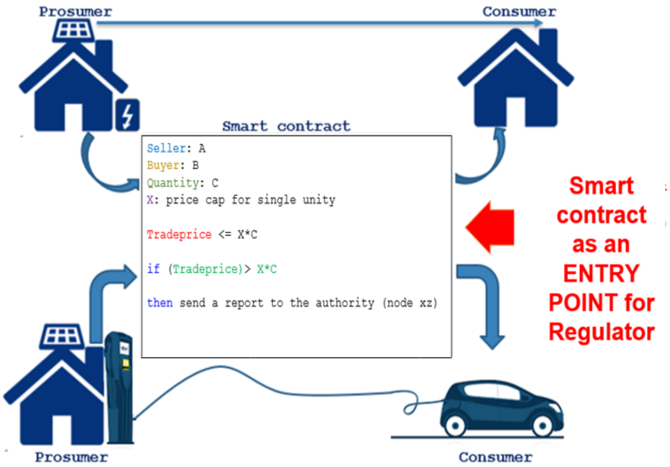
[14] Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the EU was amended several times as the system has evolved. The most recent changes were agreed in March 2018.

[15] Regulation UE 2018/841, "Inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework".

[16] See https://docstore.entsoe.eu/Documents/News/ee-in-the-media/2017-02-03-montel-interview.pdf.

In other words, it is not clear why the smart contract cannot free itself from the crypto-anarchist ideals from which it originates to become instead an instrument of public intervention aimed at liberalizing the market; from an expression of "law of private entities", it could also become a new form of manifestation of traditional regulation.
In fact, given the conditional nature of regulation, since the smart contract also responds to the logic "if this, then that", it would seem feasible to insert among the clauses a "condition x" corresponding to previously identified market distortions (for example, a price higher than a certain threshold) for which, upon the occurrence of the condition, a real-time notification would be sent to the Authority, which is also a node (or a group of nodes) inside the Blockchain network.
For example, an active customer who owns a photovoltaic system and a column for the private recharge of electric vehicles could coordinate through DApps with other consumers, exchanging self-produced renewable electricity through the charging column and crystallizing the supply contract, in the form of a smart contract, within the Blockchain. More importantly, the active consumer could be free to set the "market-based supply price" (to which article 5 of the Directive (EU) 2019/944 refers), but, at the same time, the Authority could impose some conditions in the smart contracts, providing for example that, if the price is higher than a certain amount, a report will be sent to the Authority.



The prices could then reflect the peaks of energy in real-time, according to the principle of scarcity and the logic of the market; at the same time, however, it would be possible to guarantee a widespread and almost instantaneous public control of all the individual transactions carried out through Blockchain, of which the same provides proof, thus significantly innovating the current system. Price could be more market-oriented because *ex-post* public control of individual transactions becomes capillary and almost real-time. This solution seems to be very revolutionary, and could maybe also impose a new speculative reflection on the boundaries between *ex ante* regulation and antitrust enforcement.

Conclusion

In the previous analysis, Blockchain technologies applied to peer-to-peer energy transactions were analyzed under a novel point of view, in its (at least theoretical) ability to affect the regulatory mechanisms and the need for public intervention in the electricity market. In particular, regarding the Blockchain platforms ability to affect electricity trading regulation, it has been argued that Blockchain could maybe constitute itself a mean of regulation, replacing the current certification systems and so allowing the market itself, when the electricity transactions take place, to quantify and qualify the origin of the electricity exchanged, with greater consumer involvement and empowerment.

At the same time, smart-contracts – normally seen with suspicious being not state-originated – could become a new "entry point" for regulators, allowing an innovative form of capillary public intervention in the market, which currently is not possible.

Therefore, even the Blockchain is not necessarily an institution in a fight for supremacy with hierarchies and the market. Blockchain could also represent a new equilibrium in the "State-Market pendulum": it embodies a market-oriented and decentralized approach, based on horizontal relationships between active and passive consumers in a demand-supply mechanism, but, at the same time, it could create an "entry point" to traditional regulators through smart contracts.

In conclusion, contrary to conventional wisdom, Blockchain peer-to-peer trading does not define only a relationship of "mutual suspicion and un-easy co-existence" between Blockchain technologies and traditional regulation (Yeung, 2019), but it also allows a "virtuous cooperation", namely an evolution of public intervention modes in energy markets.

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TURNING ROME INTO A ZERO WASTE CAPITAL: TOWARDS A CIRCULAR ECONOMY SYSTEM

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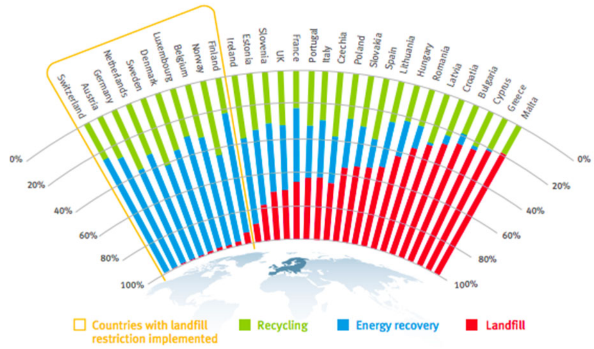
In a scenario where the process of transition to a sustainable zero-emission economy has an increasingly growing influence, the uncontrolled production of waste has become an urgent issue for our ecosystem.
With the increase of the population consumption, the total amount of waste produced and thrown irresponsibly into the environment is growing steadily (particularly in Italy, due to the phenomenon of "ecomafia").
The waste situation in the city of Rome has become unmanageable, creating clear inconvenience to the population. Therefore, wastes are not collected, remaining on the streets for days.
For this reason, efficient actions of circular economy must be taken to prevent waste from being dispersed into the environment or in landfills, and to convert them into energy (energy recovery).
Giving an intrinsic value to waste may turn into an incentive to manage it correctly and prevent its dispersion in the environment increasing the GDP and decreasing the dependence on foreign countries (Cash From Trash).

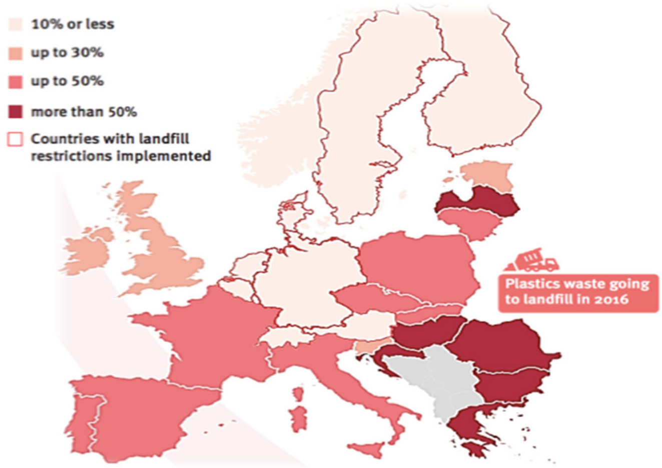
The European Union is at the frontline of efforts to implement an efficient Circular Economy system.
The European Circular Economy Package identifies a series of measures to help businesses and consumers make the transition to an economy in which resources are used in a more sustainable way; such us reaching: 65% of urban waste-recycling, 25% of Energy recovery and 10% of use of landfills.
Moreover, the Directive 2006/12 /CE, provides a regulation framework on effective and innovative waste management adapting technological developments to the waste-production scenario at local level.
This would result in the requirement for each Member State to consider waste as a raw material, to reach autonomy in waste elimination, to minimize waste transportation and to optimize disposal processes while minimizing environmental impact.
Therefore it specifies indications on waste management, in order to privilege effective and innovative processes that adapt the technological evolution to the production scenarios of waste present in the territory.
Are we doing it in the right way?
In order to understand if the EU waste system is working efficiently is useful to focus on the European plastic waste collection.
Tanking in to account the data from Plastic the fact 2019, although the total EU situation is improving, in many countries, landfill is still the first or second choice of treatment for plastic post-consumer waste.
Switzerland, Austria, Germany, Netherlands and Sweden are in the top 5 of the list collecting most of plastic post-consumer waste in Energy Recovery and in Recycling.
Instead, Italy is in a position where Landfill is still a strong option to collect plastic waste (up to 30%).

Plastic post-consumer waste collected per country in 2016



Plastic the fact 2019

Plastics post-consumer waste landfill rate across Europe



Plastic the fact 2019

In order to be aligned with EU Directive 2006/12 /CE, therefore, Italy needs to invest in technology and in clear policies/regulations which are essential not only to simplify bureaucracy but even to reduce the use of landfills and transportation of waste inside (from a region to another) and outside the country (from a region to another country).
Consequently it is fundamental to implement a national strategy and an action plan (consistent with European Strategies) able to exploit Italy's potential and to promote a Circular Economy model.

The Circular Economy focuses on the production, consumption and management of waste concentrating on innovation, development of investments and employments while promoting the bio-economy.

In addition, working on incentives for and the development of a circular economy will support the climate, ecological and social challenges proposed by the "Green Economy" increasing at the same time the competitiveness of Italian' companies.
The National integrated plan for energy and climate (PNIEC) was implemented to incentivise the decarbonisation process and is structured on five interventions line that will be developed in an integrated manner.
For this reason, the attention is going to be focus on decarboniaìsation, efficiency, energy security, market development indoor energy and search, innovation and competitiveness.
To build a path consistent with "circularity", the reduction of emissions in the waste sector is mainly linked to reduce the use of landfills, increase waste collection end grow up recycling.
How the chart below shows, in 2017 the number of plants was 123, -8,2 % compared to 2016 (-11).
In addiction, the total amounts of urban waste disposed in landfills was around 6.9 million tons (-6.8% compared to 2016).

Landfills disposing urban waste (geographical macro area) 2013-2017

	N° Plants					Quantity disposed of (t/y)				
Country	2013	2014	2015	2016	**2017**	2013	2014	2015	2016	**2017**
Nord	76	77	65	53	51	2.780.921	2.612.535	1.933.133	1.683.816	1.718.705
Center	39	40	34	31	27	2.933.230	2.144.275	1.847.089	1.781.454	1.533.108
South	65	55	50	50	45	5.200.202	4.575.088	4.038.573	3.966.342	3.647.735
Italy	180	172	149	134	**123**	10.914.353	9.331.898	7.818.796	7.431.612	**6.926.548**

Even if the number of landfills is reducing year by year, the Italian situation regarding the energy recovery sector is still inefficient comparing with the European scenario.
Italy needs more technological plants, such us incinerators, able no just to reduce the use of landfills but even to convert waste in energy reducing all the issues inked with the waste management.
How the ISPRA' data below underline, the 67% of incinerators are located in northern Italy.
This means that large quantities of waste are transported from the south to the north (polluting), to be collected and transformed into energy not respecting the EU Directive 2006/12 /CE.
Taking in to account the Lazio Region, the number of installed plants is equal to 1.

However, in the last years, the number of incinerator has not seen any significant increase.
Having this behaviour, without the right maintenance techniques or new constructions, in 2035, we will lose about the half of the current capacity.
Therefore, the low birth rate of the new "waste-to-energy" plants is not sufficient to compensate the mortality rate.
In the absence of repowering or building additional plants, the cumulated capacity after a period of stability will begin to fall from 2029 to reduce to about one third in 2040.

Number of incineration plants that treat urban waste - 2017

INCINERATION PLANTS		
	N°	%
Nord	26	67
Center	7	18
South	6	15
Italy	**39**	**100**

Source: ISPRA

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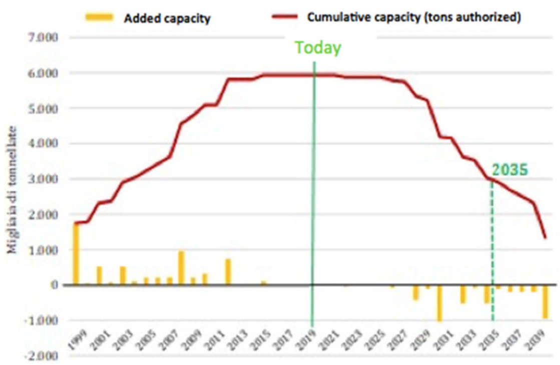

Source: Waste Strategy 19 - Althesys

Given the Italian average construction times (around 7 years), it is therefore necessary to act immediately, especially in the region with the lower number of plants installed.

Under an Italian perspective, the Municipality of Rome is the one facing the most challenges and holding the most critical position due not only to an unsustainable plants - that appears to be affected by a chronic shortage of the system, composed of intermediate treatment plants (MBT and MT), but also because of the non compliance of AMA (the company in charge of waste-collection in the capital).

Taking into account the data from Lazio Region[1], in 2017, the municipality of Rome reached almost 58 % of the total urban waste generated overall within the region.
It appears therefore necessary to provide proper technologies to the Lazio region and the municipality of Rome such as composting or energy recovery plants in order to manage in an efficient way the total waste produced and to reduce the level of exportation to other regions or even outside the country.
Moreover, it is fundamental to underline that the 67% of the thermal incinerators are located in the northern regions; according to ISPRA's data in fact, Lombardy has 13 plants follow by Veneto with 8 (Lazio nowadays has just 1, and it is unsustainable) [2].

To manage waste in an efficient way and address them to "waste-to-energy power plants" - creating "clean" electricity and heat - would appear to be essential to invest in facilities and technologies within the Lazio Region and inside the cities.
The installation of those plants will create significant benefits increasing the employment rate and reducing in the same time the reliance on third parties.
Nowadays the situation in Rome appears to be heavily dependent on extra-regional engineering systems.
In particular, the situation in the city of Rome does not respect European Directive 2006/12 /CE, producing almost 66.4% [3](166 thousand tons) of the total waste destined for treatment in plants outside the region.

But, why turn Rome into a Zero Waste capital?

Following data from Regione Lazio, in 2017, the Municipality of Rome exported to Austria around 50,520 tons of non-recyclable waste. For each tonne of waste, AMA paid € 139.81, for a total of approx. 7 million €.
If this outstanding amount was invested towards innovative and sustainable technologies, it would have given clear and relevant benefits as proven in other European countries such as Germany, Austria, Netherlands and Sweden.

The process of transition from a linear economy (based on: take-make-dispose) to a circular economy necessarily requires bearing transition costs, but it would bring perhaps significant economic, environmental and social benefits.
A striking and huge example is the Copenaghen's Amager Bakke-CopenHill plant, which cost 470 million € and has replaced the old waste-to-energy incinerator.
It burns 400 thousand tons of waste a year to produce electricity and heat for 150,000 homes in Copenhagen, and the only thing released by chimneys, according to authorities, is water vapour, thanks to the new generation filters which are able to retain all harmful fumes and dust.
The plant utilizes more than 100% of the fuel's energy content, has a 28% electrical efficiency rate, reduces sulphur emissions by 99.5%, and minimizes NOx emissions to a tenth, compared to the former plant.

[1] Piano di Gestione dei Rifiuti della Regione Lazio - Linee Strategiche, Gen 2019, Regione Lazio
[2] Rapporto Rifiuti Urbani 2018 - ISPRA
[3] Piano di Gestione dei Rifiuti della Regione Lazio - Linee Strategiche, Gen 2019, Regione Lazio

Moreover, this plant offers different touristic attractions considered a value added and a perfect example of a Smart City where technology, architecture and social life are interconnected in a sustainable way.
Therefore, an efficient circular economy would reduce the demand for imported raw materials, decreasing dependence on foreign countries and reducing the uncertainty caused by factors of scarcity and / or geopolitics.

To be aligned with EU Directive 2006/12 /CE, the city of Rome needs to invest in Technology , Research and Development, to clear policies/regulations which are essential to simplify bureaucracy, to decrease the export of waste that can be managed locally creating energy and reducing dependence on foreign countries, to reduce the transportation of waste inside (from a region to another) and outside the country responsible for producing further emissions , to consider waste as a raw material reducing the use of landfills and to improve the adequacy of the plant system.
Moreover, it looks to be fundamental to invest in communication and education using positive narrative and creating awareness among citizens on the sustainability of new technologies such us incinerators, which are still considered dangerous for the environment.

In conclusion, the logic of the circular economy is that waste can function as a “fuel” for other processes.
It is therefore an opportunity to significantly improve the ability to obtain economic benefits from the use of natural resources.
The main problem, which makes Rome's current production and consumption model unsustainable, is how to dispose waste.
In the Lazio region, the possibility of allocating new sites to landfills has become increasingly difficult. It is fundamental therefore to find alternative solutions.

The most critical issue currently present in the Lazio Region is the scarce availability of *Waste-to-energy plants adds to the inefficient Waste System in Rome that is an able to manage all waste present in the territory.*
The system offer of undifferentiated waste treatment in the Region is based on two types of plants: the Mechanical Biological Treatment (MBT), that treats undifferentiated waste where the organic fraction is still present, and the Mechanical Treatment (MT), which treats undifferentiated waste without the presence of organic fraction (in operation only 3 plants). Both are not able to work properly.
The plant configuration of the Lazio Region does not allows the closure of the urban waste management cycle which it should guarantee not only the location of undifferentiated urban waste but also waste produced by intermediate treatment plants (MBT and MT).

The European directives of the "Circular Economy Package 2018 " set the goal of reaching the 65% in urban waste-recycling and shifting to below 10% in the use of landfills by 2035 (recycling capacity in Italy is just over 50% and landfill is still 25%).
Nevertheless, the National Report “The Circular Economy in Italy - 2019” has found positive results; the report highlights that Italy can not be satisfied because looking at the progress of the circularity index, it is slowing down. At the same time, other countries are instead growing thanks to the new measures required by EU Directives (in 2018, Italy grew by just one point in comparison to the previous year; while France grew by 7 and Spain by 13).

In order to focus on research and innovation it is necessary to improve specific tools to re-launch the role of cities and urban regeneration, to accelerate the approval of European directives and dedicated infrastructures.
Recovering more resources from waste means using raw materials more efficiently and diversifying them, designing, distributing and selling products according to another conception of value creation - from a product to a service.
However, it is essential to underline that factors such as corruption and “eco-mafia”, slow down the actual development of effective solutions, especially in Rome, Lazio (according to Legambiente’s report on "eco-mafias" 2019, the Lazio Region appears to be in the top position for illegal waste disposal crimes - one of the most lucrative and dangerous field of eco-mafias’ activities).
A cocktail that, mixed with a slow and confusing bureaucracy, reduces the development of an efficient Circular Economy (for example it takes 7 years to begin construction works of an incinerator).
Therefore, the plant configuration of the Lazio Region does not allows the closure of the urban waste management cycle which it should guarantee not only the location of undifferentiated urban waste but also waste produced by intermediate treatment plants (MBT and MT).

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IRREVERSIBLE THERMODYNAMICS VIEW OF THE NEED FOR A CIRCULAR ECONOMY

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Abstract

On a macro-economic scale the application of irreversible thermodynamics considerations shows that a more efficient economic organization (i.e. local decrease of entropy), has an impact on the environment that can be measured by the energy intensity dynamics. This component of environmental temperature increase, may be estimated as temperature increase values for selected economies. The reduction of this temperature increase may be done, in this case, by using circular economics actions that make more efficient the exchange of energy, resources and waste with the environment and generate technologies that turn the waste liabilities into assetts.

***Keywords**: irreversible thermodynamics, climate change, energy intensity, circular economy*

1. Introduction

The relation of human society and Nature has been analyzed from various view-points in the last more than two decades since the first global agreement related to climate change. It is clear now that by exchanging energy and mass with the environment human society is producing sizeable effects in this last one. Beside energy and mass (call it material resources and waste) there is though an effect given by the exchange of entropy resulting from the increase of anthropic system organization hence the decrease, locally, of its entropy. On a product and technology scale lifecycle evaluations of the entropy source have been attempted as well as the determination of the value of the entropy production of a technological process or even an economy in correlation with energy or exergy (Bakshi et.al. (Ed.) 2012). All these attempts recognize the fact that by a better economic and technological organization there is a decrease of entropy that can be evaluated. At the scale of the whole economy of a given country there is a way to measure the impact, in terms of temperature variation, on the environment of increasing socio-economic organization. This is given by the evolution of commercial energy intensity in each economy.

On a large time scale commercial energy intensity dynamics show a first period of increase followed by one of decrease. The change is given by the implementation of new technologies and by a more efficient economic system structure that uses energy to create GDP. Thus in the increasing portion of the energy intensity the economy uses energy not only to ensure its survival, measured by the GDP, but to change its organization into a more efficient one. Once this is done the energy used produces more GDP than before (Purica, 1992). Based on this reasoning the increasing part of energy intensity evolution is proportional to the energy consumed from environment while the following decreasing part is proportional to the level of new more efficient organization i.e. to the lower entropy that this achieves.

2. Irreversible Thermodynamics approach

Considering the two systems: economy and environment interconnected one may write the irreversible Thermodynamics equation to describe the interconnection (Guminski, 1964 and deGroot, 1984). The terms in describing the exchange of material resources are neglected for now.

$dU/dt+TdS/dt=0$

where: dU – energy exchange ; dS – entropy variation ; T - temperature ; t - time

this transforms to:

$T=(dU/t)/(-dS/t)$

Now the increasing part of the energy intensity curve has a positive trend and is proportional to dU/dt and the decreasing part has a negative trend and is proportional to -dS/dt (resulting in a positive dS/dt value). From the Temperature formula above there results a positive temperature value i.e. an increase of temperature of the environment given by the economy evolution toward more efficient production of GDP.

This effect of temperature increase of the environment due to a more efficient organization of the economy has to be compensated in order not to accumulate and lead to the elimination of the local (subsystem) of low entropy.

The compensation may come from the term that we have willingly neglected above i.e. the exchange of material resources between economy and environment. This adds one more term to the above equation:

$dST/dt+dU/dt+\Sigma\kappa_i dm_i/dt=0$

where:
k_i – a constant of each resource i measured in energy per unit of resource; it describes the technologies available for using the said resource;
m_i – the quantity of resource i exchanged

Analyzing this term leads to considering the resources versus the waste treatment in the economic dynamic. The analysis is focused not on absolute values but on variations.

3. Circular economy

For example, to diminish the temperature increase one needs to reduce the new denominator $(dU/dt+ \Sigma\kappa_i dm_i/dt)$. This is done by e.g. reducing the velocity of transfer of primary resources by increasing product use time i.e. -dm/dt.. In economic terms this would mean e.g. to make more durable products with more possibilities to increase their use time by a better maintenance capability in their design and by a better type of service in operation. Also, the recycling of waste may contribute to diminishing the rate of transfer of primary resources from/to the environment. Making steel from scrap metal rather than from ore has an impact both on less primary resource transfer and on the smaller overall consumption of energy for metallurgical production. Moreover, using fuels with a high energy content such as uranium (obviously with the right conversion technologies) is also diminishing the mass transfer.

From the above it results that there is a natural inter-connection of the environment and the organization of the economy (in the sense of reducing entropy and also in increasing its capability to produce more GDP - as a measure of development), in regard to the temperature increase of the environment and transfer of primary resources to the economy system. Moreover, new approaches based on non-equilibrium economics (Berger, 2009) and on nonlinear decision models Purica, 2010) are bringing better instruments to describe the process.

4. Estimating temperature increase

To have an evaluation of the order of magnitude of the temperature increase in the case of no resource transfer, the data from the evolution of energy productivity curves for selected economies are used as presented in Appendix 1. The energy productivity is the reverse of energy intensity so the trend is first downward and then upward. Thinking in financial terms this looks like an investment of energy into a more efficient economy organization that is paid back in energy once the new organizational structure is in place. Thus, in this case, the trend (slope) proportional to energy use is negative and the one proportional to entropy decrease is positive, resulting in the same positive increase of the temperature. Again the Energy Return on Investment (EROI) has been analysed at a technology scale but not at the scale of an economy.

The results are given in *Table 1,* below:

Table 1. **Estimated temperature increase for selected economies** [ºC]

	dU	**dS**	**T=dU/-dS**
USA	-164.17	79.54	2.06
UK	-128.20	114.58	1.11
Germany	-64.10	102.27	0.62
Japan	-48.19	48.19	1.00
Italy	-21.97	40.81	0.53

Source: author's calculations based on data in Appendix 1

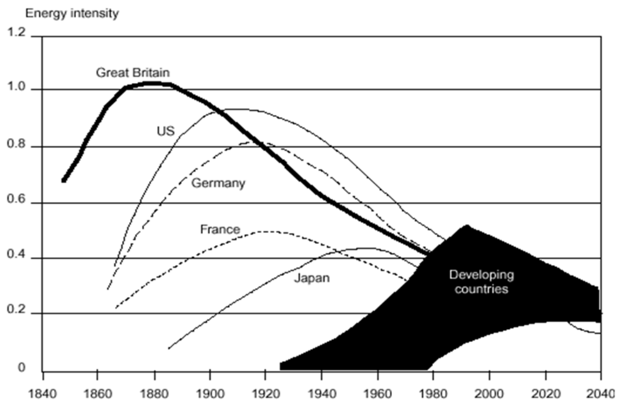
The estimated value of the temperature increase is actually occurring over a period of time that represents, in the 'energy investment for more efficient organization' interpretation, a pay back time for the energy spent to create a better organization. So for the countries selected the estimated payback times are: UK – 160 years; USA – 170y; Germany – 140y; Japan – 80y.

One thing to notice here is the fact that a given temperature increase over a longer time priod is allowing the environment to adapt and absorb it while a fast temperature increase is not. One would be, thus, interested in assessing the environmental resilience limit to a temperature increase velocity beyond which the environment will not be able to absorb the shock.

Related to economic organization and temperature increase one may look at the two figures below where the fact that temperature increase periods are actually happening during the periods of decreasing energy intensity of the large economies. Moreover, during the period of the Second World War and its aftermath of economic reconstruction, the temperature increase stagnated, to start again after the middle of the seventies (with the advent of new more efficient economic activity). A new wave of economies is coming along that may bring more impact on temperature increase if they do not learn from previous experience and if no common action is agreed by everybody. The Paris COP21 (December, 2015) agreement is a promissing start provided it will be applied.

The occurrence in recent years of climate change generated conflicts and the increasing risks of large confrontations that would disorganize economic activity are, obviously, not a solution to generate more ‘anthropic’ entropy that would reduce the increase in temperature.

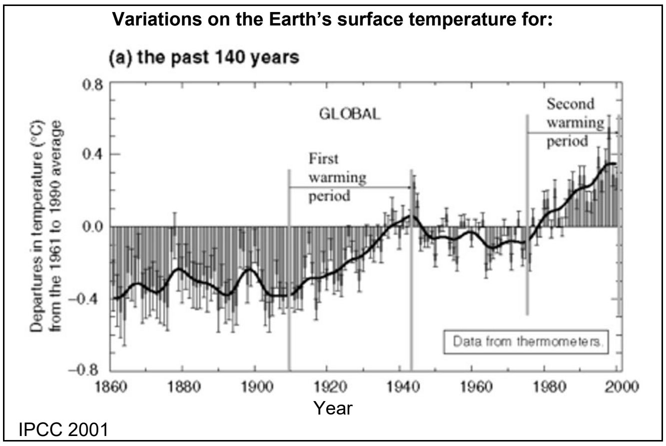
Figure 1. **Energy intensity reported to the British Parliament**



Source: POST UK 2007

Figure 2. **Variation of the Earth’s surface temperature**

The Earth’s surface temperature has risen by about 0.6± 0.2°C in the past century, with accelerated warming during the past two decades



5. Conclusions

The fact that human economies are organizing themselves into more efficient structures that create more GDP per unit of used energy has an effect of diminishing the local system entropy. This generates an increase of the environmental temperature, measurable if an irreversible Thermodynamic model is used to describe the dynamics of energy intensity.

The increase in temperature is evaluated based on the energy productivity (reverse of the energy intensity) data series for selected economies resulting in temperature increases of the same order of magnitude with the measured ones for the last 160 years.
The evolution of the temperature increase shows some dependency on the periods of increased or decreased organization of the economies that should be more extensively analyzed. Also, it is suggested to prepare for the effects of extended conflicts expected to occur from climate change.
One important conclusion is the fact that to compensate for the temperature increase associated to the entropy decrease due to new organization of economies it is important to consider the transfer of resources and management of waste, in such a manner as to diminish the temperature increase effect. Some suggestions are provided on the matter, especially regarding the concept of 'circular economics'.

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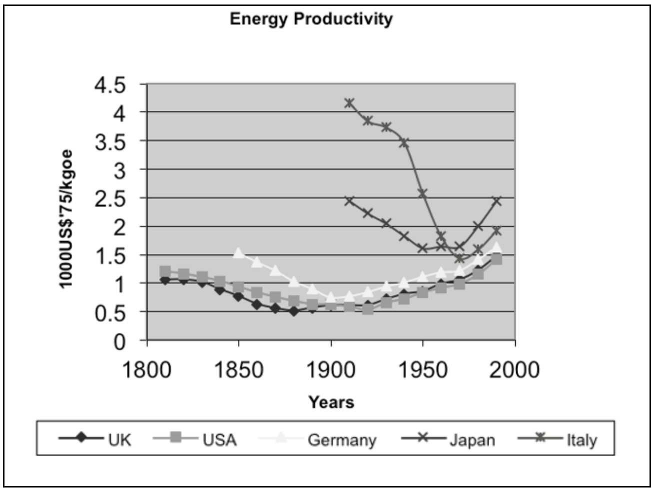
Appendix 1.

Table A1.1. **Energy Productivity of selected economies**

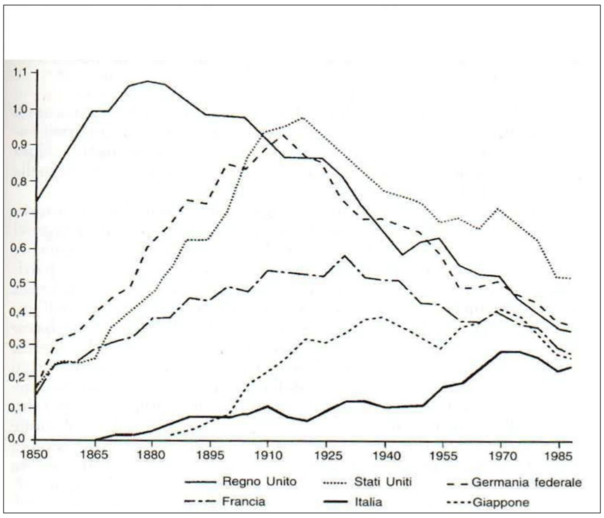
Year	UK	USA	Germany	Japan	Italy
1810	1.056	1.2			
1820	1.053	1.16			
1830	1.01	1.099			
1840	0.88	1.031			
1850	0.76	0.93	1.53		
1860	0.625	0.83	1.37		
1870	0.55	0.75	1.22		
1880	0.51	0.68	1.03		
1890	0.56	0.625	0.9		
1900	0.602	0.619	0.75		
1910	0.603	0.58	0.77	2.44	4.16
1920	0.604	0.53	0.84	2.22	3.84
1930	0.71	0.65	0.94	2.04	3.73
1940	0.8	0.72	1.01	1.82	3.45
1950	0.85	0.83	1.11	1.61	2.56
1960	0.98	0.91	1.19	1.64	1.81
1970	1.052	0.98	1.22	1.64	1.43
1980	1.22	1.15	1.41	2	1.59
1990	1.47	1.41	1.63	2.44	1.92

Figure A1.1. **Energy productivity of selected economies**



Source: Author's calculation based on U.Colombo et.al. 2000 and Martin 1990

Figure.A1.2. **Energy intensities of GDP, selected countries,1850-1990**
(tep/1980 dollars x1000)



Source: Martin, 1990, Tonnelli, 2008

APPLICATION FIELDS OF ARTIFICIAL INTELLIGENCE IN THE ENERGY SECTOR - A SYSTEMATIC OVERVIEW

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Abstract
AI is a promising technology to accelerate the energy transition. Participation shall be enabled by customized products and services, the efficiency shall be increased by a higher degree of automation and a greater utilization of the given assets. Several examples applied in research and the industry can be found, but a structured overview of the application fields of AI in the energy sector, possible development paths and its drivers is missing. By the development of a framework to map the applications and an extraction of application examples from the literature, three superordinate clusters are identified with nine application fields for artificial intelligence in the energy sector.
In the cluster "general foundations for decision-making", applications for predictions, operation and asset optimization support the market integration of renewables and allow a higher utilization and better long-term planning of the grid, generation plants and storages.
In the cluster "maintenance and security", applications enable an efficient, smooth and reliable operation of the grid and of generation assets by predictive maintenance, by assistance services for technical measures and by security measures. The cluster "distribution and consumer services" comprise of applications where benefits for the consumers are created by enabling a better participation at the energy transition. This is done with the help of tailored predictions and optimization advices, customized products and process automation of retailing and customer services.
In general, the most used applications in the energy industry are found in the cluster "general foundations for decision- making", as those are straightforward applications based on advanced data analytics (the so-called narrow AI). Applications based on more advanced AI methods (e.g. different forms of input and output data like video, audio or other physical data- the so-called broader AI) can be found in the other two clusters. For a broader application of AI in the energy industry, the most important bottlenecks referring to a missing work force, needed technology improvements and adaptions of the regulatory framework which have to be addressed.

1. Introduction

With forecasting, scheduling and billing, the energy sector is traditionally a data driven industry developing even further because of digitalization. Existing business models are adapted, and new business models are created, in particular, by linking several stages of the energy value-creation chain. Individual examples for AI applications in the energy sector (especially in research) are widely known. In recent times, examples for planning or process improvements due to artificial intelligence[1] (AI) have emerged. Looking into research publications of AI and comparing the sectors for application of AI, energy had the third largest share of AI-related publications from 1996 to 2016 (OECD 2019).
Therefore expectations of the impact of machine learning algorithms and the application of artificial intelligence are high in the energy sector, but a comprehensive and systematic overview of application fields of artificial intelligence in the energy sector is missing. This gap is addressed[2] with this paper by developing a framework for AI applications in the energy sector based on a literature review and interviews with different stakeholders.

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[1] The most frequently used AI branch is Machine Learning (ML) that deals with algorithms and statistical models that enable computer systems to learn, i.e. that they can perform a given task independently and without direct instructions, e.g. recognising patterns in many examples. In the course of the paper, most AI application refer to ML
[2] The results are part of a report by Klobasa, Pelka and Plötz, which can be downloaded here: https://www.isi.fraunhofer.de/en/competence-center/energietechnologien-energiesysteme/publikationen.html

The main goal is to identify possible impacts of AI applications on the integrated energy transition, the current stage of the development and main drivers and barriers for future development. After explaining the methodology in the second chapter, the AI and energy related categories for the framework are derived from literature and the framework is designed. In the fourth chapter, the application examples are extracted from the literature, assigned into the framework and clustered into application fields to give an overview about the state of AI in the energy sector. The chances, barriers and drivers of the further development of AI are derived from interviews with experts and documented in chapter five. The final chapters are the discussion of the results and conclusion on the main application fields.

2. Methodology

The present application fields are identified by a **literature review** and by conducting interviews with stakeholders. The literature review and the identification of the application fields is done in three steps.

- First, a framework for mapping the present applications is developed. Therefore, categories representing energy and artificial intelligence applications are respectively chosen from the literature. The categories aim to be comprehensive and concise. This is tested incidentally in the second step. If needed, the categories are adapted.
- In the second step, examples from the literature are extracted and filed in the framework. For the examples applied in research, a systematic literature review with peer-review journals is conducted. For the examples applied in the energy industry, also grey literature is screened.
- Third, the applications are clustered into application fields to map the present state and derive trends for AI in the energy sector.

Contextual information about the reasons for mapping and identifying current state of applications is done by complementing qualitative content analysis of the literature and by doing interviews with different stakeholder. With semi-structured interviews, the potential of AI in the energy sector, its barriers and drivers are identified. Five experts in the energy domain who either supply or use AI services are interviewed about their prominent use cases, their implementation, up- and downsides of the AI and lessons learnt. The information from the interview transcripts is extracted in three steps.

- First, a coarse deductive category system is derived from the interview questions. The transcripts are analyzed by assigning information from the transcripts to the categories.
- Second, inductive categories are created based on the assigned information in the categories. With this refined category-system the transcripts is analyzed a second time.
- At the end, the assigned information is aggregated and processed.

3. Design of the framework for mapping AI applications in the energy sector

With the help of the literature analysis, main parameters for the analytical framework are defined, which consists of the categories for the energy and the AI context of the applications.

AI-Categories - Two distinguishing rationales for the AI categories are identified.

- First, Fraunhofer 2018; Backes-Gellner et al. 2019; World Economic Forum 2018 differentiate by the form of the input and output, which can be visual, audible, physical or solely based on data. Physical applications, such as robots, combine visual, audible or elements solely based on sensor data (also called broader AI) and are a more complex and advanced application compared to the others.
- Second, it can be differentiated by the value creation step of AI. According to Hammond

2016, AI asses a certain situation, creates meaning by inferring and responds. For an AI application, those steps occur solely or are combined for a more complex composition.

Energy Categories - For the energy dimension, a common approach is to classify the application according to the energy value chain of generation, transmission, trading and retail. Given the interdependencies of value chain steps, this approach falls short to capture the nowadays complexity of the applications. To address this shortcoming, business model languages are screened. Vu et al. 2019 evaluate different business model languages for business models in the energy transition and highlight the eBusiness Model Schematics by Weill and Vitale 2001, e3value by Gordijn and Akkermans 2001, the value network by Schneider et al. 2016, the Smart Grid Architecture Model (SGAM) by Dänkes et al. 2014 and the ABC model by Schäffler 2018. The SGAM is selected for three reasons.
First, the three-dimensional structure combines technical, economic and processual aspect, which are all relevant for AI applications.

- Second, the modular structure of the interoperability aspects at the z-axis fit to the structure of AI applications.
- Like stated in the previous paragraph, AI application can combine different forms of input and output (visual, audible etc.), steps of value creation (assessing, inferring, responding) or occur solely[3].
- Third, Richard and Vogel 2017 modify the SGAM and propose to mirror the energy value chain steps at the x and y axis to create overlapping fields combining two steps of the energy value chain to express the interdependencies of the value chain steps for new business models in the energy transition.

All in all, the framework is based on the SGAM. For the energy dimension, the energy value network by Richard and Vogel 2017 is used are the x and y axis. Deciding between the two kinds of identified AI categories, the input and output format is selected. The AI categories are general data, audio & speech, image & face, robotics & assistance systems. By these, the kind of application is not only well described, but also the state of development is expressed. Ranking from general data as the most straightforward approach to robotics as a form of broader AI, the advancement is stated.

4. From application examples to application fields

As a starting point, literature is reviewed for AI application examples in the energy sector. Perera et al. (2014), Cheng und Yu (2019), Hossain et al. (2019) and Mosavi et al. (2019) give an overview of examples applied in the energy research. Prediction is identified as a key application for every step of the value chain. For the generation and the grid, AI is used to monitor and increase the utilization of the assets, to choose the capacity and location of future investments and for predictive maintenance. AI supports these decisions not only for large scale assets, but also for small scale assets at the household level. For trading, energy management systems, customer service and billing, AI is used for automation of the processes. Additionally, AI is used to analyze customer data for customized products or marketing measures. Looking at the AI methods, classification approaches are frequently used for the optimization of asset utilization and investments and for predictions regression. For analyzing more complex relations, artificial neuronal networks (ANN) are used.

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[3] The one-dimensional AI is called narrow AI, the multi-dimensional broad AI

By assigning the mentioned examples applied in research and adding examples applied in the energy industry in the framework, nine application fields for artificial intelligence in the energy sector and three superordinate clusters are identified in the framework (see figure 1). The clusters and their applications fields are explained in the following.

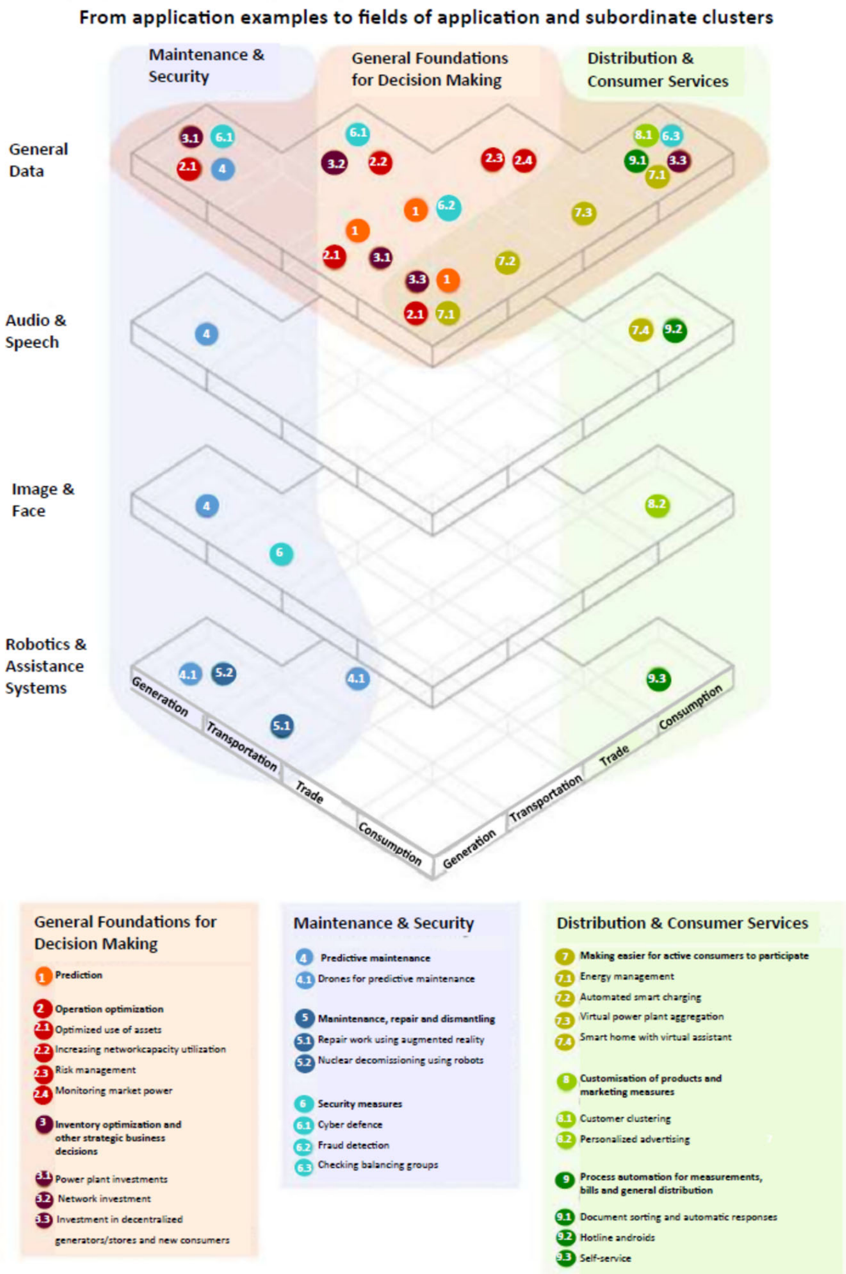

Figure 1: **The AI framework and its application fields for the energy industry**

General foundations for decision-making - the first cluster is called "general foundations for decision-making". It contains the application field prediction, operation optimization and inventory optimization. Predictions can be used for different cases in the energy sector. Especially, predictions of fluctuating renewables with a high regional or temporal resolution identify single peaks more precisely like shown in Sharma et al. 2011 and Crespo-Vazquez et al. 2018. Predictions can be used for short-term (operation) or long-term (inventory) optimization. For instance, Fraunhofer IOSB uses AI for fault detection in the grid and enabling a higher grid utilization (Fraunhofer 2019). Furthermore, in China, a support vector machine approach is being developed for determining network expansion measures in order to estimate measures from 2018 to 2022. Validation with historical data has shown that network expansion measures can be planned with a forecast error of less than 1 percent (Dai, Niu, Han 2018).

Maintenance and security - the second cluster is called "maintenance and security". It comprise the maintenance planning based on measured data instead of regular terms, the so called predictive maintenance. GE states that the average annual cost for unplanned operating breakdowns of approximately $49 million for offshore oil and gas platform can be halved by predictive maintenance (CXP Group 2018). The other two application fields are the operational assistance for maintaining, repairing or dismantling assets and security measures[4].

Distribution and consumer services - in the last cluster "distribution and consumer services", benefits for the consumers are created from three angles. First, they are enabled to contribute to the energy system by improved energy services. With the high automation degree of AI, prediction and optimization services cannot only be used for large scale assets, but also for small scale generators and household consumers, which would not be economically feasible otherwise. Examples are MacDougall et al. 2016; Lopez et al. 2019; Valogianni 2016; Jurado et al. 2015. Furthermore, the processes for billing and customer services become faster and leaner by automation and the products and marketing measures become more customized.
All in all, two states of AI can be identified for the three clusters. Whereas the cluster "general foundations for decision making" is concentrated at the general data layer and broadly distributed in the energy dimension, the other two clusters have a high concentration on one side of the energy value network and combine different AI application groups. The first cluster which use only one AI application group (also called "narrow AI") is more established in the industry than the others. In contrast to that, the other two show more sophisticated applications that make use of several AI application groups. It is expected that further applications using multiple dimensions of the framework will be established in the future. Which application fields are expected by the experts of the interview and which barriers they face to evolve the described potential is shown in the following paragraphs. The chances, barriers and drivers are differentiated by work force, technology and regulatory framework.

5. Chances, barriers and drivers of AI in the energy sector

Chances, barriers and drivers of AI in the energy sector are extracted from the literature in the first step and then contrasted with the results of the interviews. Khashei und Bijari 2011 and MacDougall et al. 2016 summarize the up- and downsides of AI in contrast to conventional statistical methods, such as time series regressions with ARIMA (Auto Regressive Integrated Moving Average) in three points.

[4] for a more detailed description, please check the report by Klobasa, Pelka and Plötz, which can be downloaded here: https://www.isi.fraunhofer.de/en/competence-center/energietechnologien-energiesysteme/publikationen.html

First, AI can identify non-linear developments, but especially for ANN, the results are not traceable from the model run. Second, the model is based on data. Therefore, it is independent from the limited or specific knowledge and bias of the editor. Third, it is robust towards single missing data in a time series. At the same time, a multitude of data is needed for creating the model. Additionally, Döbel et al. 2018 highlight the high computational power and training time that is needed for creating and running the model. In the case of Makridakis et al. (2018), a double computational power is needed for ANN compared to ARIMA. At the same time, once a model is developed, the model runs can be highly automated. Whereas the mentioned points by the literature mainly concerned technology aspects, the interviewed experts also mentioned barriers and drivers concerning the work force and the regulatory framework. The results of the interviews are presented in the following divided by work force, technology and regulatory framework.

Work force - the experts name three barriers that hinder the widespread use of AI. First, prejudice towards AI (e.g. replacing human work force) lead to resistance of the employees. Second, hierarchical structured companies tend to be skeptical towards adapting innovations such as AI, especially when AI takes part of the decision making process and interfere management competencies. Lastly, it is challenging for so far non-AI-users to identify the cases in which the additional effort of AI (e.g. longer training, higher computational power) results in a great added value (e.g. more precise prediction, time saving due to automation). Based on the interviews and the literature analysis, four key prerequisites for using AI can be derived:

- *Complexity*: The causalities of the parameters are not explicit.
- *Regularity*: The decision is made frequently.
- *Data benefit*: Sufficient historical data for the training of the algorithms is available.
- *Data volume*: Sufficient new data is available to be processed in the application.

To tackle the three barriers, a corporate culture must be created that encourages innovation, educate and highlight the potential of AI.

Technology - a pivotal aspect for the adaptation of AI is the availability of data. From the technical perspective, two barriers are identified. First, data is not collected at points of a high informational content. In this sense, data collection does not necessarily be pervasive, but it needs to be done at characteristic points of the given environment. In a project of one interviewed expert, sensors are only installed at 5 to 10 percent of the grid nodes to track the utilization, as the precise utilization of the low voltage grid was not monitored before. Second, the data is available but fragmented in different formats, at different platforms or at a low quality. Unified standards, platforms or interfaces at the company level or national wide help to tackle this bottleneck.
Two aspects of the literature analysis were not prominently mentioned during the interviews. First, as rather simple AI approaches are in use (e.g. regression and classification), the limited traceability of ANN is a minor subject for the experts at the moment. Second, the experts state that for most applications the computational power is not a bottleneck. This could change, if they move from simple regression and classification methods to approaches of broader AI. Whereas additional computational power is well accessible via cloud services, the retrofit of special hardware (e.g. for image processing) is effort and cost intense and need to be planned.

Regulatory framework - no collected data or fragmented data is also an issue in the regulatory context. Open data approaches would help to have sufficient data available for training of the algorithms, but it must be carefully examined to what extent this is allowed by

German data protection guidelines. For instance, standards for anonymizing private data or unified transparent data classes as a guideline for data business cases can be established to accelerate the process. In case of limited available data in the distribution grid, more investment security for additional sensors should be guaranteed. The usage of smart meter data can also contribute to a more transparent low voltage grid.

6. Discussion

The interviews confirm the application fields of AI that have already been discovered by the literature analysis. This is
also the case for most of the drivers and barriers. So far, the focus of implementation in the industry has been set on simpler AI methods. Therefore, the industry does not face some of the major problems found for applications in an early development stage discussed in the research literature (e.g. limited traceability and computational power). Further research is needed to limit the impact of these bottlenecks, before the approaches can be applied in the energy industry. At the same time, the industry can collect experiences with AI applications to better understand and address these problems to enable a smooth transition.

The framework is a first snapshot of the current situation and should be extended with new applications and updated in the future to integrate the further development of AI methods. It is recommended to repeat the screening and clustering of application and integrate it in the framework after some years. At the same time, the interviews can be updated with new and a greater number of experts.

7. Conclusions

Overall by using AI in the energy sector, the three clusters "general foundation for decision-making", "maintenance and
security" and "distribution and consumer services" show potential for a higher degree of automation and more detailed analysis at the same time. This enables a higher level of utilization of the given assets and raising new potentials along the entire value chain. The state of the art research and applications in the energy sector focus either on narrow AI applications or on one step in the energy value chain respectively energy value network. In the future, application can be based on more dimensions of the framework, if the highlighted bottlenecks referring to the work force, the technology and the regulatory framework are addressed.

Several future research questions occur that have to be addressed like “How can AI contribute to more sustainability and environmental protection?”. To answer this question the related business models, relevant actors and the underlying data economy have to be better understood. Also expectations of the society as a whole and ethical guiding principles should be considered and developed further in the future to allow the usage of a broad range of data.

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THE HISTORY COULD REPEAT ITSELF: HYDROGEN-OXYGEN FUEL CELL IS THE ‘GAME CHANGER’[1]

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Overview

20 July 2019 marked the 50th anniversary of the moon landings, and while most of us are very familiar with the iconic scenes of this ‘giant leap for mankind’, many of us are completely unaware that the hydrogen-oxygen fuel cell invention made Neil Armstrong’s ‘small step’ possible. “Without you, we would not have gotten to the moon” said President Richard Nixon to Francis Thomas Bacon, referring to Bacon’s invention of the first practical hydrogen-oxygen fuel cell. The Bacon hydrogen-oxygen fuel cell was been the ‘game changer’ and made Neil Armstrong’s ‘small step’ possible.

During last 50 years a tremendous technological progress are made in all fields, also in the field of hydrogen-oxygen fuel cells and hydrogen has seen several waves of interest, none of which fully translated into rising, sustainable investment. For long time hydrogen and fuel cells has seemed to be a Cinderella in energy, transport and climate change debates and only recently this low-carbon solution has had a strong comeback in energy portfolio options and now it is considered as one of possible ‘game changer’.

From longtime I underlined the possible relevant implication of hydrogen and fuel cell use in stationary and transport applications and, in recent years I presented works in which I argued that it’s time to consider Fuel Cell Vehicle (FCV) as a relevant possible low-carbon solution in energy debate. The electricity produced by a hydrogen fuel cell can be used both for stationary and transport application. In fact the Hydrogen Fuel Cell Powertrain (H_2FCPowertrain) or, in other words, the propulsion system of a FCV, is a small power generation plant, typically the size is around 100 kW. In the coming years the high volume associated with the possible FCVs mass production will permit to reduce dramatically the FC system manufacturing costs, in order to be competitive with gasoline in hybrid-electric vehicles. In a mass production perspective H_2FCPowertrain will be so cost competitive to be useful adopted also for stationary power generation application, also in LCOE terms.

From 2010 I wrote, presented and published studies where I compared the H_2FCPowertrain LCOE, based on the U.S. Department of Energy (DOE) public data, with the traditional power generation technologies with very promising results, in the U.S. context and in many other contexts around the world. From 2017 in my analysis I use also the International Energy Agency (IEA) public data for the H_2 production costs.

In this paper, starting from the conclusions of my 2018 *“Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5°C Perspective”* (M.V. Romeri, 2018), I analysed the most recent published data and elaborated other considerations in light of: the ‘climate emergency’ highlighted by Greta Thunberg; the Holy Father Francis’ warnings, exhortations and initiatives on climate change and ecological crisis; the launch of the ‘EU Green Deal’ by new President of the European Commission Ursula von der Leyen.

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[1] Presented at *4th AIEE Energy Symposium on “Current and Future Challenges to Energy Security”* Rome, Lumsa University, 11 December, 2019. Presentation available at: <http://www.aieeconference2019rome.eu/files/ROMERI.pdf >.

This analysis confirmed, in LCOE terms, the economic advantage 'to consider an H_2FCPowertrain as power generation plant' and explained related possible long-term effects in power generation, but this option has still not been considered.

According to Intergovernmental Panel on Climate Change (IPCC) "*Special Report on Global Warming of 1.5°C"* (SR15): "in the next few years it will be necessary to start unprecedented changes and to speed up CO_2 emissions reduction. … For these reasons next few years are probably the most important in our history" (IPCC, 2018).
The history could repeat itself. In 1969 the hydrogen-oxygen fuel cell invention made Neil Armstrong's 'small step' possible. Today, the 'state of the art' hydrogen-oxygen fuel cells seems to be able to be, in next future, the 'game changer' against the 'climate emergency', to play a relevant role in the 'economy of tomorrow' and maybe to be a new 'giant leap for mankind'.

2019: the 50th anniversary of the moon landings
Saturday 20 July 2019 marked the ***50th anniversary of the moon landings***, and while most of us are very familiar with the iconic scenes of this **'giant leap for mankind'**, many of us are completely unaware that **the hydrogen-oxygen fuel cell invention made Neil Armstrong's 'small step' possible. "Without you, we would not have gotten to the moon"** said President Richard Nixon to Francis Thomas Bacon, referring to Bacon's invention of the first practical hydrogen-oxygen fuel cell. The Bacon fuel cell was perfect for powering NASA's spacecraft: it was lighter and much less bulky than batteries of the time, it was more efficient than 1960's solar panels, and hydrogen and oxygen were already going to be on board the ship for use as rocket fuel. What's more, the only waste product from the reaction was water – needed on Apollo 11 for the astronauts to drink (University of Cambridge, Dept. of Chemical Engineering and Biotechnology, 2019 July, E. Hall).

Hydrogen is today enjoying unprecedented momentum
During last 50 years a tremendous technological progress are made in all fields, also in the field of hydrogen-oxygen fuel cells. Hydrogen has seen several waves of interest in recent history, none of which fully translated into rising, sustainable investment.
For long time hydrogen energy vector and fuel cells technologies seem to be a Cinderella low-carbon solution in energy, transport and climate change debates but recently something happened. As I pointed out in my 2018 study (cit.) "in recent years **this low-carbon solution has made a strong comeback in energy portfolio options and it is considered as one of possible 'game changer'"**.
This fact was confirmed during 2019. In June at the **Japan's G20** (G20 Osaka, 2019 and G20 Energy Karuizawa, 2019) and with the publication of the **IEA** report *"The Future of Hydrogen"* (IEA, 2019a). According to Fatih Birol words: "**Hydrogen is today enjoying unprecedented momentum. ... The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future**" (IEA, 2019b, F. Birol).
In September IRENA presented the report *"Hydrogen: a Renewable Energy Perspective"* (IRENA, 2019a) prepared for the 2nd Hydrogen Energy Ministerial Meeting (METI, 2019) and underlined that **"Hydrogen has emerged as an important part of the clean energy mix needed to ensure a sustainable future"** (IRENA, 2019b**).**

Considering H_2FCPowertrain as a Power Generation Plant
From longtime I underlined the possible relevant implication of Hydrogen and Fuel Cell use in stationary and transport applications and, in recent years I presented different works in which I argued that it's time to consider Fuel Cell Vehicle (FCV) as a relevant possible low-carbon solution in energy debate.
The electricity produced by a Hydrogen Fuel Cell can be used both for stationary and transport application and the traditional model to link transport to energy sector is the Vehicle-to-Grid

(V2G) approach. I think that it is time to consider this link not only in a V2G approach but in another perspective, more direct, relevant and disruptive.
The H_2FCPowertrain or, in other words, **the propulsion system of a FCV, is a small power generation plant** (typically 100 kW, or 80kW$_{net}$). **In the coming years the high volume associated with the possible FCVs mass production will permit to reduce dramatically the FC system manufacturing costs, in order to be competitive with gasoline in hybrid-electric vehicles. In a mass production perspective, H_2FCPowertrain will be so cost competitive to be useful adopted also for stationary power generation application, also in LCOE terms. In this perspective it will be possible to consider the H_2FCPowertrain as a power generation plant.**

Considering H_2FCPowertrain as a Power Generation Plant: LCOE Analysis
Today Energy Sector is capital intensive and characterized by long-term investment. **Investment costs** are probably most important element in any investment decision also in power generation. They vary greatly from technology to technology, from time to time and from country to country. **Overnight cost** is a common unit of measure of power investments. Overnight cost is the cost of a construction project if no interest was incurred during construction, as if the project was completed 'overnight'.
Levelized Costs of Generating Electricity (LCOE) is as a handy tool to analyze generation costs and to compare the unit costs and the overall competiveness of different generating technologies. Focus of estimated average LCOE is the entire operating life of the power plants for a given technology. In LCOE model different cost are taken into account: capital costs, fuel costs, O&M costs, decommissioning costs and so on.

In order to calculate the H_2FCPowertrain LCOE it is necessary to know some specific data: system cost and efficiency, expected system lifetime and fuel cost (i.e. hydrogen production cost). This analysis is based on DOE and IEA public data.

The U.S. DOE Fuel Cell Data[2]
In my 2018 study (cit.) I presented these DOE data**: "Current Status (2017) - 80-kW$_{net}$ PEM 11FC System:** Overnight cost, 45 USD/kW (at 500k units/year; 50 USD/kW at 100k units/year; 179 USD/kW 1k units/year); 52% System efficiency; Lifetime, 4,100 hours; Hydrogen cost: 5 UDS/kg-GGE (based on natural gas steam reforming, high volume projection; including: production, delivery & dispensing) (DOE, 2017)." and "**2020 DOE technical targets**: Overnight cost, 40 USD/kW (at 500k units/year); 60% System efficiency; Lifetime, 8,000 hours; Hydrogen cost, 4 UDS/kg-GGE (same assumptions of current status) (DOE, 2016 and 2017)".

The 2019 DOE data[3] **present three main difference from the previous year**: **the closest 'target year' move from 2020 to 2025** and the ultimate target date remains indefinite; **the available 2018 'cost analysis' is not adjusted to account for durability,** see data in the next left DOE figure (DOE 2019a, D. Papageorgopoulos); **only one 2018 data is a 'preliminary durability-adjusted' cost**; see the next right DOE figure (idem).

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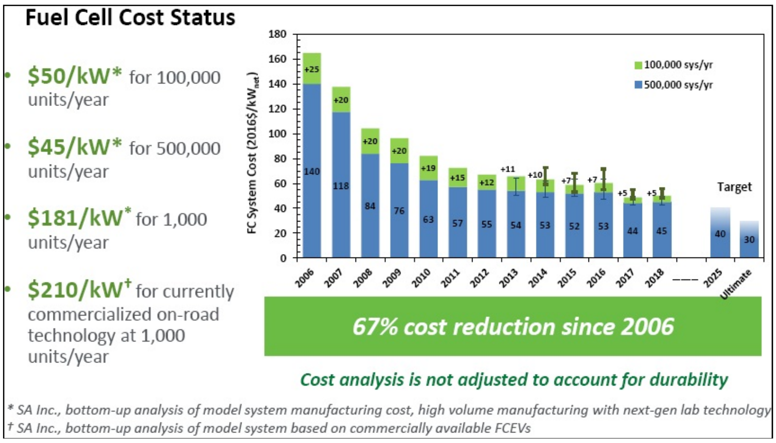
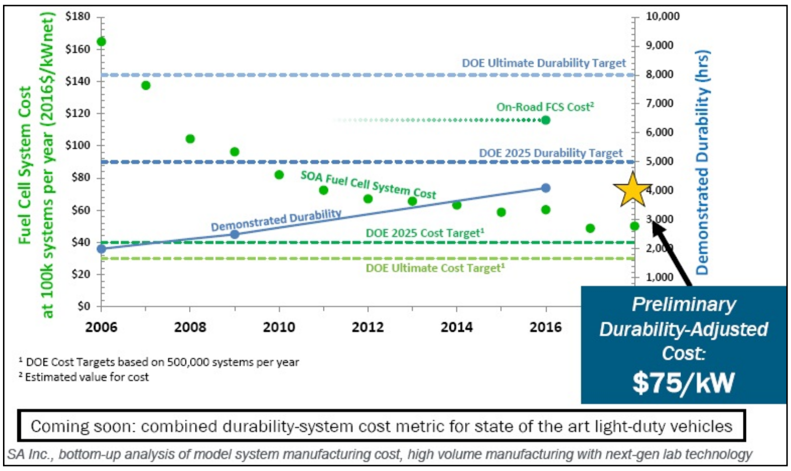
[2] Key numbers and facts are often cited or referenced by the DOE Hydrogen and Fuel Cells Program in its materials. To document the source of these numbers or facts DOE Hydrogen and Fuel Cells Program has developed and published specific 'Program Record' to explain the inherent assumptions, source data, and calculation methodologies. These records are being updated almost annually and are accessible at <https://www.hydrogen.energy.gov/program_records.html>. From 2007 to 2017 (November) it was published annually the *"Fuel Cell System Cost"* 'Program Record'. In 2006, 2012, 2015 and 2016 (November) it was published the *"Fuel Cell Stack Durability"* Records.
[3] In 2019 all the DOE Fuel Cell System data came from DOE presentation and not from specific 'Program Record'. Probably additional Records are being updated and they will be published upon their approval on the web but, until 15 January 2020, the data used are the most updated available.





Current Status (2018) - 80-kW$_{net}$ PEM FC System: Overnight cost: 45 USD/kW at 500k units/year; 50 USD/kW at 100k units/year or 75 USD/kW, based on preliminary durability-adjusted cost (DOE 2019b, S. Satyapal) and 181 USD/kW at 1k units/year (210 USD/kW for currently commercialized on-road technology). Data in previous DOE figures (DOE 2019a, D. Papageorgopoulos).

Fuel Cell Targets and Status

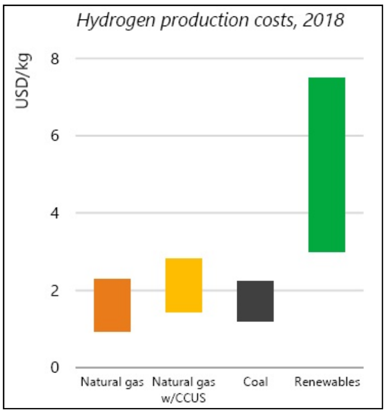
Application	Power (kW)	Cost ($/kW)	Durability (h)	Performance
Light-duty vehicles	80	30 75* 120*	8,000 5,000 4,100	70% efficiency, ≤0.125 mg_{PGM}/cm^2 ~0.35 mg_{PGM}/cm^2

Green: target; black: lab-demonstrated tech; blue: on-road/installed tech
*Projected system cost for 100,000 units/year

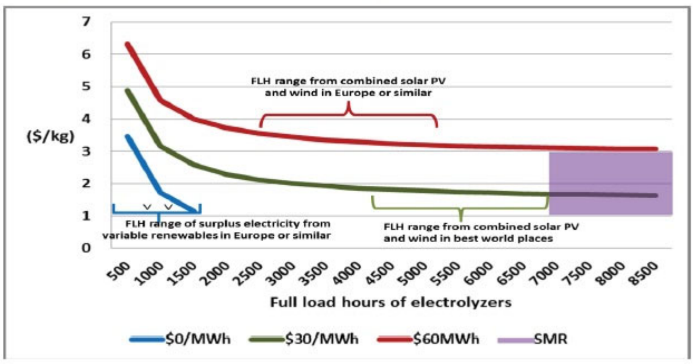
2025 DOE technical targets not adjusted to account for durability (DOE 2019a, D. Papageorgopoulos): Overnight cost, 40 USD/kW (at 500k units/year); 65% System efficiency; Lifetime, 5,000 hours.
DOE Technical Targets and Status (DOE 2019b, S. Satyapal)**. Ultimate target**: Overnight cost 30 USD/kW at 500k units/year; 70% System efficiency; Lifetime 8,000 hours. **Lab-Demonstrated Technology**: 75 USD/kW at 100k units/year; Lifetime 5k hours. **On-Road/Installed Technology**: 120 USD/kW at 100k units/year; Lifetime 4,100 hours. Data in right DOE figure (DOE 2019b, S. Satyapal).

The IEA Hydrogen Production Costs Data

Considering the fact that DOE hydrogen data including ‘production, delivery & dispensing’ costs, from 2017, I started to use the IEA hydrogen production costs presented in *“Producing ammonia and fertilizers: new opportunities from renewable”* (IEA 2017, C. Philibert) and, according to Philibert: “Thanks to the recent cost reductions of solar and wind technologies, ammonia production in large-scale plants based on electrolysis of water can compete with ammonia production based on natural gas, in areas with world-best combined solar and wind resources” and “similar hydrogen prices could be reached in countries with lower-quality renewable resources if “surplus” electricity is considered free”. Data in next left IEA figure (IEA 2017, C. Philibert).



Cost of hydrogen from electrolysers at USD 450/kW Capex for different electricity costs and load factors.



Assumptions: Capex of electrolysers $ 450/kW (NEL 2017), WACC 7%, lifetime 30 years, efficiency 70% (IEA 2015); cost of hydrogen from SMR $ 1 to 3/kg H_2.depending on natural gas prices.

The IEA hydrogen production costs data-range is 1-4 UDS/kg-GGE and includes both hydrogen from natural gas steam reforming and hydrogen from electrolyzes, for different electricity costs and load factors. This data-range is confirmed in 2018. Data in next right IEA figure (IEA 2019c, M. Wörsdörfer).

The H_2FCPowertrain LCOE

In my 2018 study (cit.) combining 2017 DOE fuel cell data and 2017 IEA hydrogen production costs I found that **2020 H_2FCPowertrain LCOE value-range, projected at a mass production level of 500k FCV/year, would be 55,5-205,5 USD/MWh**[4]. All data are in next table.

H2FC Powertrain Levelised Cost of Electricity (USD/MWb)								
Efficiency	LIFE Hours	IEA Hydrogen Cost USD/kg-GGE^	Capital Overnight Cost USD/kW	Levelized Capital Cost LCC USD/MWh	O&M+ Others (Assumed Equal to 10% LCC) USD/MWh	Fuel Cost USD/MWh	LCOE USD/MW h	ASSUMPTIONS
60%	S000	4,0	40,0	5,0	0,5	200,0	205,5	2020 DOE Targets (2017) & H2 IEA (201T)
60%	S000	3,0	40,0	5,0	0,5	150,0	155,S	2020 DOE Targets (2017) & H2 IEA (201T)
60%	S000	2,0	40,0	5,0	0,5	100,0	105,S	2020 DOE Targets (2017) & H2 IEA (2017)
60%	S000	1,0	40,0	5,0	0,5	50,0	55,5	2020 DOE Targets (2017)& H2 IEA (2017)

^Production costs: H_2 from natural gas steam reforming and H_2 from electrolizers (for different electricity costs and load factors)

In 2019, combining new DOE fuel cell data and IEA hydrogen production costs I found that 2025 H_2FCPowertrain LCOE value-range, projected at a mass production level of 100k FCV/year, would be 62,7-201,1 USD/MWh[5]. All data are in next table.

H_2FC Powertrain Levelised Cost of Electricity (USD/MWh)								
Efficiency	LIFE Hours	IEA Hydrogen Cost USD/kg-GG E^	Capital Overnight Cost* USD/kW	Levelized Capital Cost LCC USD/MWh	O&M+Others (Assumed Equal to 10% LCC) USD/MWh	Fuel Cost USD/MWh	LCOE USD/MWh	ASSUMPTIONS- REFERENCES
65%	5000	4,0	75,0	15,0	1,5	184,6	201,1	2025 DOE Targets (2019a,b) & H2 IEA (2017, 2019a,c)
65%	5000	3,0	75,0	15,0	1,5	138,5	155,0	2025 DOE Targets (20 l9a,b) & H2 IEA (2017, 201 9a,c)
65 %	5000	2,0	75,0	15,0	1,5	92,3	108,8	2025 DOE Targets (2019a,b) & H2 IEA (2017, 2019a,c)
65%	5000	1,0	75,0	15,0	1,5	46,2	62,7	2025 DOE Targets (20l9a,b) & H2 IEA (2017, 201 9a,c)

^Production costs: H2 from natural gas steam reforming and H2 from electrolizers (for different electricity costs and load factors)
*Capital Overnight Cost: Assumed Equal to DOE 2018 data(75 USD/kW, based on preliminary durability-adjusted cost, projected system cost at 100k units/year)

The U.S. Energy Information Administration (EIA) Levelized Cost of New Generation Resources

Based on new projected mass-production volume assumption of 100k FCV/year (compared to the 500k FCV/year) the **2025 H_2FCPowertrain LCOE value-range would be 62,7-201,1 USD/MWh** and, for the lower value of this range, it appeared competitive with many of the U.S. power generation technologies analyzed by the U. S. EIA that annually realizes forecast about Overnight Costs and LCOE in the *Annual Energy Outlook*[6]. So, **in favorable conditions of hydrogen production costs, H_2FCPowertrain seems to be useful to be adopted also for stationary power generation application.** LCOE data for different plant types for the period

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[4] It is interesting to note that, in 2018, the LCOE value-range is mainly due to the hydrogen production costs that impact for 50-200 USD/MWh.

[5] It is interesting to note that, also in this study, the LCOE value-range is mainly due to the hydrogen production costs that still impact for 46-185 USD/MWh, less than in 2018 analysis, due to the DOE forecasted growth from 60% to 65% of fuel cell system efficiency.

[6] In the mid 70's EIA began publishing the *Annual Energy Outlook* (AEO) in which, annually, presents a forecast and analysis of U.S. energy supply, demand, and prices. Since 1996 AEO considers and realizes forecast about Overnight costs and LCOE. Fuel Cells technologies were mentioned and included in EIA documents since 1994, but EIA never provided data about the Fuel Cells LCOE. From 2010 the LCOE data for Central Production Power Plant are published in a separated document *Levelized Cost of New Generation Resources from the Annual Energy Outlook* and revised annually. In 2014 EIA introduced the new concept of "Levelized" Avoided Cost of Electricity (LACE) that provides an estimation of the value of build the new capacity. by considering the avoided cost, a measure of what it would cost the grid to generate the electricity that would be displaced by a new generation project. Estimating avoided costs is more complex than estimating levelized costs because it requires information about how the system would operate without the new option being considered. I don't take it in consideration.

2014-2019 and Overnight Costs for years 2014-2018 are in next table (EIA, 2019a and EIA, 2019b).

Tbe U.S. LCOE of New Generation Resources from the EIA Annual Energy Outlook 2014-2019
(Plants Entering Service** in **2022-2023)

Plant Type	2014 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2014 (USD/kW 2013)	2015 Capaciy Factor (%)	2015 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2015 (USD/kW 2014)	2016 Capaciy Factor (%)	2016n.s. Total LCOE (USD/MWh)	Overnight Cost in 2016 (USD/kW 2016)	2017 Capacity Factor (%)	2017 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2017 (USD/kW 2017)	2018 Capaciy Factor (%)	2018 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2018 (USD/kW 2018)	2019 Capaciy Factor (%)	2019 n.s. Total LCOE (USD/MWh)
Conventional Coal	**95,7**	2726	85	**95,1**												
Advanced Coal IGCC	**115,9**	3483	85	**115,7**												
Advanced Coal IGCC ,with	**147,4**	5891	85	**144,4**	5098	85	**13, 95**	4586-5072	85	**123-140**	4641-5132	85	**119-130**	4713-5212	85	**98,6-104**
CCS Conventional Gas	**66,3**	869	87	**75,2**	956	87	**58, 1**	923	87	**57,3**	935	87	**50,1**	952	87	**46,3**
Combined Cycle Advanced Gas	**64,4**	942	87	**72,6**	1080	87	**57,2**	1013	87	**56,5**	1026	87	**49,0**	736	87	**41,2**
Combined Cycle Advanced Gas	**91,3**	1845	87	**100,2**	2132	87	**84,8**	1917	87	**82,4**	1936	87	**74,9**	1963	87	**67,5**
Combined Cycle ,with CC'	**128,4**	922	30	**141,5**	922	30	**110,8**	1040	30	**109,4**	1054	30	**98,7**	1072	30	**89,3**
Conventional Combustion Gas	**103,7**	639	30	**113,5**	664	30	**94,7**	640	30	**94,7**	648	30	**85,1**	658	30	**77,7**
Turbine Advanced Combustion	**96, 1**	4646	90	**95,2**	6108	90	**102,8**	5091	90	**99, 1**	5148	90	**92,6**	5224	90	**77,5**
Gas Turbine Advanced Nuclear	**47,8**	2331	92	**47,8**	2331	91	**45,0**	2331	91	**46,5**	2615	90	**44,6**	2654	90	**41,0**
Geothermal	**102,6**	3399	83	**100,5**	3498	83	**96, 1**	3540	83	**102,4**	3584	83	**95,3**	3642	83	**92,2**
Biomass																
Fuel Cells		*604 2*			*7181*			*6252*			*6192*			*6250*		
Wind	**80,3**	1850	36	**73,6**	1536	40	**64,5**	1576	39	**63,7**	1548	41	**59, 1**	1518	41	**55,9**
Wind - Offshore	**204,0**	4476	38	**196,9**	4605	45	**158,1**	4648	45	**157,4**	4694	45	**138,0**	4758	45	**130,4**
Solar PV	**130,0**	3787	25	**125,3**	2362	25	**84,7**	2169	24	**85,0**	1763-2004	29	**63,2**	1698-1876	29	**60,0**
Solar Thermal	**243,1**	3123	20	**239,7**	3895	20	**235,9**	3908	20	**242,0**	3952	25	**165,1**	4011	25	**157,1**
Hydro	**84,5**	2651	54	**83,5**	2191	58	**67,8**	2220	59	**66,2**	2634	64	**61,7**	2680	75	**39, 1**

* ns= no subsidy

Possible Long-Term Effects in the Power Generation Sector

As I underlined in my 2018 study (cit.): "**Thanks to the introduction and use of H_2FCPowertrains as power plants,** considering the low level of Overnight Cost, **it seem to be possible to think that the present capital intensive profile of the Power Generation Sector could change gradually. In terms of plant Lifetime,** the H_2FCPowertrain appears poor (also considering the DOE target of 8000 hours lifetime) if compared either to the other generation technologies or to the U.S. DOE CHP target (80000 hours). But, in a long term investment perspective, it is possible to foresee a planned replacement of the H_2FCPowertrain stack at the end of each lifetime at a cost that is estimated around 42% of the whole system (and this, without taking into account the value of recoverable Platinum from the exhaust stack). **Thanks to the introduction and use of H_2FCPowertrains as power plants it seems to be possible also to think that the present long-term investment profile of the Power Generation Sector could change gradually"**.

These disruptive long-term possible effects are confirmed in the present analysis.

Three Icons of 2019:

Greta Thunberg

During 2019 **Greta Thunberg**[7] has had the ability to attract attention, raise awareness and create a new conscience in millions of young people and in their parents against the challenge of climate change, united behind the science[8].

Greta Thunberg first highlighted the 'climate emergency' and clearly described it also in her speech at the United Nations (UN) Climate Action Summit: **"To have a 67% chance of**

[7] Greta Thunberg first became known in August 2018 when, at age 15, she began spending her school days outside the Swedish parliament to call for stronger action on climate change. Soon, other students engaged in similar protests in their own communities. Together, they organised "Fridays for Future" a school climate strike movement.

[8] In March 2019 Greta Thunberg published in social medias ***"A list of rules and recommendations for all those on school strike for the climate"*** an impressive message to young students: **"No violence. No damage. No littering. No profit. No hate. Minimise your carbon footprint. Always refer to science. Our demand: Follow the Paris Agreement and the IPCC report. Stay below 1,5°C. Focus on the aspect of equity and climate justice, clearly stated throughout the Paris Agreement. Because no manifesto can be more radical than that. Unite behind the science"** (Greta Thunberg, 2019 March).

staying below a 1.5°C[9] temperature rise the world had 420 gigatons of CO_2 left to emit back on Jan. 1st, 2018. Today that figure is already down to less than 350 gigatons. … **With today's emissions levels, that remaining CO_2 budget will be entirely gone within less than 8 1/2 years.** … There will not be any solutions or plans presented in line with these figures here today, because these numbers are too uncomfortable. … **Change is coming, whether you like it or not"** (UN, 2019).

Holy Father Francis

During 2019 **Holy Father Francis** continued and intensified his commitment[10] to take urgent action against the injustice of climate change and the ecological crisis started in 2015 with his encyclical letter *Laudato Si*' (Holy Father Francis, 2015).

According to **Holy Father Francis** words: "In 2015, the COP 21 adopted the Paris Agreement, the implementation of which 'will require concerted commitment and generous dedication by each one'. Its rapid entry into force, in less than a year, showed a growing awareness of **the importance and need to 'work together in building our common home'.** … **But current commitments** made by States to mitigate and adapt to climate change **are far from those actually needed to achieve the goals.** … **Numerous studies tell us that it is still possible to limit global warming. To do this we need a clear, far-sighted and strong political will**, set on pursuing a new course that aims at refocusing financial and economic

[9] **The 'Paris Agreement 1.5°C Perspective'** is stated by Article 2 of the *"Paris Agreement"* (UNFCCC, 2015) and the first assessment of his global implications was published in 2018 by IPCC with the *Special Report on 'Global Warming of 1.5°C'* (IPCC, 2018). **Main difference between *'below 2°C'* and *'1.5°C'* perspectives are the timelines.** Simplifying data, according to IPCC *SR15* in order to limit global warming to *'1.5°C'* CO_2 emissions need to decline by about 45% by 2030, reaching net zero around 2050. For limiting global warming to *'below 2°C'* CO_2 emissions are projected to decline by about 25% by 2030, and reach net zero around 2070. **"Limiting warming to 1.5°C is possible** within the laws of chemistry and physics **but doing so would require unprecedented changes"** and, for this reason "**the next few years are probably the most important in our history"** (IPCC, 2018).

[10] During 2019, in addition to many other words, comments and speech done in several other circumstances and/or moments of prayer, Holy Father Francis made: **8 March**, address to participants at the conference on *"Religions and the Sustainable Development Goals (SDGS): Listening to the Cry of the Earth and of the Poor"* <http://w2.vatican.va/content/francesco/en/speeches/2019/march/documents/papa-francesco_20190308_religioni-svilupposostenibile.html>; **25 March**, post-Synodal Apostolic Exortation *"Christus Vivit. To young people and to the entire people of God"* <http://w2.vatican.va/content/francesco/en/apost_exhortations/documents/papa-francesco_esortazione-ap_20190325_christus-vivit.html>; **1 May**, letter for the event *'Economy of Francesco'* [Assisi, March 2020], <http://w2.vatican.va/content/francesco/en/letters/2019/documents/papa-francesco_20190501_giovani-imprenditori.html>; **27 May**, speech at the meeting *"Climate Change and New Evidence from Science, Engineering, and Policy"* <https://press.vatican.va/content/salastampa/it/bollettino/pubblico/2019/05/27/0454/00933.html>; **14 June**, address to participants at the meeting promoted by the Dicastery for Promoting Integral Human Development on the Theme: *"The Energy Transition & Care of our Common Home"* <http://w2.vatican.va/content/francesco/en/speeches/2018/june/documents/papa-francesco_20180609_imprenditori-energia.html>; **6 July**, message to participants in the *"Second Forum of the Laudato sì Communities"* in Amatrice, Italy, <http://w2.vatican.va/content/francesco/en/messages/pont-messages/2019/documents/papa-francesco_20190706_messaggio-comunita-laudatosi.html>; **1 September**, message for the *"World Day of Prayer for the Care of Creation"* <http://w2.vatican.va/content/francesco/en/messages/pont-messages/2019/documents/papa-francesco_20190901_messaggio-giornata-cura-creato.html>; **12 September**, message for the launch of the *"Global Compact on Education"* [Rome, May 2020], <http://w2.vatican.va/content/francesco/ en/messages/pont-messages/2019/documents/papa-francesco_20190912_messaggio-patto-educativo.html>; **23 September**, video message to participants at the *"UN Climate Action Summit 2019"* <http://w2.vatican.va/content/francesco/en/messages/pont-messages/2019/documents/papa-francesco_20190923_videomessaggio-climate-action-summit.html>; **11 November**, address to the member of the *"Council for Inclusive Capitalism"* <http://w2.vatican.va/content/francesco/en/speeches/2019/november/documents/papa-francesco_20191111_consiglio-capitalismo-inclusivo.html>; **1 December**, message to the participants in the *"United Nation Framework Convention on Climate Change"* <http://w2.vatican.va/content/francesco/en/messages/pont-messages/2019/documents/papa-francesco_20191201_messaggio-carolina-schmidt.html>; **8 December**, message for the celebration of the 53rd World Day of Peace *"Peace as a Journey of Hope: Dialogue, Reconciliation and Ecological Conversion"*, [1 January 2020] 2019, <http://w2.vatican.va/content/francesco/en/messages/peace/documents/papa-francesco_20191208_messaggio-53giornatamondiale-pace2020.html>; **20 December,** video message with UN Secretary-General Antonio Guterres <http://w2.vatican.va/content/francesco/ en/messages/pont-messages/2019/documents/papa-francesco_20191220_videomessaggio-guterres.html>.

investments toward those areas that truly safeguard the conditions of a life worthy of humanity on a 'healthy' planet for today and tomorrow. **All this calls us to reflect conscientiously on the significance of our consumption and production models** and on the processes of education and awareness to make them consistent with human dignity. We are facing a **'challenge of civilization'** in favour of the common good and of a change of perspective that places this same dignity at the centre of our action, which is clearly expressed in the 'human face' of climate emergencies. **There remains a window of opportunity, but we must not allow it to close"** (Holy Father Francis, 2019c).
"**Sadly, the urgency of this ecological conversion seems not to have been grasped by international politics, where the response to the problems raised by global issues such as climate change remains very weak and a source of grave concern. The COP25,** held in Madrid last December, **raises serious concern about the will of the international community to confront with wisdom and effectiveness the phenomenon of global warming,** which demands a collective response capable of placing the common good over particular interests" (Holy Father Francis, 2020).

"**Never have we so hurt and mistreated our common home as we have in the last two hundred years.** … **The problem is that we still lack the culture needed to confront this crisis. We lack leadership capable of striking out on new paths and meeting the needs of the present with concern for all and without prejudice towards coming generations**" (Holy Father Francis, 2015, No. 53).
With the aim to start a journey capable to give an answer to these lacks **Holy Father Francis** announced two global events. The ***"Economy of Francesco"*** [Assisi, March 2020][11] to reflect with young people around these challenges and to **"help bring us together and allow us to meet one another and eventually enter into a 'covenant' to change today's economy and to give a soul to the economy of tomorrow"** (Holy Father Francis, 2019a). The **"*Reinventing the Global Compact on Education"*** [Rome, May 2020][12] **"to dialogue on how we are shaping the future of our planet and the need to employ the talents of all, since all change requires an educational process aimed at developing a new universal solidarity and a more welcoming society"** (Holy Father Francis, 2019b).

Ursula von der Leyen
In July the new European Commission President **Ursula von der Leyen gives a new prospective for EU.** According to von der Leyen words: "**Our most pressing challenge is keeping our planet healthy. This is the greatest responsibility and opportunity of our times. I want Europe to become the first climate-neutral continent in the world by 2050.** To make this happen, we must take bold steps together. Our current goal of reducing our

[11]According to Holy Father Francis words to young people: "As I wrote in my Post-Synodal Apostolic Exhortation *Christus Vivit*: "Please, do not leave it to others to be protagonists of change. You are the ones who hold the future! Through you, the future enters into the world. I ask you also to be protagonists of this transformation… I ask you to build the future, to work for a better world" (No. 174). And I am confident above all in you young people, who are capable of dreaming and who are prepared to build, with the help of God, a more just and beautiful world." (Holy Father Francis, 2019a). Official *"Economy of Francesco"* event website: <https://francescoeconomy.org/>.
[12] According to Holy Father Francis words: "This meeting will rekindle our dedication for and with young people, renewing our passion for a more open and inclusive education, including patient listening, constructive dialogue and better mutual understanding. Never before has there been such need to unite our efforts in a broad *educational alliance*, to form mature individuals capable of overcoming division and antagonism, and to restore the fabric of relationships for the sake of a more fraternal humanity. Today's world is constantly changing and faces a variety of crises. Every change calls for an educational process that involves everyone. There is thus a need to create an "educational village", in which all people, according to their respective roles, share the task of forming a network of open, human relationships. According to an African proverb, "it takes a whole village to educate a child". We have to create such a village before we can educate. To reach these global objectives, our shared journey as an "educating village" must take important steps forward. First, we must have *the courage to place the human person at the centre*. Another step is to find *the courage to capitalize on our best energies*, creatively and responsibly. A further step is *the courage to train individuals who are ready to offer themselves in service* to the community" (Holy Father Francis, 2019b).

emissions by 40% by 2030 is not enough. We must go further. We must strive for more. A two-step approach is needed to reduce CO_2 emissions by 2030 by 50%, if not 55%. **The European Union will lead international negotiations to increase the level of ambition of other major economies by 2021 because, to achieve real impact, not only do we have to be ambitious at home – we have to do that, yes – but the world also has to move together.** To make this happen, I will put forward a **Green Deal for Europe** in my first 100 days in office. **I will put forward the first ever European Climate Law, which will set the 2050 target in law. This increase in ambition will need investment on a major scale.** Public money will not be enough. I will propose a Sustainable Europe Investment Plan and turn parts of the European Investment Bank into a Climate Bank. This will unlock EUR 1 trillion of investment over the next decade. **It means change"** (von der Leyen, 2019a).
On December 11 President von der Leyen presented the *'European Green Deal'* and said: "The European Green Deal[13] is on the one hand our vision for a climate neutral continent in 2050 and it is on the other hand a very dedicated roadmap to this goal. It is fifty actions for 2050. **Our goal is to reconcile the economy with our planet, to reconcile the way we produce and the way we consume with our planet and to make it work for our people.** … **The European Green Deal is our new growth strategy** – it is a strategy for growth that gives more back than it takes away. And we want to really make things different. We want to be the frontrunners in climate friendly industries, in clean technologies, in green financing. …We do not have all the answers yet. Today is the start of a journey. But this is Europe's **'man on the moon' moment**" (von der Leyen, 2019b).

On January 14, 2020 President von der Leyen presented the 'European Green Deal Investment Plan and Just Transition Mechanism' to mobilise public investment and help to unlock private funds through EU financial instruments which would lead to at least EUR 1 trillion of investments (European Commission, 2020).

The History Could Repeat Itself: Hydrogen-Oxygen Fuel Cell is the 'Game Changer'
In my 2018 study I wrote: *"in recent years hydrogen and fuel cell made a strong comeback in energy portfolio options and now this low-carbon solution is considered as one of possible 'game changer'.* … So, other detailed analyses seem to be needed in order to well understand the relevance of hydrogen and fuel cells in "1.5°C" perspective and to suitably assess all the economic, financial an geopolitical implications" (M.V. Romeri, 2018). During 2019 new and detailed analyses have been done (IEA, 2019a; IRENA, 2019a) that confirmed, also with different magnitudes, the future relevance of hydrogen and fuel cells in '*1.5°C'* perspective and other studies and roadmaps are still in pipeline.

Frans Timmermans, EC Executive Vice-President for the European Green Deal, on 21 November at "2019 Fuel Cells and Hydrogen Joint Undertaking (FCH JU) Stakeholder Forum" said: **"***The green energy transition is not an option but a necessity. I see a pivotal role for clean hydrogen... it is an area where Europe is still leading. The most important thing is that you help us to find ways to make relatively quick successes to show people that it works***"** (FCH JU, 2019).

In my analysis the economic advantage 'to consider an H_2FCPowertrain as power generation plant' and related possible long-term effects in power generation **are confirmed. This solution, if rapidly adopted at scale level, seems to be able to give a contribution to**

[13] European Commission, 2019 December: *"A European Green Deal - Striving to be the first climate-neutral continent"* <https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en>; *"Annex to the Communication on the European Green Deal 'Roadmap - Key actions'"*<https://ec.europa.eu/info/sites/info/files/european-green-deal-communication-annex-roadmap_en.pdf>.

the climate emergency challenge. However, this low-carbon solution has still not been considered in international energy and climate change debate.
According to IPCC SR15 in the next few years it will be necessary to start unprecedented changes and to speed up CO_2 emissions reduction. For these reasons next few years are probably the most important in our history.

The history could repeat itself. In 1969 the hydrogen-oxygen fuel cell invention made Neil Armstrong's *'small step'* possible. Today, the *'state of the art'* hydrogen-oxygen fuel cells seems to be able to be, in next few years, the *'game changer'* against the *'climate emergency',* to play a relevant role in the *'economy of tomorrow'* and maybe to be a new *'giant leap for mankind'.*

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MIGRATION RELATED TO CLIMATE CHANGE

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Immigration and climate change are among the most critical and divisive topics in politics today. People in many parts of the world are on the move escaping environmental devastation and deterioration.

The National Geographic Society's definition of climate change is "*the long-term alteration of temperature and normal weather patterns in a place. This could refer to a particular location or the planet as a whole. Climate change is currently occurring throughout the world as a result of global warming".*[1] Global warming is the long-term increase of the average temperature in the planet's climate system and causes the so-called "greenhouse effect" which happens when the earth's atmosphere traps the heat which radiates from our planet preventing it from travelling towards space. The layer that blocks the heat but allows sunlight to pass is formed by gasses such as water vapor, carbon dioxide (CO_2), methane, nitrous, oxides and chlorofluorocarbons (CFCs). The problem is that the natural "greenhouse" has been and is being affected by human activities which increase the release of gasses into the atmosphere for example, by the burning of coal and oil which increase the concentration of CO_2.[2]

Since the beginning of time our planet Earth has always experienced climate shifts, living through alternating eras of global cooling and global warming. These past events of climate change were generated by natural factors and remained restricted to regions or certain areas of the Earth. The changes which took place in the past were also more gradual and did not strike with the level of violence we are witnessing today. Studies, in fact, show that in the last 2000 years the current global warming phenomenon is the first to affect the whole world with episodes of sudden and extreme weather events. The increase in industrial activities plays a major role in the current global climate change.

In a recent study researchers say that the biggest and most damaging hurricanes are now three times more frequent than they were 100 years ago. They say that by using a new method of calculation this increase in frequency is "unequivocal" and that this increase is linked to global warming.

Just as hurricanes are more frequent than previously, so are droughts more severe and longer lasting, fires more frequent, sea levels higher because of ice melting in the Himalayas, Andes, Alps, etc..[3]

These drastic climate change impacts transform the environment, in some cases to the point where it is no longer possible or extremely difficult to live there and can potentially lead to the migration of individuals or of entire communities and mostly concern vulnerable people.

The term migrant means *"any person who lives temporarily or permanently in a country where he or she was not born, and has acquired some significant social ties to this country."* However, this definition has to be determined depending on state policies. Every country has its own different concept of who is a migrant.

The International Organization for Migration (IOM)[4] defines a migrant as any person who is moving or has moved across an international border or within a State away from his/her habitual place of residence, regardless of:

[1] https://www.nationalgeographic.org/encyclopedia/climate-change/
[2] https://svs.gsfc.nasa.gov/20114
[3] https://www.bbc.com/news/science-environment-50380431
[4] www.iom.int/key-migration-terms

1) the person's legal status;
2) whether the movement is voluntary or involuntary;
3) what the causes for the movement are;
4) what the length of the stay is.

International migration can be classified depending on the duration and on the reasons of the movement.

It is said that "climate change will be the border control of the future"[5] as we are already witnessing the first climate refugees. Men, women and children are forced to move because of the rising of sea levels, melting Arctic permafrost and other violent weather patterns. It is estimated that there will be at least 200 million people displaced by climate change by 2050.Experts say that "migration may be an adjustment mechanism of first resort or a survival mechanism of last resort".[6]

Human migration is certainly not a new phenomenon. The majority of immigrants are forced to leave their homeland due to pull or push factors. The term migration encompasses people from different backgrounds, cultures, religions, skills, etc. and is motivated by multiple factors such as economic, social, political, cultural, environmental, security, etc. To further complicate matters, these factors are usually interconnected when speaking about population movement.

In 1966 Everett Lee formulated his Theory of Migration and identified four categories of factors that forge mobility.

1) factors associated with the origin area,
2) factors associated with the destination area,
3) intervening obstacles, and
4) personal factors.

Lee's contribution cemented the push-pull framework as one on the most lasting conceptual tools used in migrational studies to present times as can be seen in related literature published since. Lee observed that cost-benefit calculations are not sufficient as an incentive to migration but much stronger incentives are needed. Also, there are "intervening obstacles" between any two given origin and destination points such as physical distance and policy regimes that may condition how feasible a move is for any given individual (Lee, 1966).

Although the percentage of international migrants, compared to global population, has increased from 2.8% in the year 2000 to 3.4% in the year 2017, it is still a low percentage. This reflects Lee's observation that really strong motivations are needed to migrate.[7]

The number of international migrants, according to the Department of Economic and Social Affairs of the United Nations Secretariat, grew from 173 million in 2000, to 220 million in 2010 and reached 258 million in 2017.

Over the years the number of push factors that can be listed for having induced climate migration has become greater. Lonergan (1998) spotted five groups of factors that can be identified and analyzed one by one as environmental push elements that might lead to human mobility[8]:

1. Natural disasters;
2. Development projects that involve changes in the environment;
3. Progressive evolution of the environment;

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[5] https://qz.com/1124055/climate-change-will-be-the-border-control-of-the-future/

[6] Gil Marvel Tabucanon and Brian Opeskin, "The Resettlement of Nauruans in Australia: An Early Case of Failed Environmental Migration" (2011) *The Journal of Pacific History* Vol. 46
Source: Climate Change, Forced Migration, and International Law. McAdam. Oxford University press

[7] https://www.un.org/en/development/desa/population/publications/pdf/popfacts/PopFacts_2017-5.pdf

[8] https://www.unhcr.org/research/working/47a316182/climate-change-forced-migration-etienne-piguet.html

4. Industrial accidents;
5. Environmental consequences due to conflicts.

The IDMC[9] reports 28 million newly displaced people due to conflict and disasters across 148 countries and territories during the year 2018.

The potential for global environmental change to result in conflict is strong. This is why particular focus is given to the climate-migration-conflict course. Despite the fact that, historically speaking, there is little material regarding the linkage between resource scarcity, population pressure and conflicts, these issues emerge because studies recognize that human movements may follow conflicts but also that conflicts may result from human mobility.

Alexandra Bilak, IDMC Director states: *"The number of people living in internal displacement is now the highest it has ever been. Unresolved conflicts, new waves of violence and extreme weather events were responsible for most of the new displacement we saw in 2018*." - The Internal Displacement Monitoring Centre estimates a total of 41.3 million people living in internal displacement as a result of conflict and violence as at the end of 2018. This is the highest figure ever recorded. Three-quarters, or 30.9 million people, are located in just ten countries, including Syria, Colombia and the DRC and the number of people who were displaced as a result of disasters that occurred in 2018 remains unknown.

Numerous examples of non-climate related migration leading to increased tensions and conflict, in particular where international migration is involved, have been observed.

When new migrants arrive at a host site, be it a new town, city or country, there is a potential risk of tension or conflict. The new migrant is seen as the "other". The "other" poses a series of socioeconomic issues , for example he is the competitor for jobs, shelter, food, etc. Then there is the aspect that extends to national identity in the case of international migration. Receiving countries are not always equipped to adequately handle the arrival of migrants with different cultures, languages and religions.

Then there is the uncertainty of what the future holds that can lead to conflict. To add to this uncertainty is the fact that the insecurity perceived is greater than the insecurity itself. Therefore, even a perceived "insecurity" or "threat" can potentially provoke a conflict.

This shows how migration in general can potentially provoke conflict. Yet when talking about climate migration it is also important to consider increased resource competition. This has been defined as the "neo-Malthusian" concept which argues that as populations increase, so will competition for resources and that resources will become scarcer due to climate change. Consequently, climate migration may intensify the potential of conflict specifically because it is migration within a "climate change" context, that is to say, a context where available resources decrease and people must compete. In the event of climate change, it is extremely uncertain how significant migration will be as a cause of conflict. In fact, great caution is taken today not to overstate the potential impact of climate-migration as a cause of conflict. The reason for this being that since the 1950's the countries that have received the majority of migrants, although they may have experienced intergroup conflict, have never engaged in armed conflict.

According to scholars like Michael Humphrey the West has placed extra focus on migration because of the terrorist attacks on the United States which took place on the 11th September 2001. Humphrey says that this can overshadow the fact that migration is necessary and intrinsic to global population dynamics and that it does not normally pose a security threat. This emphasizes the fact that other elements may be more important than migration as causes of conflict. This point of view is supported by the sociologist Slettebak who claims that populations frequently unite after devastating events and that in such disastrous situations the risk of conflict may be quite low. This theory is drawn from an extensive study conducted in 1961 during which over 16,000 people were either interviewed or filled in questionnaires. The

[9] Internal Displacement Monitoring Centre

study's conclusion was that most *"produce a great increase in social solidarity...[which] reduces the incidence of most forms of personal and social pathology"*. Slettebak actually notes that disasters may in fact unite even those people whose differences, such as cultural, religious or socio economic, are at first seen as sources of conflict. Political stability and the ability of a government to maintain peace are other elements that contribute to a populations' security. A country that can offer healthcare, education and livelihood assistance is more likely to maintain order and stability if faced with environmental change. Furthermore, a well-functioning government may also have plans on how to deal with climate change. It would, in particular, be of great help to have early warning systems in place in order to permit prompt and appropriate action when faced with climate hazards so as to render migration an adaptation measure instead of a last resort.

Democracies are considered protective forms of government as they are accountable to their populations. Thus, they take steps against conflicts and may also have plans for water and land conservation in the event of resource depletion. This is in contrast to the neo-Malthusian model, which does not account for elements of solidity in a nation, such as political and economic stability that may outweigh competition for resources and in so doing limit potential conflict.

Likewise, it has been suggested that human ingenuity and technology could exceed the potential dangers of environmental degradation.

The possible flaws in the neo-Malthusian model include the fact that social stress caused by scarce resources is only rarely linked to an increased risk of domestic conflict. This however, does not take into consideration potential climate changes which may lead to extreme or unparalleled land degradation and resource scarcity but which in any case does not necessarily imply an increased risk of conflict. Of course, if considered in the context of international conflict, a different outcome could be possible.

Climate change, conflict and migration do not follow a linear pathway which makes it a complex matter. [10]

Some claim that the current Syria crisis, which began in 2011, was due partly to a period of drought. This ongoing crisis to date (2019) has seen 6.6 million internally displaced persons, 13.1 million people in need and over 5.6 million people have fled Syria. [11] This migration, in turn, may lead to future conflict which reminds us that the three factors, climate, migration and conflict, do not follow a linear pathway.

It must also be considered that migrations caused by industrial accidents, development projects and conflicts are in fact induced by human activities, are non-climatic drivers and are indeed a crucial variable. The vulnerability of a population to climate change varies greatly depending on government policy, population growth, income distribution, etc., that is to say all those variables that push people to live on marginal lands. Therefore, a population's vulnerability may increase or decrease due to factors that have nothing to do with greenhouse gas emissions. These non-climatic drivers which push populations to a marginal situation can be as important as the "climate signal" itself. Unfortunately, these are also difficult to quantify or predict.

It is not an easy task to elaborate scientific predictions by combining climate and migration models (Perch-Nielsen 2004). However, past experience of climate change can be compared to the foreseeable future climate change events and their consequences. This in turn enables the pinpointing of the populations most at risk and the quantification of the potential migration flows.

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[10]Source:https://www.researchgate.net/publication/301638313_Exploring_the_Climate_Change_Migration_and_Conflict_Nexus

[11] https://www.unhcr.org/syria-emergency.html

According to the IPCC (Intergovernmental Panel on Climate Change 2007b) forecast for the end of the 21st century, the three most threatening potential causes of migration are all due to global warming and are:

- Stronger tropical hurricanes and increased frequency of heavy rains and flooding, caused by increased evaporation induced by the rise in temperatures;
- The growth in the number of droughts, with evaporation contributing to a decrease in soil humidity, often associated with food shortages;
- The increase in sea levels resulting from both water expansion and melting ice.

The first two phenomena result in sudden natural disasters whilst the third is something that occurs over a long period of time. These three phenomena have different implications in terms of migration.

A potential driver of migration is a change in the environment which makes the territory no longer habitable, thus spurring people to migrate. Although this assumption is fundamental to the theory of climate migration, the fact that different factors interact in human movement often makes it difficult to establish any particular driver as being necessary or sufficient. For example, when land becomes unfit for agriculture it may have a negative effect on economic opportunity and induce out-migration, but it is difficult to establish if the driver is the environment or the lack of economic opportunity.

The complexity of interconnections between principles that drive people to move for economic and employment reasons, can rarely be disconnected. The interplay of these factors may press people either to move or stay in a place. Hence, numerous factors can contribute to either enabling or constraining people to remain where they are or force them to leave. When migration is a choice, economics and social ties are the main influence on the sort of migration chosen, for example permanent or cyclical, internal or international. This complex interaction between social, political, economic, cultural and environmental factors influences an individual's, community's or family's vulnerability and can result in population movement.

Vulnerability: can be quantified according to how susceptible people are to falling victims of a crisis such as floods, conflicts or economic downturn.

Capacity: this is the individual's, community's or country's ability to cope, respond to and acquire new skills to deal with crisis situations.

An individual's vulnerability is based in part on personal factors such as disability or age, but other more complex and interconnected factors play their part. These can be social inequalities, marginalization, poor services, poor governance and unequal cultural and social power systems which lead to chronic vulnerability.

The ability to deal with hazardous situations, including those caused by climate change, depend greatly on access to education, diverse livelihoods and decent infrastructures (e.g. roads, etc.). Any type of stressor, be it sudden or slow in its effect, can bring about 'severe alterations in the normal functioning of a community or society due to the hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects' (IPCC, 2014b: 1,763). Both vulnerability and capacity are subject to change over time and any kind of change, be it positive or negative, can potentially increase or decrease the amount of migration.

Normally migration in the context of climate change is thought to be a "last resort" there being no alternative in the face of devastating events. However, in recent years it seems that migration in these conditions is rather an adaptation strategy.

Migration in fact implicates both opportunities and challenges. This is true for the migrant, the host destination and for those remaining in the place of origin (Figure 5). In a context of climate change, these opportunities and challenges depend greatly on policies and cultures at the receiving location as well as individual circumstances (Lenard and Straehle, 2012; Nijkamp and Poot, 2012; Conway and Potter, 2009; McKenzie and Rapoport, 2004). In situations of climate migration some family or community members may be left behind giving rise to a change in responsibilities, roles and vulnerability However, although this type of migration can have negative aspects, it usually has a more positive overall outcome than normally believed. Those who leave the place of origin may only opt for temporary migration and once they find employment send remittances to their family or community therefore contributing to a successful adaptation to better living in the place of origin.[12]

Over hundreds of years, migration has contributed to the richness and emerging of various cultures worldwide. In 2018, the millions of people who were on the move across the world contributed about $689 billion to global remittance flows. Estimation of officially recorded annual remittance flows to low and middle-income countries is of $483 billion in 2017 and of $529 billion in 2018 which means there was an increase of 9.6%. Remittance flows for 2019 to low and middle-income countries are expected to increase to $550 billion and therefore the largest source of external financing to these countries.[13] Remittances in cash flows from migrants has a huge impact on halving the budget of the countries they come from, thereby mitigating poverty, creating jobs back home and strengthening the home community's resilience to climate extremes. We must also take into consideration the remittances in form of technology and brain gain when and if migrants manage to return back home and put into practice their experiences and skills gained while working outside their home countries. This may reduce vulnerability at home. Migration, in fact, not only reduces poverty in countries dealing with unbearable circumstances, but it can also reduce female and child labour.

When environmentally displaced persons[14] abandon the degraded area, it also means they are reducing pressure on that same area and are giving a chance for it to recover. By promoting land tenure and environmental protection though governance and policies, adaptation can also be accomplished by the people unable to migrate from places with fragile ecosystems. In this way, people may be given the opportunity to use types of resources other than natural ones and give birth to urbanization.

With a changing climate each country will need to decide on a series of cost-benefit actions necessary to protect their populations and territories, e.g. sea walls, refuge for disaster hit communities, etc. The ability to predict climate change events and measures taken by the governments will define the gravity of the impact and the amount of people forced to migrate.

The island of Kiribati, for example, because of the rise of the sea-level and the decrease of freshwater due to the saline intrusion, faced an urgent need to adapt and prevent a disaster displacement[15] and as an alternative has taken into consideration either to build a sea-wall worth $1 billion or a $2 billion floating island. These drastic actions are being studied because the Kiribati people have no feasible migration plan. On one hand the Kiribati people have strong cultural ties to their land which means that many do not wish to leave, whilst on the other those willing to migrate lack the money to do so.[16]

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[12] https://environmentalmigration.iom.int/infographics

[13] https://www.worldbank.org/en/news/press-release/2019/04/08/record-high-remittances-sent-globally-in-2018

[14] *Environmentally displaced person* refers to "*persons who are displaced within their country of habitual residence or who have crossed an international border and for whom environmental degradation, deterioration or destruction is a major cause of their displacement, although not necessarily the sole one"* (IOM, 2011:34 in IOM, 2014:13). https://migrationdataportal.org/themes/environmental_migration

[15] The term *disaster displacement* "refers to situations, where people are forced or obliged to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of disasters triggered by natural hazards. Such displacement may take the form of spontaneous flight or an evacuation ordered or enforced by authorities. Such displacement can occur within a country, or across international borders." (The Nansen Protection Agenda, 2015). https://migrationdataportal.org/themes/environmental_migration

[16] Exploring_the_Climate_Change_Migration_and_Conflic.pdf – https://www.researchgate.net/publication/301638313_Exploring_the_Climate_Change_Migration_and_Conflict_Nexus

One great challenge in accelerating any rural-to-urban movement is that of not increasing the vulnerability to climate change either of the migrants or the host communities. Hence, the necessity for a series of initiatives aimed at greater sustainability when receiving migrants, for example: urban planning, infrastructure development, building codes, etc. These help build urban resilience to natural threats.

On the whole, migration can be seen as part of a rank of adaption measures to pinch-hit vulnerability and risks.

"Every migrant is a human being"[17] but yet, the impact of climate change varies depending on the gender. The UN estimates that women make up more than half of the population living in poverty. Women, especially the poorest or the ones being marginalized because of factors such as race or social status, are generally extremely harmed by climate change, disasters and all that follows. During manageable calamities, women in poor rural communities have the responsibility to collect food and water, the collection of which probably means longer traveling distances compared to those travelled during peaceful periods. They are also likely to eat smaller portions of food when this needs to be rationed. When a household depends on a female head it is more likely to be poor and rely on rain-fed subsistence agriculture. Often, they do not own any land and have more dependents than able-bodied workers. Women are burdened with multiple tasks that span from agriculture to family care including their children, the elderly and the disabled. In very poor areas of Africa, for example, women only hold 1% of the land, but still produce almost all of the agricultural goods. In case of natural disasters, faced with a situation that obliges them to move they are in fact unable to do so and therefore become "trapped" (see figure 14) by their position. In fact, it frequently happens that female households do not have adequate or sufficient resources and therefore are not able to migrate. Facts and evidence from climate disadvantaged territories show that men's migration is simplified due to the opportunity of access to land as opposed to women who have fewer options when forced to leave environmentally degraded areas.

During crisis and emergencies, the number of female deaths is higher that the males' mostly because woman have less access to information, less chances of mobility outside of their homes and acquire less life skills.

Women face many disadvantages when trying to recover after natural disasters. They are frequently left out of decision-making regarding prevention of or adaptation to climate change events. Nevertheless, during disastrous events, they are often activists, take on leadership roles in their communities or become the main breadwinner for their families. They can also lack national identity documents more frequently than men and therefore are unable to access government aid schemes, for example as was documented after the 2010 floods in Pakistan. Under these conditions women also become more vulnerable to gender-based violence.

Low-income countries tend to have a high birth rate therefore children make up a large part of the population. In fact, one in three children is multidimensionally poor in comparison to one in six adults. This means that almost half the people living in this type of poverty, which total 663 million, are children. The youngest children suffer the most.[18]

Many poor children live in areas prone to high risk for severe floods, cyclones, drought, etc. When a climate hazard strikes children can accidentally be separated from their families putting them at risk of being trafficked, exploited, abused, subjected to violence, etc. A traumatic experience of this sort can negatively condition the rest of their lives impacting aspects such as: health, education, economic status, etc.

When disasters strike access to education becomes limited or impossible. School buildings may be damaged or they may be needed as shelter for families made homeless. Some children are on the move with their families fleeing from disaster areas. Others, especially boys, may

[17] UN Migration

[18]http://hdr.undp.org/en/content/new-data-challenges-traditional-notions-rich-and-poor

find work to help their families economically, which contributes to avoiding displacement but leaves them little or no time for school.
Children suffer also when there is a gradual climate change. Often when their parents migrate they are left behind with relatives or other community members. This situation frequently has a negative impact on their education, psychological and physical wellbeing.
On the 18th September 2019 the Executive Director of UNICEF, Henrietta Fore, issued an open letter to commemorate the 30th anniversary of the Convention on the Rights of the Child – the world's most widely ratified human rights treaty. In the letter Fore addresses eight growing challenges for the world's children: *"prolonged conflicts; pollution and the climate crisis; a decline in the mental health; mass migration and population movements; statelessness; future skills for future work; data right and online privacy; and online misinformation".*
More specifically she says that the global climate crisis and growing destruction of the planet could potentially undermine many of the gains in child survival and development achieved over the past 30 years. All of which affects mainly the poorest and most vulnerable children.
"And your generation, the children of today, are facing a new set of challenges and global shifts that were unimaginable to your parents," writes Fore. *"Our climate is changing beyond recognition. Inequality is deepening. Technology is transforming how we perceive the world. And more families are migrating than ever before. Childhood has changed, and we need to change our approaches along with it."*[19]
Besides women and children there are other very vulnerable categories during climate and displacement emergencies. Other persons that fall into the specific group of "disproportionately harmed categories" include older people, disabled people, migrant workers and people historically marginalized.
During displacements, people like the elderly who suffer from health problems are the ones who risk mostly as their situation could easily worsen. Not only, over a long duration displacement, family and communities on which they rely may have problems supporting them. Even so, disabled people are the most forsaken and damaged because they usually do not receive proper assistance and protection, vital to face the hard situations.
Migrant workers often live in areas vulnerable to climate hazards such as floods, storms or landslides. Many live in poorly built housing, increasing risks.
Communities that already live on the margins of society become even more discriminated when disaster strikes. This means that they are not given access to the assistance they need. One such group of people are the Dalits, found in India and other Southern Asian countries, the so called "untouchables", the lowest of the caste system. In 2015 when the Dalit families were the worst hit by the flooding in Tamil Nadu they were reportedly neglected during relief efforts.[20]
Defining persons who migrate or are displaced because of climate events is a complex task. The very first definition used was "ecological refugee" in 1948[21]. So far, the mostly used definitions are "climate refugees" and "environmental refugees", yet it may not be appropriate to use the term "refugees". The word 'refugee' is used by campaigners because it stresses the urgency of the issue as people need to find a refuge and escape from climate change hazards. They argue that these people need to 'seek refuge' from the impacts of climate change and any

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[19]https://www.unicef.org/press-releases/protracted-conflict-climate-crisis-rise-mental-illness-and-online-misinformation
[20]https://reliefweb.int/report/india/tsunami-2015-floods-no-respite-dalits-disaster-response-tamil-nadu-report-initial
[21] William Vogt, Road to Survival (William Sloane Associates, 1948) in François Gemenne, 'How They Became the Human Face of Climate Change: Research and Policy Interactions in the Birth of the "Environmental Migration" Concept' in Etienne Piguet , Antoine Pécoud, and Paul de Guchteneire (eds), Migration and Climate Change (Cambridge University Press and UNESCO Publishing, 2011) 227.

other terminology would not confer the correct gravity of these people's situation. Also, the word 'refugee' carries more weight with the general public who can sympathize with the implied sense of hardship. It also has a fewer negative connotations than 'migrant' which tends to imply a voluntary move towards a more attractive lifestyle.

However, the use of the word 'refugee' to describe those fleeing from environmental pressures is not strictly accurate under international law. The United Nations' 1951 Convention and 1967 Protocol relating to the status of refugees are clear that the term should be restricted to those fleeing persecution: *"a refugee is a person who owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion, is outside the country of his nationality, and is unable to or, owing to such fear, is unwilling to avail himself of the protection of that country"*.

As a matter of fact, there are various problems with using the term 'refugee'. Strictly speaking, a refugee is a person who crosses an internationally recognized border. Someone displaced within their own country is an "internally displaced person" (IDP). Since most people displaced by climate change will probably remain within their own borders, restricting the definition to those who cross international borders may seriously understate the extent of the problem.

Secondly, the idea of 'refugee' tends to imply that the person has a right of return once the persecution that triggered the original flight has ceased. Of course, this is impossible in the case of sea level rise and so the term in this case is not appropriate.

Thirdly, there is the concern that by including environmental stressors in the definition of 'refugee' the international mechanisms and goodwill to care for existing refugees may diminish.

The question of definition is subject to fervent debate amongst international human rights lawyers. However, they are largely against any expansion of the definition of a 'refugee'. The developed countries are concerned that by calling people fleeing climate disasters 'refugees' they would be eligible for the same protection as political refugees. Something that no country has yet been willing to give. The international institutions that currently provide for refugees, mainly the office of the United Nations High Commissioner for Refugees (UNHCR), are unable to cope even with the current refugees. In fact, UNHCR is already carrying out an expanded role by providing care to IDPs and is unwilling to take on any further expansion.

Since there is no adequate alternative, the term 'climate refugee' is still used on occasion. 'Climate evacuee' implies temporary movement within national borders (as was the case with Hurricane Katrina). 'Climate migrant' gives an incorrect impression of why these people "migrate" emphasizing the 'pull' of the destination more than the 'push' of the source area.

IOM describes Environmental migrants as *"persons or groups of persons who, predominantly for reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad"*.

To date there is no clear international legal regulation to protect "climate refugees". There have been many requests to meet this requirement which have been answered by a series of proposals, for example add optional protocols to existing conventions or formulate a new treaty, so as to provide 'climate refugees' with international protection, including legal status and resettlement/integration solutions.

This however is a difficult problem to address for a number of reasons. Firstly, it is not easy to identify those who have been forced to migrate primarily because of climate change. This makes it hard to define the legal scope and application of the provision and also makes it an arduous task to make sure that those intended to be covered actually are. Secondly, a 'climate refugee' treaty would give priority to those displaced by climate change over other forced migrants, for example those escaping poverty, probably without a good legal and/or moral reason for this discrimination. Thirdly, in the event of mass displacement it would be inappropriate to offer protection on an individual context basis. Fourthly, there is need for an enormous amount of aid. Lastly, but certainly not least, there appears to be little political inclination towards formalizing a new international agreement on this matter.

When studies are carried out on international legal and protection policies relative to climate change the following categories tend to fall through the cracks:

1. The people who do not move;
2. The States which already have secure migration options.

Policies available, while offering an opportunity to migrate may not be an all-round solution. Although the assistance available allows people to flee to safety it does not mean that all their problems have been solved. Thus, further aid and assistance is needed.

In situations of risk both forced migration and the inability to migrate are signs of vulnerability. Those who are left behind may be exposed to even more dangers.

The fact that the countries which suffer the most from climate change are amongst those who have contributed the least to global warming and therefore to global carbon emissions, spurs activism and a desire for social change. Regarding the unfairness of this phenomenon the Director of the leading human rights NGO in Bangladesh says that people forced to move by climate change should receive special attention. He says this is because climate change is 'not natural', and it is the fault of other governments' failure to reduce greenhouse gas emissions that in turn makes people climate change victims.

The conceptualization of a phenomenon is important when deciding the best regulation approach and its implementation. When climate migration movement is discussed, all the contributory factors should be taken into account. The concept and consequent regulation will depend on:

- Whether the human mobility is identified as voluntary or involuntary;
- Whether or not international boarders are crossed;
- The type of trigger (a rapid onset disaster versus a slow-onset process)[22];
- Whether or not there are political incentives involved in defining the movement as being related to climate change (defining who comes within or is left out of its scope of application);
- Whether human factors aggravate or push the movement (i.e.: discrimination).

At the macro level, responses to the problem can be categorized in multiple ways depending on the six issues listed below:

1. *Protection[23] issue*: supposes that the movement is forced due to sudden natural disasters and hence, should be considered as refugee-like in nature. In the case of

[22] Elizabeth Ferris Humanitarian Perspectives on "Protection of Persons in the Event of Disasters" remarks: *'...sudden-onset disasters-cyclones, hurricanes, earthquakes... are they "easy" events to identify'*, and also, '*Do people who migrate because of slow-onset, persistent drought have a privileged claim on the international community, in comparison, to people who flee grinding urban poverty? Or simply demographic pressure? Is the international community's response to people fleeing "natural" conditions in their homelands a function of the suffering they endure? The magnitude of the effects of the phenomenon? Or the suddenness of its impact? How sudden does a phenomenon need to be to trigger an emergency humanitarian response? The effects of an earthquake may be felt in a matter of minutes, a tsunami in matter of hours, hurricanes and cyclones in days, flooding sometimes over a period of weeks, droughts over a period of months or even years. Can a dividing line be drawn between sudden and slow-onset disasters? Or is the question of time even relevant in deciding whether a particular phenomenon constitutes a disaster?'.* https://www.brookings.edu/on-the-record/humanitarian-perspectives-on-protection-of-persons-in-the-event-of-disasters/

[23] The Inter-Agency Standing Committee (IASC) has defined protection in a common policy as: '*All activities aimed at obtaining full respect for the rights of the individual in accordance with the letter and the spirit of the relevant bodies of law (i.e. International Human Rights Law, International Humanitarian Law, [and] International Refugee law).*' This definition covers:

people who remain in their country of origin when faced with a climate crisis, their protection could be seen as a human rights deprivation.

2. *Migration issue*: the movement is often seen as one's free will and initiative. As a voluntary move it would not need help from the "international community". Even so, the problem that rises is that of understanding as and when the States can respond by adopting their domestic immigration policy.
3. *Disaster issue:* depending on the type and magnitude of the disaster, either assistance and humanitarian aids can be provided on site or temporary relocation can be undertaken.
4. *Environmental issues:* the reduction of carbon emissions and the need to protect endangered ecosystems, can be effectively advocated by using the image of people fleeing the islands which are destined to disappear because of rising sea levels. The use of the word "refugee" in this case can increase the dramatic effect.
5. *Development issue*: assistance and fund adaption measures can be achieved through foreign aid and from tools such as investments. By means of such supports, climate-change contrived countries manage to escape various problematic situations such as poor governance or poverty and thereby boost their capacity to adaptation to climate change.
6. *Security issue*.

The role of regulations and governance is crucial for an advantageous chain reaction and successful advancement in practice. As stated by Warner: 'policy interventions will largely shape the outcome'[24]. Moreover, she reports that the governance structures of States set up will 'play a leading role in determining the degree to which migration is a form of adaptation, or an indicator of a failure to adapt'.

It is actually a vicious circle because all these events, together with other drivers may bring about a series of other negative consequences and increase the risks of violence potentially leading yet again to other environmental changes and thus further increasing global warming. Climate migrants may put pressure on the receiving countries regarding requirements for: infrastructures, services and economy.

The immigration phenomenon will never be presented with reliable and definite data as there are too many uncontrollable flows to make a definitive picture at a certain point in time. In situations of climate migration some family or community members may be left behind giving rise to a change in responsibilities, roles and vulnerability. Although this type of migration may have negative aspects, it usually has a more positive overall outcome than normally believed. Those who leave the place of origin may only opt for temporary migration and once they find employment send remittances to their family or community. They therefore help them financially to adapt successfully to the changes in the living conditions in the place of origin. Over hundreds of years, migration has contributed to the richness and emerging of various cultures worldwide. On the whole, migration, when done in a regular manner , goes to benefit all, the individuals first and foremost, the country of origin and the host country.

• 'Protection under International Humanitarian Law (IHL), which applies to situations of armed conflict as addressed principally in the four 1949 Geneva Conventions and their Additional Protocols of 1977.'

• 'Protection under International Refugee Law (IRL), which applies to persons who meet the refugee definition under international, regional, or domestic laws, or under the mandate of the United Nations High Commissioner for Refugees (UNHCR).'

• 'Protection under International Human Rights Law (IHRL), which applies to all persons at all times, and is grounded in the Universal Declaration of Human Rights (UDHR) and the 9-core international human rights instruments.' https://www.ohchr.org/Documents/Issues/Migration/GlobalCompactMigration/Protection.pdf

[24] Koko Warner, 'Assessing Institutional and Governance Needs Related to Environmental Change and Human Migration'. Source: 'Climate Change, Forced Migration, and International Law'- Jane McAdam Oxford University Press

What will happen in the future? – There are no certainties, but only developed forecasts.
Several factors that will influence the degree of impact that climate change as a driver may have on future forced migration are:

- the quantity of future greenhouse gas emissions;
- the rate of future population growth and distribution;
- the meteorological evolution of climate change;
- the effectiveness of local and national adaptation strategies.

Therefore, it is important to reduce greenhouse emissions and limit temperature rise this century to less than 2°C or better still to 1.5°C as laid out in the Paris Agreement in 2015 at the COP 21. 187 Parties have ratified out of 197 Parties to the United Nations Framework Convention on Climate Change (UNFCCC).[25] This limit on global temperature comes under goal n°13 of the UN Sustainable Development Goals which is intrinsically linked all the other 16 goals of the 2030 Agenda for Sustainable Development.
Implementation of this agreement will reduce emissions and build climate resilience and combat climate change impacts. If successful it would also help limit climate migration. Since the future scenario presents us with a significant amount of the world population on the move seeking a safer and friendlier environment to call home, one which can ensure a better future, governments and institutions should make adequate provision for the foreseen enormous numbers of climate migrants. A legal definition should be established for this kind of migrant in order to ensure they have the rights they are entitled to. Migration that will come about as a consequence of climate change should not be seen as an emergency, but rather as a long-term change in the geopolitical and demographical structure which will affect the upcoming decades. Urgent action is needed in order to win the battle against climate change.

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ASSESSING ENERGY EFFICIENCY: ECONOMETRIC EVIDENCE AND IMPLICATIONS FOR ITALIAN ENERGY POLICY1

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Abstract.
Energy efficiency represents one of the key objectives of the Clean Energy Package. In this context, EU member countries determine the optimal policies for energy efficiency. This papers aims to develop econometric evidence on country-level energy efficiency performance based on stochastic frontier analysis, with a specific focus on Italy's efficiency levels. The analysis is based on data for a sample of 17 European companies over the period 1996-2016. Overall, Italy's historical efficiency and performance ranking is consistently above the sample average and is on an increasing path since 2012. However, efficiency benchmarking shows that there may be scope for efficiency savings above and beyond the 2030 targets in the set out in the National Energy Plan. Disaggregate econometric analysis shows that part of these additional efficiency savings may stem from the industrial and residential sectors. To the authors' knowledge, this is the first attempt to directly compare the efficiency assumptions in a National Action Plan using econometric benchmarking approaches.

1. European objectives and energy efficiency targets

Promoting efficiency is one of the key energy policy priorities in the European Union (EU). In 2010, the EU adopted strategy Energy 2020 for competitive, sustainable and secure energy. Energy efficiency improvements was one of the top five priorities (EC, 2010).[2]

The European Efficiency Directive (EED) (Directive 2012/27/EU) sets the EU energy efficiency target for 2020, which can be expressed in terms of either primary energy consumption or final energy consumption (EU, 2012).[3,4] Meeting both targets requires a reduction in primary and final energy consumption by 20% compared with levels projected for 2020 in the European Commission's Energy Baseline Scenario. Taken together, these targets should contribute to achieving the EU's objective of reducing energy consumption by 20 % by 2020. Directive 2012/27/EU sets an indicative 32,5% target by 2030 relative to 2007.

Table 1. **Energy efficiency objectives at the EU level**

	2020 objective	**2030 objective**
Reduction in primary energy consumption compared to the PRIMES 2007 scenario	-20%	-32,5% (indicative)
Reduction in final energy consumption through energy efficiency obligations	-1,5% per year (without transport)	-0,8% per year (with transport)

Note: based on a common methodology, 2030 targets are set by country

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[1] This paper reflects the views of the authors and does not necessarily reflect the views of Oxera or UCL.
[2] European Commission (2010), "Energy 2020 – a strategy for competitive, sustainable and secure energy. COM (2010) 639 final", Brussels, 10 November 2010.
[3] European Commission (2012), "Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC" (OJ L 315/1, 14.11.2012, pp. 1-56).
[4] Primary energy consumption covers consumption of the energy sector itself, losses during transformation and distribution of energy, as well as final consumption by end users.

However, if energy consumption were to continue growing at its current rate, the EU would not meet its 20% energy efficiency target for 2020.[5] In a recent statement to the Commissioner of DG Energy, President of the European Commission Ursula von der Leyen stated the importance of following the energy-efficiency-first-principle, specifically looking at how to 'further improve the energy performance of buildings and speed up renovation rates'.[6]
During the last two decades most of the EU member states have introduced different types of efficiency enhancing measures. Performance standards in buildings, heating systems and electrical appliances have been introduced in an attempt to improve the level of energy efficiency in the residential sector. Member states have also introduced monetary incentives such as subsidies and tax credits. Germany is the country that has put in place the largest number of policy savings measures, followed by France and Spain. For the sample examined by MURE, household measures are the most common ones (25%), followed by those in the services sector (24%) and the transport sector (21%). In 2006, the European Commission (2006) identified the residential sector as the one with the greatest potential for cost-effective savings which are estimated to be 27%, where large energy saving opportunities were found to lie in retrofitted roof and wall insulation of buildings as well as improved appliances and other energy-using equipment.

2. National targets, efficiency levels, and future policies: the case of Italy

Italy's 2030 target amounts to 43% reduction in primary energy and 39,7% of final energy compared to 2007. This would amount to 158 millions of tonnes of oil equivalent (mtoe) and 124 mtoe respectively of primary and final energy consumption.

Table 2. **Energy efficiency objectives in Italy**

	2020 objective	**2030 objective (PNIEC)**
Reduction in primary energy consumption compared to the PRIMES 2007 scenario	-24%	-43% (indicative)
Reduction in final energy consumption through energy efficiency obligations	-1,5% per year (without transport)	-0,8% per year (with transport)

Note: The PRIMES model simulates a market equilibrium solution for energy supply and demand and is used to create energy outlooks for the EU.

Source: Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'Energia E Il Clima, December.

The Italian National Action Plan (Piano Nazionale Integrato Per L'Energia E Il Clima, PNIEC) outlines the measures that will be taken going forward, and aims to use a mix of regulatory and financial measures articulated across different sectors and aimed at different actors.[7]
Interestingly, the PNIEC indicates the possible scope of saving in energy consumption by economic sector. Compared to period 2016-2018, PNIEC estimates a cumulated saving in total

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[5] For Italy, this is shown in table 3.16 of ENEA (2018), "Rapporto Annuale Efficienza Energetica 2018: principali risultati", luglio. The table shows that only around 52% of the energy saving target will be reached by 2020.
[6] Ursula von der Leynen (2019), "Mission letter to Kadri Simson, Commissioner-designate for energy", September.
[7] Ministero dello Sviluppo Economico, Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Ministero delle Infrastrutture e dei Trasporti (2018), "Piano Nazionale Integrato Per L'energia E Il Clima", December.

final energy consumption amounting to 51,4 Mtoe, or 9,3 Mtoe per year. For 2030, efficiency savings are broken down as follows:

Table 3. **2030 objectives for Italy**

	Energy savings (Mtoe)	Share of saving, %
Residential	3,3	35%
Tertiary	2,4	26%
Industry	1,0	11%
Transport	2,6	28%
Total	**9,3**	**100%**

Source: Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'energia E Il Clima, December.

PNIEC's targets are based on an assessment of cost-effectiveness and aimed at identifying the sectors with the greatest efficiency potential. Limited information is available on the methodology used and the sources of evidence considered. However, it is indicated that TIMES (a bottom-up model generator for energy scenarios) was used.

PNIEC shows evidence on the annual efficiency savings achieved over period 2011-2017 in comparison to the expected efficiency savings for 2020:

Table 4. **Difference between expected efficiency savings in 2020 and efficiency improvement achieved since 2011**

	Energy savings (Mtoe) Achieved until 2017	Energy savings (Mtoe) Expected in 2020	% Target
Residential	3,64	3,67	99,2%
Tertiary	0,22	1,23	17,5%
Industry	2,5	5,1	49,0%
Transport	1,69	5,5	30,7%
Overall	**8,05**	**15,5**	**51,9%**

ENEA (2018), Analisi e Risultati delle Policy di Efficienza Energetica Del Nostro Paese, June, table 3.16.

The table shows that, until 2017, the tertiary, the transport and the industry sectors are the one characterised by the greatest gaps between achieved savings and 2020 savings targets. Almost all expected savings associated with residential consumption have already been met.

From the analysis, it is possible to draw a number of general considerations. First, the residential sector is the only sector where Italy has made significant progress. The residential sector will continue to have a key role in achieving longer term targets. For 2030, the largest expected share of savings is from residential (35%), followed by transport (28%), tertiary (26%) and industry (11%). Transport (30,7%) and industry (49%) are the sectors characterised by the greatest gap relative to the European targets.

3. The concept of energy efficiency

Energy efficiency is captured in several ways. EU-level targets are set with respect to volume reductions. In the context of EU wide target setting, energy efficiency is approximated by energy intensity input-based ratios. For example, EC (2000)[8] recognises that 'Changes in energy intensity for final energy consumption are a first and rough estimate indicator for changes in energy efficiency.' IEA (2009) notes that energy intensity 'is often taken as a proxy for energy efficiency, although this is not entirely accurate since changes in energy intensity are a function of several factors including the structure of the economy and energy efficiency.'[9,10]

Filippini and Hunt (2011) developed a stochastic frontier framework for the empirical analysis of energy efficiency, as opposed to more conventional energy intensity indicators.[11] With this method, it is possible to estimate an input demand function frontier which gives the minimum level of energy input used for any given level of output. Such measure of energy efficiency controls for a range of economic and other factors and is therefore viewed as a more suitable approach to measure energy efficiency. A number of papers have used the SFA approach. For example, Filippini and Hunt (2012)[12] and Saussay et al. (2012)[13] make use of the SFA approach to analyse the impact of introduced building codes on the energy efficiency of residential space heating in selected European countries. Filippini, Hunt and Zorić (2014),[14] used SFA analysis to assess the impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector. This approach represents the focus of the present paper and is broadened to consider overall as well as disaggregate energy efficiency benchmarking in Europe.

4. Methodology

This research combines the approaches taken in energy demand modelling and frontier analysis in order to econometrically estimate the level of energy efficiency. For total consumption, the main model can be expressed as follows:

$$Consumption_{it} = f\left(EnergyPrice_{i,t}, GDP_{i,t}, Population_{i,t}, EF_{i,t}, T_t\right)$$

In other words, total final consumption ($Consumption_{it}$) is estimated as a function of real energy prices ($EnergyPrice_{i,t}$) real gross domestic Product ($GDP_{i,t}$), population ($Population_{i,t}$) and a time trend (T_t).

The error term $EF_{i,t}$ is assumed to be composed of two independent parts: an error, capturing the effect of noise, and a disturbance term capturing the effect of inefficiency. In line with Filippini and Hunt (2011, 2012) the second term is interpreted as an indicator of the inefficient use of energy. SFA models are based on a log-log specification. Similar regression models will

[8] European Commission (2000), "Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. Action Plan to Improve Energy Efficiency in the European Community. COM(2000) 247 final. Brussels, 26.04.2000", p. 3.

[9] IEA (2009), "Progress with Implementing Energy Efficiency. Policies in the G8". OECD/IEA, Paris, p. 19.

[10] Another commonly used efficiency measure is ODEX, an aggregate energy efficiency indicator. Other authors used the Logarithmic-Mean Divisia Index method (LMDI) method, to study both aggregated and sectoral energy consumption changes at EU and MS levels over the period 2005–2016.

[11] Filippini, M., Hunt, L. (2011), "Energy Demand and Energy Efficiency in the OECD Countries: A Stochastic Demand Frontier Approach", Energy Journal 32 (2), 59-80.

[12] Filippini, M. Hunt, L. (2012), "US residential energy demand and energy efficiency: A stochastic demand frontier approach", Energy Economics, Volume 34, Issue 5.

[13] Saussay,A., Saheb,Y., Quirion, P. (2012), "The impact of building energy codes on the energy efficiency of residential space heating in European countries—a stochastic frontier approach. In: International Energy Program Evaluation Conference, Rome.

[14] Filippini, M., Hunt, L., Zorić, J. (2014), "Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector", Energy Policy, January.

be estimated with respect to the transport, residential and industrial sectors. The analysis considers different SFA approaches, each characterised by specific assumptions.

The panel data models considered are Battese and Coelli (1995) (BC95),[15] the random-effects model by Pitt and Lee (1981) (PL81),[16] the true fixed effects (TFE) model,[17] and the four-component model by Kumbakhar et al (2012) (SK12).[18]

Table 5. **Modelling assumptions**

Estimation approach	**Modelling assumptions**
BC95	v_{it}: normally distributed error term $u_{i,t}$: one-sided nonnegative term representing inefficiency. Truncation at zero of the normal distribution
PL81	v_{it}: normally distributed error term u_i: one-sided nonnegative term representing inefficiency. Half-normal distribution (time invariant)
TFE	v_{it}: normally distributed error term $u_{i,t}$: one-sided nonnegative term representing inefficiency a_i: time-invariant unmeasured heterogeneity captured through fixed effects
SK12	Error term split into a normally distributed component (noise) and a one-sided component (transient inefficiency). Random effects split into one sided non-negative term representing persistent inefficiency and in a term measuring time invariant heterogeneity

BC95 and TFE are helpful in that they enable the estimation of a stochastic frontier model in which the level of efficiency can be expressed as a specific function of explanatory variables representing the number of policy measures. These two models were considered in Filippini et al (2014).[19] Unlike BC95, TFE models includes fixed effects in the equation. A shortcoming of TFE is that any unobserved, time-invariant, group-specific heterogeneity is considered as inefficiency.

PL81 was used in Filippini and Hunt (2011).[20] PL81 interprets the panel data random effects as inefficiency rather than heterogeneity. Inefficiency is assumed to be time invariant.

The limit of these models is that the level of inefficiency does not include persistent inefficiency that might remain constant over time. In the SK12, the error term is split into four components, namely time invariant heterogeneity, persistent (or time-invariant) inefficiency, time-varying inefficiency, and noise.

[15] Battese, G.E.,Coelli, T.J., (1995), “A model for technical inefficiency effects in a stochastic frontier production function for panel data”. Empirical Econ. 20, 325–332.

[16] Pitt, M., Lee, L. F.,(1981), “The measurement and sources of technical inefficiency in the Indonesian weaving industry”, .J.Dev.Econ.9, 43–64.

[17] Greene, W. (2005), “Reconsidering heterogeneity in panel data estimators of the stochastic frontier model”. Journal of Econometrics 126: 269-303.

[18] Kumbhakar, S.C., Lien, G. and J.B. Hardaker (2011), “Technical efficiency in competing panel data models: A study of Norwegian grain farming”, Journal of Productivity Analysis, September.

[19] Filippini, M., Hunt, L., Zorić, J., (2014) “Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector”, Energy Policy, January.

[20] Filippini, M., Hunt, (2011), “US Residential Energy Demand and Energy Efficiency: A Stochastic Demand Frontier Approach”, CEPE Working Paper No. 83, April.

5. Data

The data is obtained from various sources which include Eurostat and Odyssee databases, and is used to construct a perfectly balanced panel dataset of 17 countries over 21 years (period 1996-2016).

Table 6. **Main variables considered**

Variable	Unit	N	Mean	Std. Dev.	Minimum	Maximum
Total Consumption	Thousands toe	357	51.6	59.3	1.5	231.4
Consumption,	Thousands toe	357	13.1	16.4	0.2	69.0
Consumption, transport	Thousands toe	357	15.9	18.6	0.7	66.4
Consumption, industrial	Thousands toe	357	14.4	15.8	0.2	64.6
Consumption, other	Thousands toe	357	8.2	9.4	0.2	39.8
Y	€b, '10 ex. rate	357	569.4	720.6	9.8	2870.6
POP	Million	357	21552.2	24671.6	656.3	82536.7
PE	2005=100	357	78.1	22.4	20.5	121.7
DWELL	Floor area of dwellings	325	94.85	20.2	52.5	146.0
DEGREE	Heating degree days	325	2793.6	1034.5	453	4947

Note: variables DWELL and DEGREE have been considered as a sensitivity but have not been included in the key specifications due to missing data.

6. Results

The coefficients of the SFA aggregate models are shown in the following table:

Table 7. **SFA models, model coefficients, total consumption, 1996-2016**

Estimation approach	**BC95**	**PL81**	**TFE[1]**	**SK12**
Parameters of the total demand function				
Ln(Energy prices)	-0.06	-0.09***	-0.09***	-0.09***
Ln(GDP)	0.45***	0.50***	0.46***	0.51***
Ln(Population)	0.51***	0.43***	0.21***	0.38***
Time trend	-0.01*	-0.01***	-0.01***	-0.01***
Constant	-3.89***	-3.31***		-2.62***
Parameters in the one sided error (u)				
Constant	-2.70***	0.09***	-14.68	
Variance parameters for the compound error (v)				
Constant	-5.74***	0.00***	-5.93***	
Lambda	4.58***	5.68***	0.009	
Observations	357	357	357	357

Note: [1] country specific dummies are not reported in the table. *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

The estimated model coefficients are of the expected sign and are generally statistically significant (with the exception of energy prices in the BP95 models). The estimated price elasticity is negative in all four models. This is consistent with the expectation that energy price increases reduce overall energy demand.
The estimated income elasticity is positive and significant in all three models. The results suggest that EU demand is price and income inelastic, consistent to the obtained results for the US residential consumption in Filippini and Hunt (2012). Similarly, population is found to be positive and statistically significant.
Finally, the time trend is shown to significantly reduce energy demand across all models. This may be interpreted as evidence of technical progress common to all countries over time. This may also represent other exogenous factors that are not captured in the model.
The following table provides summary statistics for the efficiency scores in the sample, as well as the average efficiency score for Italy over the period 1996-2016:

Table 8. **SFA models, efficiency scores (%), total consumption, 1996-2016**

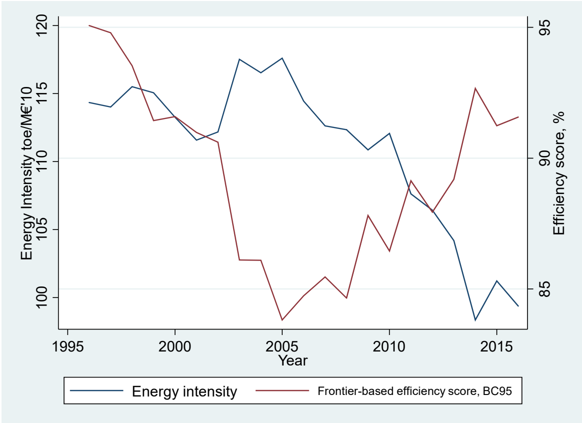
Estimation approach	Sample	Italy	Average	Standard deviation	Minimum	Maximum
BC95	357	89.28	78.62	12.5	46.0	97.9
PL81	357	86.96	79.42	13.7	50.6	98.7
TFE	357	99.95	99.95	0.0	99.9	99.9
SK12	357	97.25	97.19	0.2	96.7	97.6

Note: for SFA analysis with an enhanced specification (N=324) including area of dwellings and degree days, efficiency scores for Italy are 94.2 (BC95), 67.0 (PL81), 99.9 (TFE), 99.9 (SK12).

The most striking result concerns the TFE model, which does not show evidence of inefficiency in the sample. As stated in Filippini, Hunt and Zorić (2014),[21] 'inefficiencies of the TFE model may be underestimated as they do not include the persistent inefficiencies that might remain constant over time and are captured by the individual effects. The TFE model commonly results in very high average efficiency scores and small differences in efficiency scores between different countries, so there may be virtually nothing left to be explained by different policy measures in place.'
The BC95, PL81 and SK12 model show average efficiency scores of 78.6, 79.4 and 97.2, respectively. Italy's efficiency score is consistently above average. Based on average efficiency scores, Italy ranks 5th, 6th and 7th with BC95, PL81 and SK12, respectively.
Considering in greater detail the evolution of efficiency over time based on the BC95 model,[22] it is possible to observe an increase in efficiency since 2012 (with the exception of 2015), from 87.9% to 91,6%. This results appears to be consistent (that is, negatively correlated) with the evolution of the energy intensity indicator, which reports Mtoe/GDP:

[21] Filippini, M., Hunt, L., Zorić, J. (2014), "Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector", Energy Policy, January.
[22] The PL81 models assumes constant efficiency over the sample period.

Figure 1. **Energy intensity and efficiency score (BC95), Italy, 1996-2016**

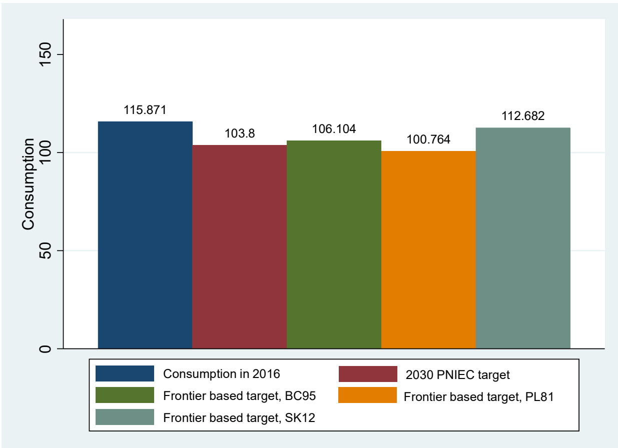


Analysis of efficiency scores across different estimation approach shows high levels of correlation for BC95, PL81 and SK12:

	BC95	PL81	TFE	SK12
BC95	1.00			
PL81	0.93	1.00		
TFE	0.26	0.00	1.00	
SK12	0.87	0.97	0.00	1.00

The analysis can be used to derive frontier based target for Italy, for a comparison with the 2030 consumption target indicated in the PNIEC, amounting to 103.8 Mtoe. It is worth noting that the two values have been derived based on significantly different approaches. While the SFA analysis is based on a backward looking analysis, the targets in the PNIEC are claimed to be based on future energy scenarios, considering the evolution of technology until 2030.

Figure 2. **SFA models, Comparison between 2016 consumption levels, 2030 targets and frontier based targets**



Compared to 2016 consumption, amounting to around 116 Mtoe, frontier-based predictions result in significantly lower consumption levels, between 100,8 Mtoe (PL81) and 112,7 (SK12). The 2030 consumption target set out in PNIEC lies within this range and amounts to 103.8 Mtoe.
For a preliminary assessment of efficiency levels across different sectors, we undertake a disaggregate analysis for the residential, industrial and transport sectors.[23] The results based on PL81 models are shown below:

Table 10. **SFA models, model coefficients, disaggregated consumption, 1996-2016, PL81**

Estimation approach	**PL81**	**PL81**	**PL81**	**PL81**	**PL81**
Demand	Total	Residential	Industrial[1]	Transport	Other
Parameters of the total demand function					
Ln(Energy prices)	-0.09***	0.03	-0.19***	0.01	-0.19***
Ln(GDP)	0.50***	0.15***	0.69***	0.88***	0.31***
Ln(Population)	0.43***	0.90***		0.01	0.65***
Time trend	-0.01***	-0.01***	-0.01***	-0.01***	0.00**
Constant	-3.31***	-8.12***	-2.29***	-3.17***	-5.92***
Parameters in the one sided error (u)					
Constant	0.09***	0.61***	2.40**	0.23**	0.23***
Variance parameters for the compound error (v)					
Constant	0.00***	0.01***	0.01***	0.00***	0.01***
Lambda	5.68***	9.77***	15.96***	7.14***	4.49***
Observations	357	357	357	357	357

[1]The population variable has been dropped in that it resulted in negative coefficients, which runs counter to expectations.
Note: country specific dummies are not reported in the table. *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

The estimated models display stable coefficients, with the exception of the residential and transport sectors. The price coefficient in the residential sector is consistent with Filippini, Hunt and Zorić (2014).[24] These models result in the following efficiency scores:

Table 11. **SFA models, efficiency scores (%), total consumption, PL81, 1996-2016**

Demand	**Sample**	**Italy**	**Average**	**Standard deviation**	**Minimum**	**Maximum**
Total	357	86,9	79.4	13.7	50.6	98.7
Residential	357	60,2	51.8	18.8	31.7	97.9
Industrial	357	17,8	29.2	21.9	11.0	97.0
Transport	357	63,8	66.6	14.4	49.2	98.5
Other	357	80,8	68.5	17.4	43.1	98.0

Overall, based on BC95 and PL81 models, it is possible to show the following rank positions for Italy over the analysis period:

[23] A sector classified as 'other' is considered to take into account other sectors of the economy, and is derived as a residual between total consumption and consumption in the main three sectors.
[24] Filippini, M., Hunt, L., Zorić, J. (2014), "Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector", Energy Policy, January.

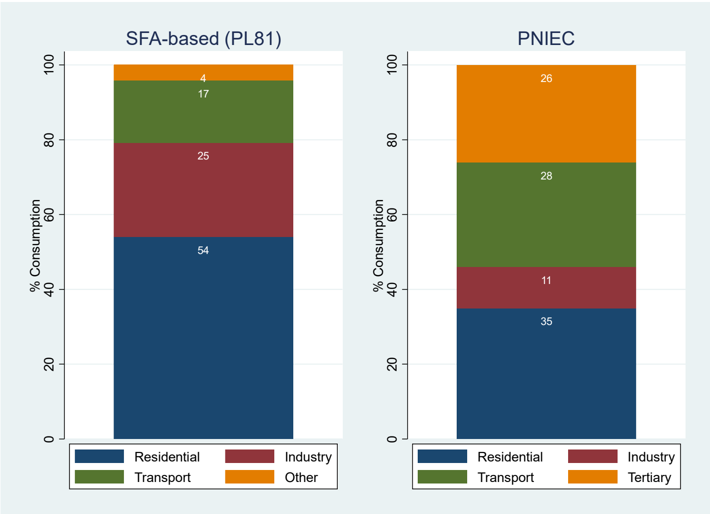
Table 12. **SFA models, Italy, rank position (out of 17), 1996-2016**

Consumption	**BC95**	**PL81**
Total	5	6
Residential	4	4
Industrial	3	11
Transport	7	11
Other	4	5

The analysis shows consistent performance for total consumption, which places Italy in the 5th-6th position. Italy's best performance is with respect to the residential sector. Mixed evidence is shown for the industrial and transport sector, since the PL81 models result in significantly lower efficiency ranks.

Disaggregated analysis can be used to derive sector-specific targets, also relative to those set out in the national plan. PNIEC expects a reduction in energy consumption based on active policies amounting to around 9.3 Mtoe/year in 2030, achieved 'mainly in non-ETS sectors'.[25] The modelling approach used in the PNIEC to establish such savings consider the different cost/effectiveness ratios for different measures, so to achieve the targets in the Directive. In addition, the modelling approach appears to take into account the evolution of performance and cost of different technologies, other sector-specific considerations and the achievement of renewables targets (e.g. in relation to heat pumps).

Figure 3. **Comparison frontier-based composition of efficiency savings versus PNIEC**



Note: composition of efficiency savings from PNIEC based on Ministero delle Infrastrutture e dei Trasporti (2018), Piano Nazionale Integrato Per L'Energia E Il Clima, December, chart n. 18 on p.55. In absolute terms, the estimated target based on PL81 amounts to 85.3 Mtoe, which compares to cumulated savings at 2030 of 51.3 Mtoe according to the PNIEC.

[25] Ministero delle Infrastrutture e dei Trasporti (2018), "Piano Nazionale Integrato Per L'Energia E Il Clima", December, p.55.

So far, as observed in section 2, most of the savings have been achieved from the residential sector. PNIEC confirms that residential sector is a significant area for improvement. SFA analysis identifies an further efficiency potential going forward (both as a share of overall savings and overall).
Based on SFA analysis, industry shows significant scope for efficiency. Although PNIEC reports relatively low expected efficiency, it states that it is a sector with ‘significant opportunities’.
The PNIEC’s targets for the transport sector are based on the expectation of significant measures and technological progress, including smart mobility, increase in freight transport by rail, car efficiency. The SFA models predict a lower efficiency gap.

7. Conclusions

The present paper provides a top-down, backward looking assessment of Italy’s energy efficiency. The results of the analysis are used to cross-check the key assumptions set out in the National Plan.
Relative to the sample, which covers 17 EU countries over the period 1996-2016, the analysis confirms the presence above-average efficiency.
Disaggregate econometric analysis shows high historical performance with respect to the residential sector, although it confirms that further scope for efficiency may exist. Mixed evidence is shown for the industrial and transport sector. It is worth noting that, based on this evidence, it can be argued that long term targets may be achieved by simply converging to existing best practice (without considering further technological change), which indicates significant scope for further efficiency improvements in the long term
To the authors’ knowledge, this is the first attempt to directly compare the efficiency assumptions in a National Action Plan using econometric benchmarking approaches. While these presents a number of limitations (e.g. it does not consider the significant evolutions in technology that may be emerge over the next decade), it represents a helpful tool to identify areas for improvement relative to existing best practice.

DOES DEMAND RESPONSE MAKE IT WORSE? IMPACTS OF AVALANCHE EFFECTS OF PRICE-OPTIMIZED VEHICLE CHARGING ON THE ELECTRICITY SYSTEM

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Abstract
Electric vehicles (EVs) are expected to possess a substantial potential for demand response (DR) and thus integration of renewable electricity sources in the future. Yet, DR can also have noticeable negative consequences, called avalanche effect. We systematically assess, under which circumstances avalanche effects occur and what impact they have on the electricity system and on cost savings for EV owners. Our results show that DR can provoke unwanted avalanche effects, which are particularly strong beyond 2030, when the leverage of EV charging has increased to a significant level. Avoiding avalanche effects is possible, if a dynamically updated DR signal is used. If this is the case, our findings confirm that shifting charging load from peaks to hours of low or negative residual load reduces peak residual load and variance of residual load and facilitates integration of renewables.

1. Introduction

In course of the electricity sector's shift towards low-emission generation technology, controllable power plants are being replaced by renewable energy sources (RES). As a large share of the renewable generation units is weather-dependent, alternative forms of flexibility are needed in order to satisfy the demand for electricity at any times. Demand response (DR) has proven to facilitate this transformation process by shifting demand according to flexibility needs [1].

Electric vehicles (EVs) as a means of replacing conventional fuels are an option of decarbonizing the transport sector [2]. The share of EVs is currently growing significantly worldwide [3]. Most studies predict a further significant increase in the market share of new EVs in the future [4–7].
The additional demand of EVs can pose challenges on the electricity system, such as increased peak demand - leading to capacity scarcity and rising electricity prices [6,8] or grid congestions [9]. On the other hand, controlled charging of EVs is expected to possess a substantial potential for DR in the future [10,11]. Thus, EVs can become part of the solution.
Beyond systemic benefits, controlled charging can also prove to be economically attractive for vehicle owners. Both the systemic and the economic efficiency of controlled EV charging depend on the signals used to incentivize a load shift [2,12,13].

There are several options to offer demand flexibility, such as on ancillary markets or by using hourly variable tariffs that depend on spot market prices [14]. In order to meet prequalification requirements for the majority of market options in terms of offered capacity, it seems, however, sensible to aggregate a critical mass of EVs. Shifting the charging time of a critical mass of load could nonetheless have noticeable consequences such as the creation of new load peaks [15]. This has been observed in the framework of simulating DR of EVs [6,15] and other demand processes, such as in the residential sector [16] and is referred to as "avalanche effect".
Avalanche effects in the context of DR have been reported before - as side effects of simulations with different scopes. Yet, to the best of our knowledge, they have never been systematically assessed as the core focus of a paper. Due to the expected high impact of EVs

on the system load, an avalanche effect caused by EVs could have incomparably stronger implications than for single residential applications. We thus identify the following relevant research questions:

- Can controlled EV charging cause avalanche effects? Can they be avoided?
- What is the impact of an avalanche effect on the electricity system?
- How does avoiding avalanche effects affect EV owners' benefits from controlled charging?

We look at controlled charging of EVs in Germany in the years 2030 and 2050. We use the model eLOAD [17] to investigate DR of EVs with a mixed-integer linear optimization approach: to target charging cost savings, we incentivize load shifting with a predicted price signal calculated using a quadratic linear regression of residual load. Within the optimization, the flexible share of the load is allocated in a cost-minimizing way complying with restrictions with regard to charging capacity and vehicle location.

To assess possible impacts of an avalanche effect, we disaggregate the total of all EVs in Germany into cohorts and vary the number of cohorts between model runs. Within each model run, the optimization signal is dynamically updated after each cohort's load shifting activity. We look at the perspective of EVs by analyzing average economic benefits for DR but also at systemic impacts in the form of implications on net load.

In section 2 of our paper, different strands of literature with regard to DR of EVs and avalanche effects of DR are presented. Additionally, an overview on current DR market schemes is given. The methodology we apply to simulate DR is outlined in section 3. In this section, a formal description of the model used is given. Section 4 describes results in terms of economic implications of DR and systemic impacts of DR, particularly with respect to the question, how avalanche effects arise and how they can be prevented. Subsequently, we discuss the conclusions that can be drawn from our modelling results and outline possible future research directions derived from the findings.

2. Literature

Several general strands of research are relevant for our paper. However, within this literature review we focus on the one hand on studies which have at least in parts addressed negative effects of DR and on the other hand we focus on research in the direction of DR signals and incentives. For impact of DR on the electricity system in general, several overview papers exist already (e.g. [14,18–20]). Further literature reviews are dedicated to modelling DR within energy system models (e.g. [21,22]).

Due to the expected substantial electricity demand of EVs [23,24], (controlled) charging of EVs is assessed by many scholars. Addressed aspects are impacts of DR of EVs on the electricity system, electricity generation and resulting CO_2-emissions (e.g. [2,8,12,24,25]), challenges arising from grid integration [9,11,26] or interactions of controlled charging with DR of other sources of flexibility [27]. While the majority of these studies draw a positive conclusion with regard to the effect of DR, a limited number of studies analyze avalanche effects of demand, i.e. negative impacts of DR. An avalanche effect is defined as an "overreaction of DR" [6], i.e. an unexpected increase of load in a certain time period because demand is allocated in a price-sensitive way [15,16,28]. In *Figure 1*, we schematically illustrate this effect: According to Gottwalt et al. [16], avalanche effects appear due to a "sequential game between price setter and taker: At first, the price setter creates a DR signal in order to incentivize load shifting (in *Figure 1*, this is visualized as red dots). Depending on the objective of DR, this signal often aims at reducing electricity price peaks resulting from high residual load[1]. Secondly, flexible devices react to this DR signal by rescheduling their demand (green dotted line in *Figure 1*). As a consequence, original peaks disappear, but if too much of

[1] Residual load in this case is defined as demand minus generation from volatile RES

the load is shifted away from original peaks and to periods of original residual load valleys, alternative peaks can occur and new valleys are created.

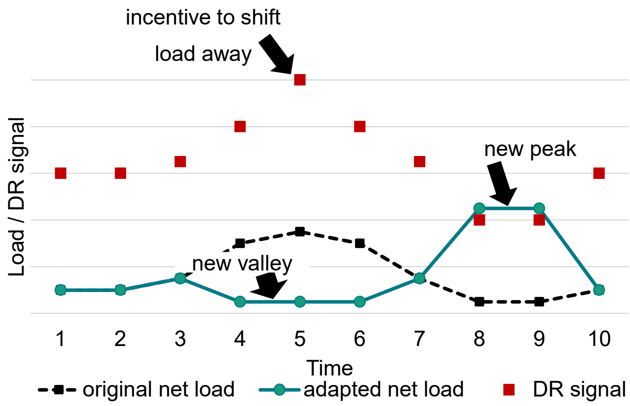


Figure 1: **Schematic illustration of an avalanche effect: Due to an overreaction of flexible load to an incentive, load is shifted away from peaks but builds new, unexpected peaks instead.**

Gottwalt et al. [16] investigate the impact of smart appliances with variable tariffs on residential electricity prices. They observe that, if appliances were able to behave flexibly, the load in hours of original price peaks decreased but new peaks were created instead. They introduce the expressions "avalanche effect" and "herd effect" to describe this phenomenon [16]. It is noteworthy that in their model, all appliances receive an identical price signal day-ahead. Thus, the appliances' behavior is similar, since they differ only in their respective technical restrictions. Gottwalt et al. emphasize that avalanche effects need to be analyzed thoroughly before introducing dynamic tariffs to a market, but do not propose means of avoiding avalanche effects.

Without explicitly using the name avalanche effect, Ramchurn et al. [29] describe the same mechanism in the context of applying time-of-use and real-time tariffs for decentralized smart appliances. In their analysis, this effect is caused by "overly-homogenous optimized consumption patterns" [29]. To avoid unwanted effects Ramchurn et al. propose an adaptive mechanism, in which the total number of devices optimizing their behavior is limited using a probability factor for each device. According to the authors, this model avoids avalanche effects without a central coordination of participants, its performance is however not compared to a system with a central control.

Focussing on DR with EVs, Dallinger and Wietschel [11] analyze how plug-in hybrid vehicles contribute to RES integration. In their model, EVs are divided into pools. If all pools receive the same price signal (in this case provided by a market equilibrium model), [11] observe residual load peaks. The authors identify this as the major disadvantage of DR with indirect control by using variable tariffs. By operating the EV pools in a predefined order and allowing to consider the behavior of preceding pools in a pool's optimization, the scholars use direct control to remedy this. However, since Dallinger and Wietschel put their research focus on implications of EV DR in terms of residual load peak reduction as well as changes regarding negative residual load and local transformer utilization, quantitative impacts of avalanche effects on economic or systemic benefits are not analyzed.

While [11] only look at one electricity market (Germany), Ensslen et al. [6] compare EV DR in Germany and France. Similar to [11], they integrate EVs in a market simulation model that sets hourly electricity prices, which the pools receive as incentive. In this special set-up, the price is received via a "charging manager" responsible for procuring the electricity needed for charging all EVs in the manager's pool at the lowest expenditures possible while on the other side controlling the pool's flexibility. By introducing the function of a "charging manager", Ensslen et al. apply a direct control mechanism, in which this manager uses information on all EVs state of charge and technical restrictions on the one hand and on the market situation on the other hand. Avalanche effects are avoided by placing bids on the spot market and iterating the price forecast afterwards. It is worth noting that in the authors' logic, EVs do not receive the price they bid for in the first place but the one calculated after the last iteration of the market simulation. Therefore, in case of [6], avalanche effects increase the market price and lead to decreased cost savings for all EV users. Regarding the differences between France and Germany, the authors find that, due to differences in the structure of the countries cost-sorted order of power plants avalanche effects are more undesirable in France than in Germany (30% cost increase in a scenario with 15 kW charging in France compared to 14.3% in Germany) [6].

DR is fundamentally based on the assumption that electrical load is shifted according to an incentive. If consumers pay a flat tariff, a deviation from the consumption pattern is not financially incentivized. Thus, the existence of a dynamic tariff is a prerequisite for DR. Due to the smart meter rollout in European countries, spot market based pricing for households and small commercial costumers becomes an option. Nevertheless, up to now it has only been established in few countries such as Great Britain, Italy, France, Finland, Estonia and Norway as opt-in possibility.

Over the past 40 years, there has been the Economy 7 tariff in Great Britain. It is a simple Time of Use (ToU) tariff with cheaper electricity prices during nighttime [30]

The so-called Tempo Tariff in France consists of three different day types (blue, white and red) dependent on the forecast of electricity demand and congestions on the electricity network [31]. Additionally, each day type has a day/night tariff design. There is a fixed number of days of each color per year. The color of the next day is available from 8 p.m.

In Finland, there is the possibility to get an hourly dynamic electricity price based on the Nord Pool spot price [32]. Prices for the following day are published at approx. 2 p.m.

Another hourly electricity price depending entirely on the Nord Pool spot price is available in Estonia. On top of the spot price there is a retailer's premium and a monthly fee. Prices and electricity consumption can be monitored via a mobile app [33].

In Norway, different models for dynamic prices are offered for household costumers. It is possible to get the average spot price of a time period of a month or less. Another possibility is a dynamic price based on the spot market price and the short term products traded on the futures market (Eurelectric 2017).

We also found opt-out tariffs in Spain and Denmark as well as a mandatory ToU tariff in Italy, which aren't further discussed here [32]. Furthermore, as the smart meter rollout in European countries is still proceeding, research projects are still being undertaken regarding smart tariff design with the aim of implementing more variable tariffs for household costumers in the future (e.g. [34]).

3. Methodology

We look at impacts of controlled charging of private EVs in Germany in the years 2030 and 2050 with a model-based approach applying the simulation model eLOAD.

We use the following approach:

1. Modelling of system load and charging load of EVs with hourly resolution
2. Simulation of DR of EVs
3. Variation of the share of vehicles that react to an identical DR signal
4. Ex-post analysis of financial benefits of DR of EVs

3.1 Modelling demand with hourly resolution

We use a partial decomposition approach to model hourly load for a base year (here: 2015) and project this load into the future (2030 and 2050) applying the simulation model eLOAD (Energy Load Curve Adjustment Tool). Within this model, the base year's historical electricity system load is decomposed into sectoral, subsectoral and application-specific load curves. To do this, we utilize a database of more than 1,000 technology-specific generic load profiles, which are scaled according to the annual application- and process-specific demand from the year 2015. The step by step modelling procedure is illustrated in *Figure 2*. Subsequently, all load curves are projected to the years 2030 and 2050 by scaling them according to their future annual demand using the underlying demand scenario. For more information on the framework scenario we refer to section 3.3 or [35]. Finally, the system load curve is generated by reassembling process-specific load curves.

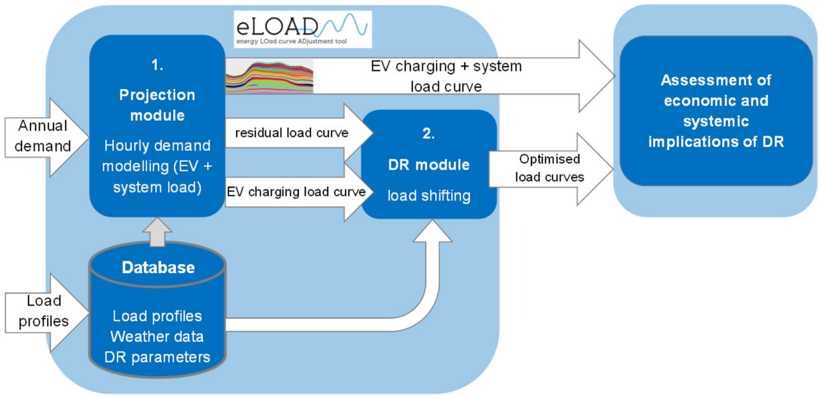


Figure 2: Step by step procedure applied in order to project hourly demand into the future (1) and simulate DR of EVs (2).

Using this method, we are capable of examining EV behavior while at the same time taking into account the influence on total hourly demand caused by other technological effects. These effects - developments regarding industrial processes or tertiarization - are not directly linked to the diffusion of EVs. Yet, they have an impact on the total hourly demand. Thus, they should be considered when evaluating DR for future years. For more information on eLOAD, please refer to [36] and [17].

3.2 Simulating DR of electric vehicles

To model DR of EVs, we use a mixed-integer linear optimization embedded in the simulation of the load projection. This means that we assume a certain share of all private EVs to be capable of adjusting their charging behavior according to a DR signal. Charging load is then allocated in a cost-optimal way using the following objective function (*equation 1*):

$$Min \sum_{h=h_{min}}^{h_{max}} \sum_{j=h_{min}}^{h_{max}} P_{ls,hj} \cdot (p_j - p_h), h \neq j, \qquad h,j \in [h_{min}, h_{max}] \qquad (1)$$

with load $P_{is,hj}$, shifted from hour h to hour j mainly depending on the DR signal p_j.

Since the usage of EVs follows a diurnal and weekly rhythm, we define an optimization interval of 24 hours for DR of EVs. In practice, this means that we have 365 optimization blocks per year. Therefore, h_{min} and h_{max} correspond to 1 and 24 for the first day.

EVs are mobile storages with load and storage capacity limits. We take into consideration, if vehicles are connected to the grid in a given hour by adapting load and storage bounds for the optimization dynamically. The location of private EVs is given in *Figure 3*. We assume that charging infrastructure is available at home and at work, thus all vehicles in a public location or currently in motion are excluded from load shifting. For more information on the dynamic modelling of the EVs mobile storage we refer to [27].

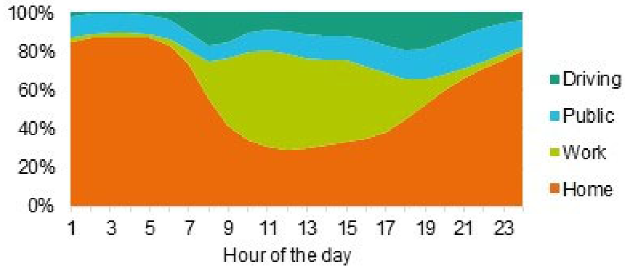


Figure 3: **Share of private passenger cars parked at home, at work, in public spaces and driving for each hour of a day**

A DR signal derived from the residual load is used as a DR signal (p_j in equation 1). Consequently, the optimization targets a cost optimal allocation of load.
The residual load is calculated endogenously in eLOAD. To provide a DR signal, we use the fact that wholesale electricity prices in Germany correlate with residual load: Prices on the German wholesale markets are set according to the intersection of demand with supply, the so-called merit-order curve [37]. The merit-order curve is a step function, in which all generation units participating in the market are included and ordered by their variable electricity generation costs [37,38]. RES, particularly PV and wind power, have very low variable costs. Thus, they are located on the lower end of the merit-order and determine the share of demand, which has to be covered by conventional power units [37], i.e. the residual load. For this reason, other scholars have already identified residual load as an important factor for explaining the formation of spot market electricity prices and have applied different forms of regressions (e.g. linear [39] or polynomial [38]) to predict prices. Roon et al. have produced good results using a linear regression for the years 2007 to 2009 [39]. However, since the merit-order assumes a steeper slope for a higher residual load (due to high variable costs of peak units like gas and oil-fired power plants), we chose a polynomial regression. This approach is similar to [38], who examined the Czech electricity market for the year 2016. We use hourly wholesale prices, hourly load and hourly generation of wind and PV (all provided by [40] for the year 2015[2] for our regression.
Figure 4 visualizes actual wholesale prices and residual load of the year 2015 and three different regression fits (linear regression, quadratic linear regression and cubic linear regression) for three selected days. The figure underlines that the different regressions are generally similar and capable of predicting wholesale prices sufficiently (linear: R2 = 0.778; quadratic: R2 = 0.781; cubic: R2 = 0.784; quartic: R2 = 0.783, quintic: R2 = 0.778), although

[2] We chose the year 2015 in order to be consistent to the scenario, since 2015 is the base year for other parameters such as solar radiation, temperature and structure of the year in terms of weekdays/weekends/holidays.

steep ramps followed by peak prices are underestimated, while the prediction overestimates steep ramps followed by very low prices.

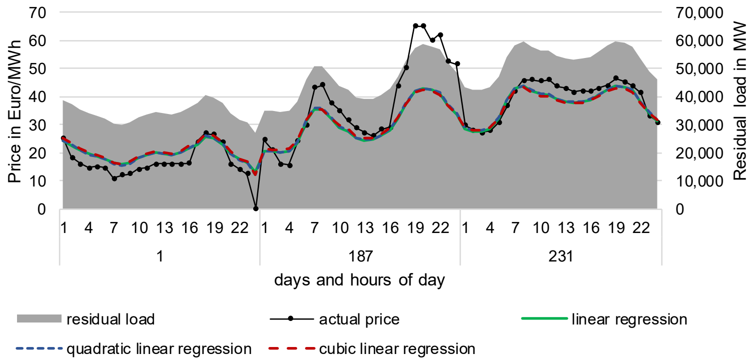


Figure 4: **Actual and predicted prices for selected days of the year 2015**

In our scenario, we assume a substantial increase of electricity generation of RES until the year 2050. This will result in hours with highly negative residual load. In *Figure 5*, we analyze the prediction's behavior for the range of values of the residual load we have observed in the model results for 2050. In the range of the historic residual load, all predictions are similar. It is, however, evident from the figure that the higher the degree of the polynomial regression, the more extreme are the predicted prices for very low or high residual load values. Merely the linear and the quadratic linear regression take on moderate values at the edges of the value range. For this reason, we choose a quadratic linear prediction for our model. Further, we assume that the level of average prices remains constant. Thus, predicted prices are shifted (up) according to the average wholesale price of 2015.

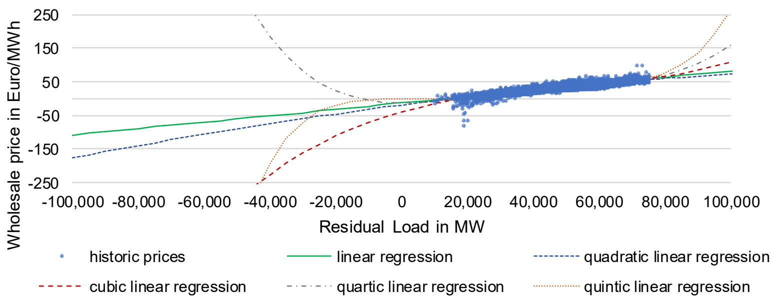


Figure 5: **Wholesale price prediction using linear regression with different polynomial regression fits. Blue dots visualize historic price/residual load tuples of the year 2015**

3.3 Case-study set up

Variation of the share of vehicles receiving an identical DR signal

During the load projection, EVs and their corresponding charging load are looked at in an aggregated way. In the simulation of controlled charging, we disaggregate the total number of EVs in Germany into smaller cohorts. The cohorts are then simulated sequentially. The DR signal is dynamically (and endogenously) updated after each cohort's load shifting activity. Due to the iterative update of the pricing signal, each cohort receives a different price signal. Thus, the DR signal always accounts for changes in the residual load due to prior load shifting activities. The order of the cohorts in the optimization queue is fixed for all days and all model runs to analyze potential differences resulting from the position of a cohort in the optimization queue. This means that in case of one cohort (so all controllable EVs in Germany), all EVs receive an identical price signal, while e.g. for two cohorts, the price signal is adapted after DR of cohort #1. In this sense, our hypothesis is that the fewer cohorts are simulated, the higher is the probability that avalanche effects occur.

To assess possible impacts of an avalanche effect, we conduct ten independent model runs, in which the number of cohorts varies from one to ten. We further assume that in 2030 50% of all private EVs participate in DR, while in 2050 we assume that 100% of the EVs is controllable.

Overall, our approach represents a central control of all EVs suitable for DR. This means that the central entity responsible for controlled charging has perfect foresight on future residual load and future theoretical charging/driving behavior of all EVs.

Framework Assumptions

In the framework scenario, a substantial increase of total electricity demand is assumed due to electrification of heating and transport but also process and fuel switches in the industry sector. According to the German RES expansion targets, RES are to account for 65% of the total electricity demand in 2030 and 80% in 2050. The RES technology-specific share is taken from [4]. RES profiles correspond to historic profiles for the year 2015 and are provided by [41]. The future diffusion of EVs is based on a total cost of ownership approach; the charging behavior was simulated on the basis of measured driving profiles of conventional vehicles using the model ALADIN, as currently representative data are not available for the future charging behavior. Table 1 gives an overview on important framework assumptions. For more information on the modelling of the charging behavior of EVs, we refer to [42,43].

Table 1: **Framework assumptions for RES, total electricity demand and EV demand in Germany. Assumptions are in line with** [35].

Technology	Generation/Demand in TWh	
	2030	**2050**
PV	100.7	180.8
Wind onshore	161.0	352.5
Wind offshore	52.6	73.4
Demand total	578.0	853.0
Electric mobility total	22.3	95.3
Electric mobility - private passenger cars	15.4	81.1

4. Results

To analyze avalanche effects of EV charging, we simulated DR varying the number of EV cohorts. In this section we look firstly at systemic impacts of DR and secondly at impacts regarding cost savings for EV owners.

4.1 Systemic impacts of DR

Figure 6 and
Figure 7 show simulation results for residual load (
Figure 7) and change of charging load after DR (charging load after DR minus charging load before DR, *Figure 6*) for two selected summer days in 2030. Without DR, charging on

weekdays takes place particularly when arriving at work (late morning) and in the evening - when arriving at home. Charging on Sundays differs from weekdays in the way that it is distributed more evenly over the course of the day.

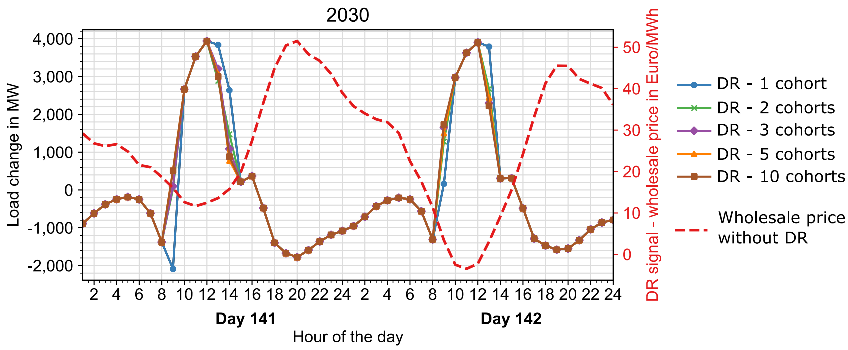


Figure 6: **Change of EV charging load (i.e. load after DR minus load before DR) for two summer days in 2030**

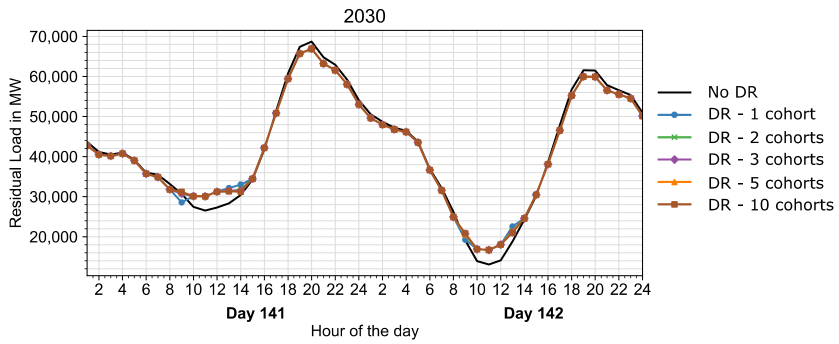


Figure 7: **Residual load without DR and after applying DR for varying numbers of EV cohorts for two summer days in 2030**

In both figures, the number of cohorts increases from one to ten between individual model runs. The wholesale price in *Figure 6* indicates that high PV radiation during noon results in low prices. The first cohort perceives this wholesale price as DR signal. Thus, for all cases high amounts of load are shifted to the midday hours and away from hours with high prices, e.g. during the evening, where uncontrolled charging load would be high. However, comparing the cohorts, it becomes apparent that the difference between different numbers of cohorts is small. Thus, implications on residual load (
Figure 7) are similar in all cases: For both days, peaks are shaved and load is shifted away from hours of low or negative residual load. The same applies on average over the whole year.

In 2050, the framework conditions change: Due to high RES generation, residual load takes on negative values for many hours, while at the same time the total demand of EVs increases by more than 500%. Thus, unlike in 2030, the leverage of EV charging is large enough to have a strong impact on residual load (*Figure 9*). In case of DR with one cohort, the figure shows that on both days a new residual load peak is developed around noon (thus in hours with negative residual load in the case without DR). This new peak is caused by high PV generation on both days. However, other principal drivers for DR such as wind generation or the absence of RES generation also play an important role for the charging behavior of EVs. This is visualized in FigureAnnex 3 and FigureAnnex 4, which show charging and residual load for two days in winter. Nonetheless, *Figure 9* underlines that for one cohort, i.e. if all EVs are shifted at once, an increasing volatility of residual load in the course of the day and between neighboring hours combined with the formation of new load peaks can be observed. Our results show that over the course of one year the charging behavior in the case of one cohort leads to an increase of peak demand by 66%, variance increases by 2.6%. This behavior can clearly be classified as an avalanche effect (see definition in Section 2 and the corresponding Figure 1).

In the cases of three or more cohorts, *Figure 9* shows that the overall charging behavior differs greatly from the one for a single cohort. This is due to the fact that the charging load of EVs is large enough to affect prices sufficiently in order to induce noticeable price changes (see *Figure 8*). As a consequence, the attractiveness of hours, in which an EV cohort's load is shifted, decreases for the successive cohorts, leading to a different optimal charging pattern. The more charging load is disaggregated, the more the residual load curve is flattened and the dispersion of residual load is reduced (maximum residual load is reduced by up to 11 GW (- 9%), variance by 24%. This can be seen in the figure for a specific day, but also applies on average over the year. In this respect, TableAnnex 1 contains details on minimum and maximum residual load for all cases examined here.

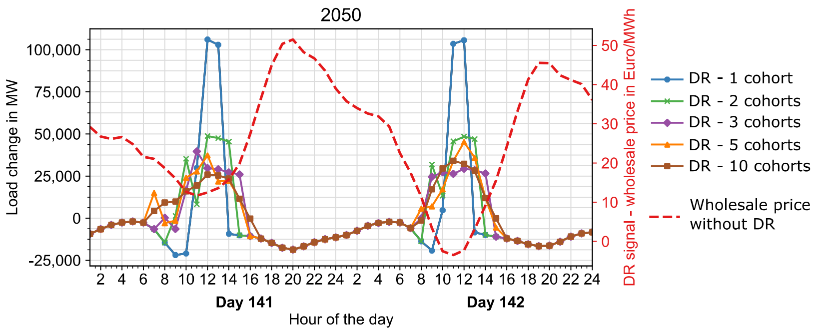


Figure 8: **Change of EV charging load (i. e. load after DR minus load before DR) for two summer days in 2050.**

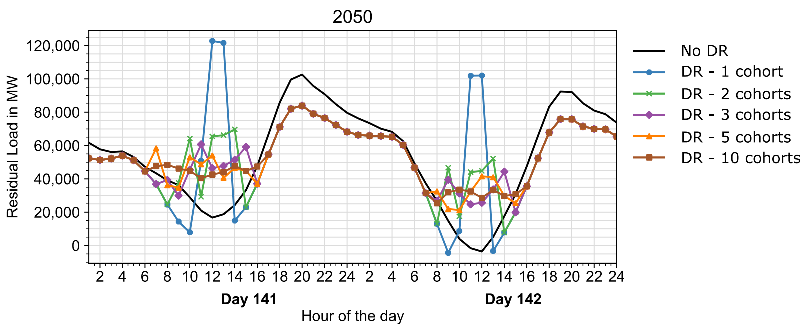


Figure 9: **Residual load without DR and after applying DR for varying numbers of EV cohorts for two summer days in 2050.**

Having shown that dividing the EVs into cohorts avoids avalanche effects effectively, our modelling results for a total number of ten cohorts in *Figure 10* show that controlled charging of EV changes the aggregated load pattern of EVs substantially and, therefore, has a noticeable impact on residual load. *Figure 10* compares uncontrolled and controlled charging assuming ten cohorts for the average weekday and Sunday for both 2030 and 2050.

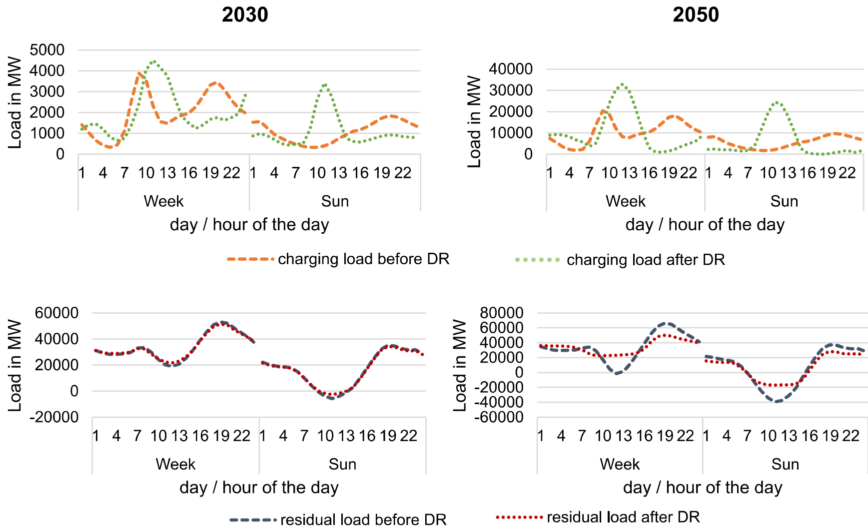


Figure 10: **Residual load and charging load before and after DR for 2030 and 2050. Controlled charging is simulated using 10 cohorts.**

If DR is applied, charging is shifted particularly to hours of high solar radiation (around noon) but also to nighttime hours. Due to comparatively lower shares of EVs, the effect on the residual load is rather moderate in the year 2030. This changes in 2050: Since the high electricity demand for vehicle charging represents a vast DR potential, the average residual load profile changes significantly. Evening peaks are reduced and midday valleys are filled.
Assuming that 50% of all EVs are suited for controlled charging in 2030, maximum residual load is reduced by about 30%, underlining that the impact of EV charging load on the total system load is substantial. Additionally, not only the extremes, but also the general dispersion of the residual load decreases (variance reduced by 5.8% in 2030). In 2050, due to the higher diffusion of EVs and their controllability, variance is decreased by 23.9%.

4.2 Impacts of DR on cost

For the assessment of financial benefits for EV owners, wholesale prices, which act as DR signal, are directly transferred to the EV owners. Thus, we assume that no additional costs or risk margins are associated with the participation in DR. *Figure 11* shows wholesale electricity costs for one to ten EV cohorts and costs for charging without DR. Since uncontrolled charging takes place in hours, in which demand is already rather high, average costs per MWh are higher than with a flat tariff if EVs are paid a real time price but do not apply DR. In all other cases, costs are reduced as EVs charge in hours with lower wholesale prices. In all cases, where EVs are disaggregated into cohorts, only the first cohort receives the most attractive prices. For all subsequent cohorts, prices are adapted and thus potential savings due to load shifting remain the same or decrease progressively. As a consequence, all cohorts have

different wholesale electricity costs. Potential savings decrease from the first to the last simulated cohort: In the case of a total of 10 cohorts, for 2030, average costs of cohort #1 are 3 Euro/MWh above those of cohort #10. For 2050, the difference sums up to 31 Euro/MWh, since a higher dispersion of the 2050 residual load compared to 2030 leads to high price spreads. In 2050, cohort #2 and cohort #3 are even able to profit from hours with negative prices, while all others still have positive electricity costs.
If we assume that we do not have a fixed but a rolling order[3] in which the cohorts receive the price signal, we get an average electricity price for all cohorts (black diamonds in *Figure 11*). In 2030, the difference in the electricity price for different number of cohorts is small (14.7 to 16.2 Euro/MWh), whereas in 2050 the spread between the different cases is much higher (-15.6 to 3.8 Euro/MWh).

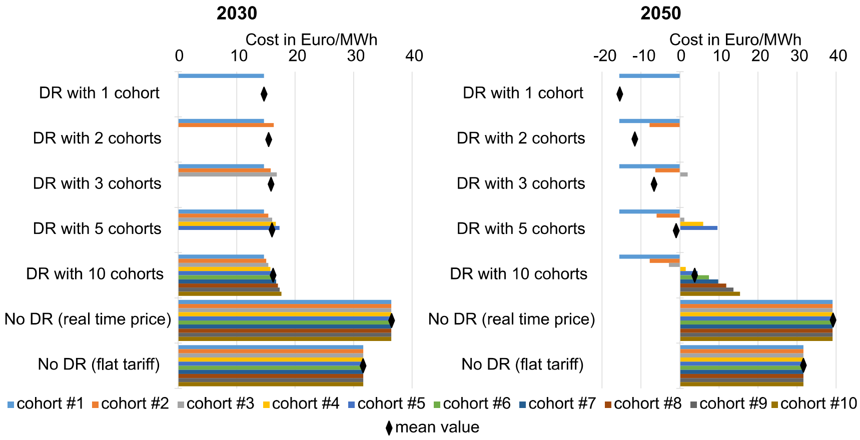


Figure 11: **Wholesale electricity cost** in Euro/MWh for 2030 (left figure) and 2050 (right figure) by cohort and total number of modelled cohorts. No DR (real time price) = actual wholesale electricity costs of charging, No DR (flat tariff) = average annual wholesale electricity price.

5. Discussion and Limitations

In the preceding section, we have simulated DR of EVs for the years 2030 and 2050. In this context, we pointed out under which circumstances avalanche effects occur.
Does DR make it worse? Our results show that in 2030 impacts of controlled EV charging can be seen as positive - also if an identical DR signal is given to all EVs. Thus, under the given assumptions we have not observed avalanche effects in 2030. However, we have only simulated DR of EVs in our model. If DR involves other processes as well, the shifted load and therefore the corresponding systemic impact could be higher and avalanche effects could occur more likely.
In 2050 - or if higher numbers of EVs are assumed - the situation is different: Since the leverage of EV charging will increase drastically, a DR strategy which does not incorporate an automatic update of the DR signal after a certain share of participating EVs does indeed induce avalanche effects. Outcomes are an increase of residual load peaks and load dispersion, both

[3] essentially, a rolling order in this respect corresponds to calculating an average electricity price for all cohorts ex-post and pass this price and resulting savings to all participating EV owners.

resulting in higher systemic costs. Yet, our results also show that new load peaks can be avoided by disaggregating the flexible EV load into cohorts. If measures are taken, the impact of DR is positive - as has already been confirmed by various scholars (e.g. [2,6,11]). As a consequence of disaggregating EV load, each cohort perceives a different price signal. This, however, creates new challenges: From the vehicle owners' perspective, we have observed strong impacts of the optimization order on cost savings of controlled charging: Prices are less and less attractive the more EVs have been optimized before. Thus, this effect lowers overall financial benefits for vehicle owners, since they cannot assume to be always first in line. This is an interesting finding, since it would mean that benefits from the same product would be different. In essence, this constitutes a price discrimination, which is not permitted in many countries. Thus, there has to be some averaging effect to treat all vehicles equally. This, however, means that the actual savings potential is lower than the maximum savings (as shown in Figure 11), which opens up further questions on how utilities could offer such a service and how they would calculate potential benefits for users.
While further research in this direction seems sensible, our case study set-up assumes a neutral entity looking for the cost-minimal solution in terms of charging load allocation. In reality, however, we should assume that utilities providing the services necessary to profit from DR pursue their own goals. For this reason, further research should also include the question of how it can be ruled out that entities profit from avalanche effects and therefore have an interest in provoking them.

Modelling DR of EVs we have simplified a number of aspects which should be considered when evaluating the results. We are aware that the polynomial regression we used to model a proxy for price is an approximation with space for improvement in terms of two major aspects. On the one hand, an electricity market model, particularly integrating a multi-agent trading simulation, could be able to model prices with a higher correctness, since techno-economic parameters such as ramping, agent behavior, withholding capacity for ancillary services, fuel switches due to a change in CO_2-prices or scarcity markups are modelled explicitly in such a model. However, since our focus was on EV demand and EV charging, we used a demand side model. Yet, in the future, it could be an option to couple our model with a market simulation model. Additionally, since our main focus was set on intraday adaptations of load we would have had to iterate the models after each of the EV cohorts. This would have increased the complexity of our methodology substantially. On the other hand, using a regression, we were able to model negative wholesale prices. We consider this a strength of our approach, since this is not possible with many electricity market models. Secondly, we built our price prediction on data from the past - historical prices and residual load for the year 2015. It is therefore based on framework conditions, which are likely to change fundamentally in the future. Particularly the fact that the majority of electricity will have to be provided by RES will have a severe impact on the way prices will be built, since this undermines the merit order principle in many hours of the year (this aspect is also not considered by currently used market models).
In terms of modelling of EV charging, we neglected the possibility of feeding electricity back to the grid (so-called "vehicle-to-grid"). Due to potentially negative impact on battery degradation, this concept is seen critical by some scholars (e.g. [12,25,44]), although others find that it has a positive impact on integration of RES (e.g. [45]). In any case, having the possibility to feed back to the grid would increase the leverage of EVs to influence residual load and profit from dynamically changing prices. Thus, neglecting the vehicle-to-grid concept reduces the peak shaving potential of EVs but also the negative impacts of avalanche effects.
Furthermore, we did not consider public charging infrastructure and commercial superchargers and did not model charging capacity larger than 3.7 kW. In practice, higher charging capacities could increase the effects of load shifting, since more capacity can be shifted to specific hours.

We know, however, from preceding studies (e.g. [46]) that higher charging capacity does not lead to substantial charging profile changes if an hourly resolution is applied. Additionally, other studies, which evaluated the charging behavior and preferences of EV owners, conclude that a high share of the charging processes will take place at home or at work while public charging plays a minor role [47,48].

Our findings show that avalanche effects can be avoided, if the DR signal is updated dynamically. Thus, DR has positive impacts on the system level. This does, however, not allow to derive statements on the regional or grid level: In our research design, we target cost minimization using the spot market price as a DR signal. Thus, the local situation in terms of demand and supply is not considered and local grid congestions can appear nevertheless. We also did not consider the possibility to participate in ancillary markets. Further studies should take these additional aspects into account, since they would mean to have additional market opportunities. At the same time this would represent a multi-objective optimization with possible interactions between the respective targets.

In order to quantify the maximum possible impact of EV charging, we neglected other sources of flexibility such as other flexible demand processes or different storage technologies. It is reasonable to assume that in a market with other sources of flexibility, there would be an increased competition between these sources. This could improve the system's economic and technical efficiency, since existing resources could be utilized even better, but could also reduce the financial benefit allocated to an individual source of flexibility.

6. Conclusions

DR of EVs addresses the need for a more flexible electricity system. Our findings show that shifting charging load from peaks to hours of low or negative residual load reduces peak residual load and variance of residual load and facilitates integration of RES. From an EV owner's perspective, it reduces electricity costs substantially, if real time prices are directly transferred to the EV owner. However, our results also show that controlled charging can provoke unwanted avalanche effects. These effects are particularly strong beyond 2030, when the diffusion of EVs will have progressed and the leverage of the charging load will have increased to a significant level. Avoiding avalanche effects is possible, if a dynamically updated DR signal is used, i.e. if EVs are divided into cohorts and DR of a cohort takes DR of preceding cohorts into consideration. From our modelling results we can derive that a total number of ten cohorts is already sufficient to avoid negative effects. Our findings, however, raise further questions concerning financial compromising and compensations for system-friendly behavior. From a systemic perspective, there is a trade-off between providing sufficient incentives in order to activate DR potential and avoiding unwanted effects.

Acknowledgement

This study was conducted in the context of the research project "LamA - Charge at Work", funded by the German Federal Ministry for Economic Affairs and Energy [grant number 01MZ18009A]. We are thankful for the financial support.

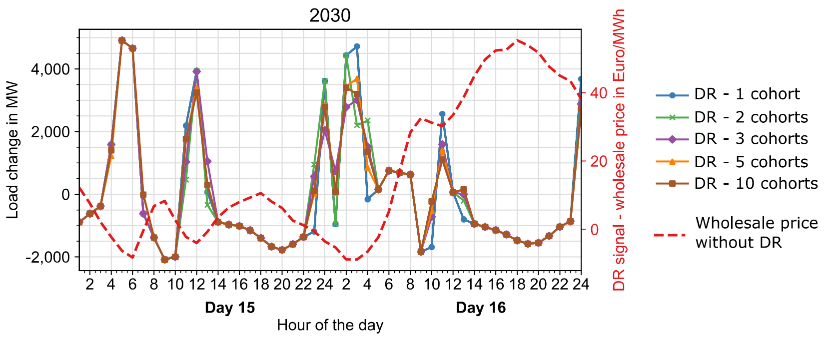
Appendix

TableAnnex 1: **Selected hourly load parameters for varying numbers of simulated cohorts**

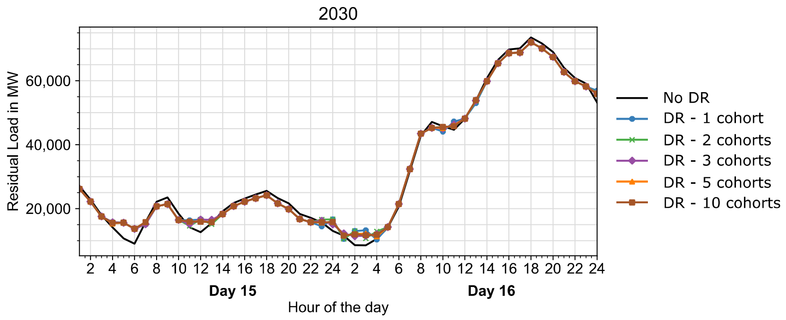
	Minimum Residual Load in MW		Maximum Residual Load in MW	
	2030	**2050**	**2030**	**2050**
Total Number of Cohorts = 1	-55,455	-123,978	85,855	204,025
Total Number of Cohorts = 2	-55,455	-114,507	85,855	141,950
Total Number of Cohorts = 3	-55,455	-104,864	85,855	131,067
Total Number of Cohorts = 4	-55,455	-102,535	85,855	120,464
Total Number of Cohorts = 5	-55,455	-100,312	85,855	118,338
Total Number of Cohorts = 6	-55,455	-100,888	85,855	118,883
Total Number of Cohorts = 7	-55,455	-99,516	85,855	114,730
Total Number of Cohorts = 8	-55,455	-98,631	85,855	113,864
Total Number of Cohorts = 9	-55,455	-99,031	85,855	113,766
Total Number of Cohorts = 10	-55,455	-98,743	85,855	112,270
No DR	-59,272	-133,409	87,231	123,221

TableAnnex 2: **Standard deviation and variance for the simulated years 2030 and 2050 for varying numbers of simulated cohorts**

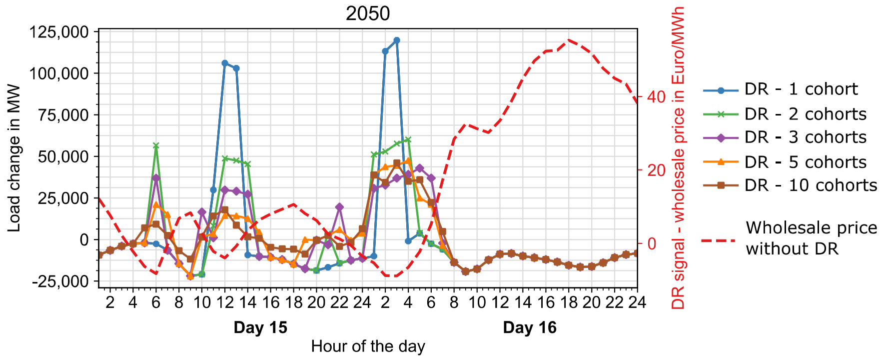
	Standard deviation change 2030	Standard deviation change **2050**	**Variance change 2030**	**Variance change 2050**
Total Number of Cohorts = 1	-2.94%	1.32%	-5.79%	2.65%
Total Number of Cohorts = 2	-2.96%	-9.23%	-5.83%	-17.61%
Total Number of Cohorts = 3	-2.96%	-11.44%	-5.84%	-21.57%
Total Number of Cohorts = 4	-2.97%	-12.04%	-5.84%	-22.64%
Total Number of Cohorts = 5	-2.97%	-12.36%	-5.84%	-23.20%
Total Number of Cohorts = 6	-2.97%	-12.52%	-5.84%	-23.48%
Total Number of Cohorts = 7	-2.97%	-12.62%	-5.85%	-23.64%
Total Number of Cohorts = 8	-2.97%	-12.69%	-5.85%	-23.77%
Total Number of Cohorts = 9	-2.97%	-12.73%	-5.85%	-23.84%
Total Number of Cohorts = 10	-2.97%	-12.76%	-5.85%	-23.89%



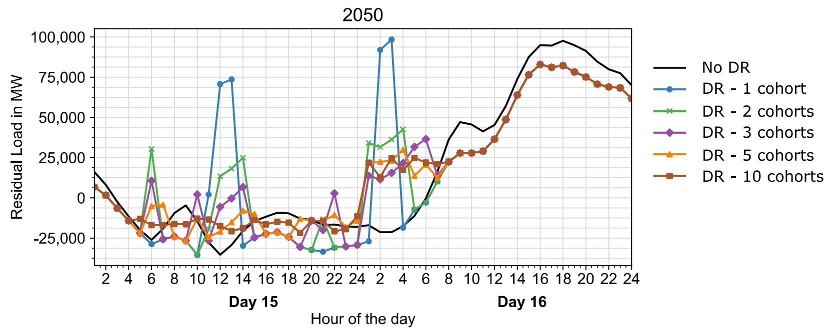
FigureAnnex 1: **Change of EV charging load (i. e. load after DR minus load before DR) for two winter days in 2030.**



FigureAnnex 2: **Residual load without DR and after applying DR for varying numbers of EV cohorts for two winter days in 2030.**



FigureAnnex 3: **Change of EV charging load (i. e. load after DR minus load before DR) for two winter days in 2050.**



FigureAnnex 4: **Residual load without DR and after applying DR for varying numbers of EV cohorts for two winter days in 2050**

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HOW RELEVANT IS THE NATURAL GAS DISTRIBUTION GRID IN COMPARISON TO THE ELECTRICITY DISTRIBUTION GRID AND HEATING GRIDS?

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and Martin Wietschel, Professor Fraunhofer ISI

Abstract
Current studies, investigating the developments of the energy system in light of the energy transition, predict a significant decline in natural gas demand until 2050. New competitors to the natural gas suppliers are entering the market to equip industry and buildings with electricity and heat, leading to challenges for the natural gas sector and especially for the distribution grid operators to remain competitive. To investigate these new challenges an interconnected approach reflecting the competition between natural gas, heat and electricity is necessary. Hence, this study focuses on sector coupling on a distribution grid level for the building sector by a combined analysis of a grid-based electricity, heat and natural gas supply. We aim at contributing to the following research question: How relevant is the natural gas distribution grid in comparison to the electricity distribution grid and heating grids in the building sector in 2050? To answer the question a techno-economic comparison of the three different grids is outlined, providing the general insight that the natural gas distribution grid could become the least relevant grid for supplying heat in buildings in 2050, but further analyses that are more detailed are necessary.

Introduction

Today, natural gas accounts for 23.8% (2017) of primary energy demand in Germany (AGEB 2018), making it to the second most important primary energy carrier for Germany after mineral oils. However, not only as a primary energy carrier, also as a final energy carrier natural gas is used in nearly every energy demand sector. Households, commerce, trade and services (CTS) as well as industry are demanding for high shares of natural gas. Only in the transportation sector, cars fueled by natural gas could not yet accomplish high market shares in Germany. However, new competitors are entering the market, especially in the building sector (households, commerce, trade and services). For example, in well-insulated buildings, heat pumps are used to provide heat or heating grids are installed on a larger scale.
Different studies show the trend to significant demand decrease of natural gas until 2050 (dena 2018; BCG and prognos 2018; Öko-Institut and Fraunhofer ISI 2015; IEA 2019). A strong decrease in natural gas demand with the similar length of natural gas distribution grid will lead to a strong increase in specific operating costs (Wachsmuth et al. 2019) and consequently, the economic performance of the natural gas distribution grid becomes questionable. To investigate this development in more detail the following question arises: How relevant is the natural gas distribution grid in comparison to the electricity distribution grid and heating grids in the building sector of Germany in 2050?

After explaining the current situation and research question, the next chapter gives an insight into the method used to compare the natural gas distribution grid with the electricity distribution grid and heating grids. Afterwards, results are shown and a brief summary and conclusion together with a critical reflection is provided.

Methods

To investigate the new synergies and competition for the gas distribution grid, we first analyze the current state and future development of the natural gas final energy demand on a national level for Germany. Therefore, recent scenario results from different studies with high policy impact are compared. The studies selected are "Integrated energy system transformation" (dena 2018) conducted by dena - German Energy Agency, "Climate paths for Germany" (BCG and prognos 2018) by the Boston Consulting Group (BCG) and Prognos, as well as "Climate protection scenario 2050" (Öko-Institut and Fraunhofer ISI 2015) compiled by Öko-Institut and Fraunhofer ISI. All scenarios selected target a Greenhouse Gas (GHG) - reduction of 95% by 2050 compared to the level in 1990. Consequently, these are very ambitious GHG - reduction scenarios. In the (dena 2018) two scenarios are selected; one with a focus on electrification and the other one using a technology mix. From (BCG and Prognos 2018), the National Focus scenario is selected and (Öko-Institut and Fraunhofer ISI 2015) provides one climate protection scenario for an ambitious GHG-reduction. Comparing these scenarios gives further insight about the changing usage of natural gas and potential alternatives to natural gas based applications.

Further, a techno-economic comparison is conducted for the three different grids. Therefore, for the economical part, the grid length in km, withdrawal volume in TWh, grid expansion in 2017 and its investment, as well as the different cost components of the price for the energy carriers are investigated. To identify the grid expansion in 2017, the grid length of 2016 is subtracted from the grid length in 2017. For the investment per additional kilometer, the investment is divided by the length of expansion. The values of investment in 2017 are taken from the monitoring report of the federal grid agency (BNetzA) in Germany. Their definition of investment includes the new gross entries to property and the values of new property, plant and equipment rented and leased (BNetzA 2019).

Afterwards, the technical analysis focuses on the sector coupling technologies leading to the synergies and competition of the different grids. For this reason, the technologies are grouped according to their demand sector and their grid connection, as well as the grid level on which they are connected.

To provide more detailed insights, an exemplary comparison of three relevant sector coupling technologies in the buildings sector, namely a heat pump, a heating grid supplied by large heat pump and a gas boiler, is outlined. The comparison is performed by taking the perspective of the end user, living in an average singlefamily house with 100 m^2 (UBA 2019) and an average heat consumption of 172.3 kWh/m^2a (Walberg 2012). Apart from taking the capital expenditures (CAPEX) for purchasing the sector coupling technologies into account, the energy carrier prices have to be converted to the useful energy, e.g. heat, by dividing the price by the efficiency of the technology connected to the grid, leading to the operating expenditures (OPEX).Based on the price per useful energy, different scenarios can be compared. The first scenario considers the current situation (status quo) with the base year 2017 and the situation in 2050. Secondly, the taxes and allocations are excluded and lastly, the influence of suppling synthetic methane imported from North Africa through the natural gas distribution grid to produce heat for building in a gas boiler is analyzed.

Results

The following chapter first provides the results gained by the scenario comparison. Thereafter, the insights provided by the techno-economic analysis are illustrated in detail and followed by the results from the exemplary comparison.

Development of the final energy demand in different studies

Based on the comparison of recent scenario results from different studies an insight into the current and future final energy demand is provided.

Figure 1 shows the comparison of the natural gas final energy demand in TWh in 2015, 2030 and 2050. The demand is split into the three main application areas: building (blue), industry (orange) and transportation (grey). It can be observed that, out of four scenarios, three contain a significant decline in natural gas across all sectors. Only the technology mix scenario, provided by dena (2018), estimates a nearly constant development of the natural gas demand in total. However, a strong decrease in demand is visible as well in the building sector.

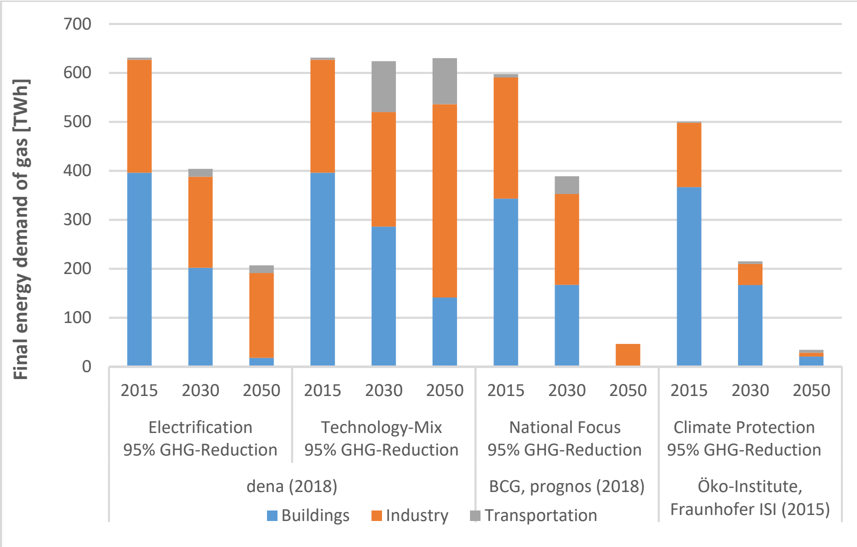

Figure 1: **Development final energy demand of natural gas until 2050**
(BCG and prognos 2018; dena 2018; Öko-Institut and Fraunhofer ISI 2015)

Taking a more detailed look into the alternatives to natural gas in the building sector *Figure 2* provides an overview of the demand development of district heating. Three out of four scenarios contain a decrease in district heating demand, whereas only the scenario of BCG and Prognos (2018) estimates a rather strong increase in district heating demand. Consequently, only in their scenario heat production in the building sector based on natural gas is partly compensated by district heating.

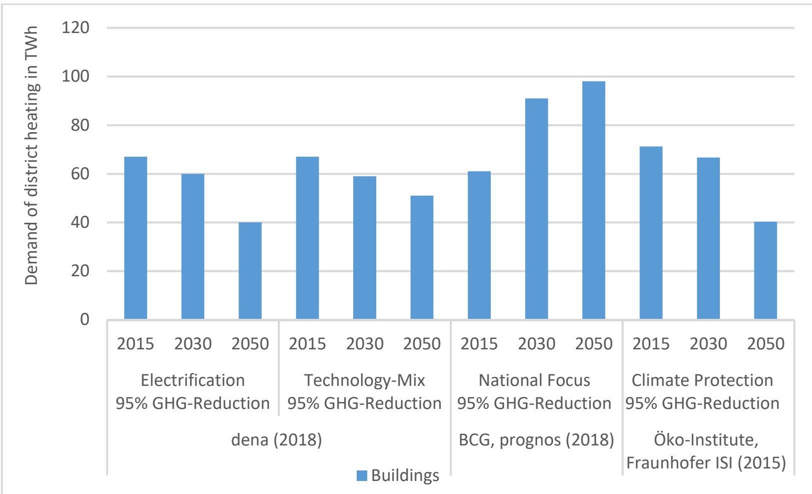

Figure 2: **Development final energy demand of district heating until 2050**
(BCG and prognos 2018; dena 2018; IEA 2019; Öko-Institut and Fraunhofer ISI 2015)

Figure 3 illustrates the development of electricity demand in the building sector (blue) and, if possible to differentiate, the electricity demand used to produce heat in buildings (orange). All scenarios comprise a slightly to strong increase in electricity demand and (BCG and Prognos 2018) as well as (Öko-Institut and Fraunhofer ISI 2015) contain a strong increase in heat production based on electricity.

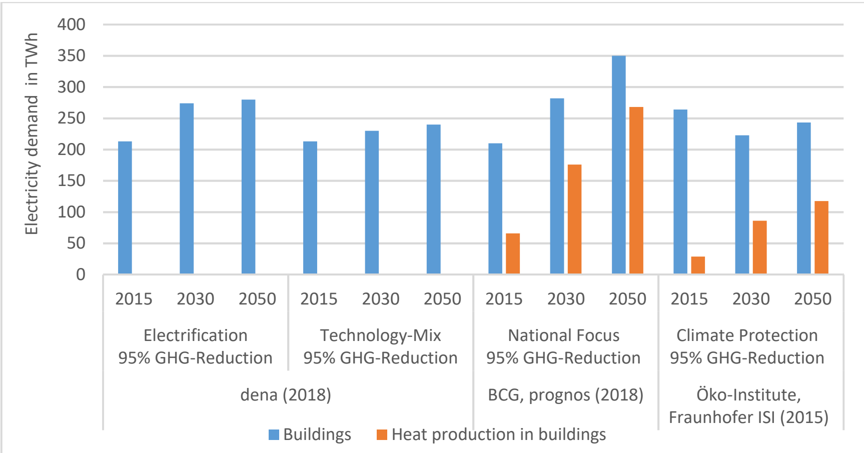

Figure 3: **Development final energy demand of electricity until 2050** (BCG and prognos 2018; dena 2018; Öko-Institut and Fraunhofer ISI 2015)

Based on this comparison, we summarize that the studies estimate a shift from natural gas based heat production in buildings towards electricity based one. For district heating, the studies see different trends, with a tendency towards a decrease in demand, so that district heating seems to be of lesser relevance for heat supply of buildings in 2050.

Techno-economic analysis of the heating grid, gas and electricity distribution grids in Germany

In this subchapter, the results gained by the techno-economic analysis are outlined. *Table 1* provides an overview of the length, withdrawal volume, grid expansion and investment in grid expansion of the three different grids in 2017 in Germany. The electricity distribution grid is with 1,807,895 km the longest grid and heating grids, being small local grids without a national wide connection, are the shortest with 21,610 km. Even though the electricity distribution grid is almost four times longer than the gas distribution grid, the latter distributes nearly double the amount of energy (withdrawal volume). Taking the grid expansion in 2017 into account, the expansion of the gas distribution grid is more than twice as big as the expansion of the electricity distribution grid, even though current studies estimate a decline in natural gas demand. Furthermore, the investment per kilometer of electricity distribution grid is significantly higher than the investment per kilometer of gas distribution grid. Consequently, expanding the electricity distribution grid appears to be far more expensive than expanding the gas distribution grid. A direct comparison between the investment in heating grids and the investment in gas and electricity distribution grid is not possible, because the heating grid investment includes the production of heat to supply the grid while the others do not.

Table 1: **Overview of economical parameters of the three grids for Germany in 2017** (AGFW 2017, 2018; BNetzA 2017, 2019)

Parameter		Gas distribution grid	Electricity distribution grid	Heating Grids
Length (2017) in km		498,081	1,807,895	21,610
withdrawal volume (2017) in TWh	**Total**	**752**	**445**	**75**
	Industry/CTS	474	324	5
	Households	279	120	71
Grid expansion (2017) in km		652	320	90
Investment in Million €2017/km		1.6	10.9	0.7

Comparing the different price components of the energy carriers in *Table 1*, one may see that the market structures of natural gas and electricity are very similar; both markets are regulated and unbundled in light of the liberalization and both prices include network charges to gain a revenue for the grid distribution operator. In comparison to that, the price for heat from heating grids is split into two main components, base price and energy price. The base price includes investment in facilities, pipeline, transfer stations as well as labor costs for operation, maintenance and repair (AGFW 2018) Further, the energy price includes the energy demand of heat production and of the pump to transport the medium through the pipelines (AGFW 2018)
The amounts of taxes and allocations of the energy carrier price are illustrated in orange in *Figure 4*. These amounts are on a similar level for natural gas and heat from heating grids, whereas for the electricity price the amounts are considerable higher, leading to a significant higher price for electricity than for the other energy carriers.

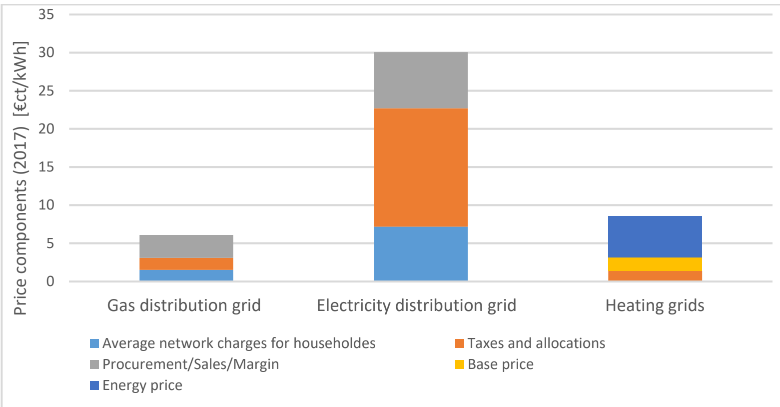

Figure 4: **Components of the different energy carrier prices** (AGFW 2018, 2017; BNetzA 2019)

For a more detailed comparison, the price of the different energy carriers needs to be converted to the same useful energy carrier, i.e. heat. Therefore, the price has to be divided by the efficiency of the conversion technology.
Focusing on the building sector, gas boilers are connected to the natural gas distribution grid. The electricity distribution grid supplies electrical heater and heat pumps that compete with gas boilers to supply buildings with heat. A strong synergy is established between electricity distribution grid and heating grids if the latter are supplied with heat by large heat pumps. Otherwise, if they are, e.g., supplied by geothermal energy, heating grids are also competing with the natural gas and electricity distribution grid for supplying heat in buildings. In the future transportation sector, gas fueled vehicles supplied by filling stations connected to the

natural gas grid compete with electric vehicle supplied by public or private charging stations connected to the electricity grid. Further, in the industry sector, natural gas is used for material use and combustion processes. Some of these processes compete with the direct use of electricity and currently, there is a synergy between the combustion processes and the use of wasted heat feeding into heating grids.

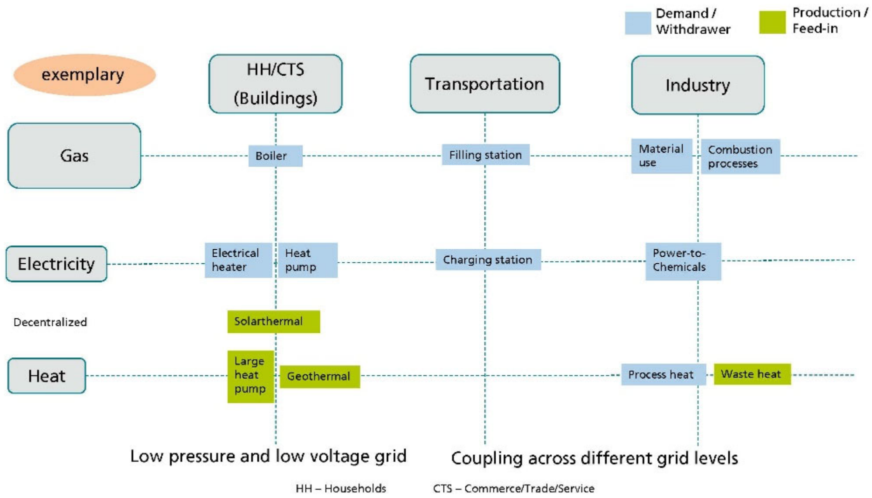

Figure 5: **Synergies and competition between heating grids, gas and electricity distribution grids**

Taking a closer look into the structure of the different grids, natural gas and electricity grids are composed out of similar grid levels, i.e. low, medium and high pressure or voltage level (Stadtwerke Troisdorf; VSE 2019). On the other hand, such different grid levels do not exist in heating grids (Agora Energiewende 2019; Panos 2009). Comparing the different grid levels on which the coupling technologies are connected to the grids, in the building sector the coupling appears on a similar level, i.e. on low pressure and voltage level, as well as the main consumers of the heat in heating grids are buildings (AGFW 2018). In contrast, considering the industry sector, the coupling appears on different grid levels. Some energy intensive companies are connected to high voltage lines but have a lower natural gas demand, leading to a connection on the low to medium pressure level. Consequently, the grid level on which sector coupling appears in the industry sector is much more diverse than for heating in the building sector. For that reason, the following exemplary comparison will focus on the building sector, comparing the coupling technologies gas boiler, heat pump and heating grid supplied by large heat pump.

Exemplary comparison of the competition in the building sector

In the following exemplary comparison an average single-family house with a living area of 100 m^2 (UBA 2019) and an average heat consumption of 172.3 kWh/m^2a (Walberg 2012), leading to an average annualenergy demand of 17,230 kWh/a, is assumed. The investment for the connection of a household to the heating grid depends on the house structure. In literature, costs between 1,500 € and 4,500 € (Walberg 2012; naturstrom 2019) are outlined, so that an average value of 3,000 € is assumed. It is further assumed that the connection costs are constant over time. The investment in gas boiler and heat pump are based on the cost development provided in (Wietschel et al. 2018). *Table 2* provides an overview of the CAPEX and specific CAPEX resulting from the investment for the different technology options. The highest costs account for heat pumps, which experience a slight decrease until 2050. Furthermore, the cost of a new gas boiler is decreasing according to the literature.

Table 2: **Capital expenditures (CAPEX) of the coupling technologies**
(Wietschel et al. 2018; naturstrom 2019; Clausen 2012; Walberg 2012)

	Gas boiler	Heat pump (Air)	Connection to the heating grid
Investment 2015 in €	4,370	12,000	3,000
Investment 2050 in €	3,974	8,155	3,000
Lifespan in years	20	25	25
Interest rate in %	5	5	5
CAPEX 2015 in €/a	351	851	213
CAPEX 2050 in €/a	319	579	177
Average energy demand of a house kWh/a	17,230	17,230	17,230
CAPEX 2015 in €ct/kWh	2.0	4.9	1.2
CAPEX 2050 in €ct/kWh	1.9	3.4	1.2

For the operating expenditures (OPEX), the energy prices have to be divided by the corresponding energy efficiency. Therefore, *Table 3* holds an overview of the efficiency developments of the technologies selected based on a literature review. The efficiency of gas boilers is assumed to remain constant while heat pumps and large heat pumps experience a strong increase in efficiency due to technology improvements.

Table 3: **Development of the efficiency of three exemplary sector coupling technologies and price development assumed of the three grid-based energy carriers**
(Hirzel 2017; Viebahn et al. 2018; Wietschel et al. 2018; AGFW 2017; BNetzA 2019; dena 2018; BCG and prognos 2018; Öko-Institut and Fraunhofer ISI 2015; Frontier Economics 2017)

		Gas boiler/ Gas	Heat pump/ Electricity	Large heat pump/ Heat
Efficiency in %	**Status quo**	90	300	300
	2050	90	400 - 700	400 - 700
Average price for households incl. taxes in €ct/kWh	**Status quo**	6.1	21.7 (29.9)	8.6
	2050	7.2 - 9.1	27.0 - 29.9	8.6
Average price for households excl. taxes in €ct/kWh	**Status quo**	4.5	10.6 (14.6)	7.2
	2050	5.3 - 6.8	13.1 - 14.6	7.2
Price for synthetic methane excl. taxes in €ct/kWh	**2050**	10.8 - 22.3	-	-

Further, the prices assumed of the different grid-based energy carriers are also included in *Table 3* and the resulting prices for the useful energy are summarized in Figure 6. For the first scenario, the current prices for useful energy including taxes and allocations are compared. The electricity price for heat pumps is subsidies, so that the regular electricity price is included in brackets. For 2050, the natural gas and electricity price developments from different studies are considered, showing an increase in natural gas price and a slight decrease in electricity price (*Table 3*) (BCG and prognos 2018; dena 2018; Öko-Institut and Fraunhofer ISI 2015). For future heat prices, no estimations are available to the best of our knowledge, so that a constant development is assumed. Furthermore, no subsidy for supplying heat pumps with electricity in 2050 is assumed. For the second scenario, the price developments are similar, yet taxes and allocations are excluded. The last scenario takes into account that in an ambitious GHG-reduction scenario natural gas cannot stay in the energy system and consequently, has to be replaced by synthetic methane. Therefore, the PtG/PtL-Calculator from (Frontier Economics 2017) is used to calculate the cost of synthetic methane imported from North Africa. To the costs 0.43 €ct/kWh are added for sales and marketing (Frontier Economics 2017) and a 10 % share of margin is assumed. The taxes and allocations are not included in the comparison, but a constant share of network charges.

		Gas distribution grid		Electricity distribution grid	District heating
		Natural Gas	Synth. Methane		
Network charges share of household price for energy carrier in %	Today	24.9		24.0	-
Price for useful energy incl. taxes in €ct/kWh	Today	6.8		7.2 (10.0)	8.6
	2050	8.0 – 10.1		3.9 – 7.5	8.6
Price for useful energy excl. taxes in €ct/kWh	Today	5.0		3.5 (4.9)	7.2
	2050	5.9 – 7.6	12.8 – 24.8	1.9 – 3.7	7.2

Figure 6: **Overview of the operating expenditures per useful energy development in the different scenarios**

Finally, the prices as operating expenditures and the capital expenditures are summed up and compared (*Figure 7*) while costs for maintenance and repair are not taken into account. For the first scenario, it can be seen that households using heat pumps have the highest level of expenditures, even though the electricity price is subsidized. Heat production by natural gas boilers is the cheapest option. However, with an increase of natural gas prices until 2050, producing heat by heat pumps will become the cheapest option.

Excluding taxes and allocations leads to a significant cost reduction for heat production by heat pumps, so that it reaches a similar level than heat supplied by heating grids. Nonetheless, the heat production by natural gas boiler remains the cheapest option today. In 2050, the heat pumps are the cheapest option while a gas boiler and heating grid reach a similar cost level.
Lastly, taking the fuel switch from natural gas towards synthetic methane into account, the expenditures for heat production by gas boilers increases significantly. Consequently, it becomes the least attractive option for heat production in new private buildings in 2050.

		Gas distribution grid: Natural Gas	Gas distribution grid: Synth. Methane	Electricity distribution grid	District heating
Total expenditures incl. taxes in €ct/kWh	Today	8.8		12.1 (14.9)	9.8
	2050	9.9 – 12.0		7.3 – 10.9	9.8
Total expenditures excl. taxes in €ct/kWh	Today	7.0		8.4 (9.8)	8.4
	2050	7.8 – 9.5	14.7 – 26.7	5.3 – 7.1	8.4

Figure 7: **Overview of the total expenditures in the different scenarios**

Excluding taxes and allocations leads to a significant cost reduction for heat production by heat pumps, so that it reaches a similar level than heat supplied by heating grids. Nonetheless, the heat production by natural gas boiler remains the cheapest option today. In 2050, the heat pumps are the cheapest option while a gas boiler and heating grid reach a similar cost level.
Lastly, taking the fuel switch from natural gas towards synthetic methane into account, the expenditures for heat production by gas boilers increases significantly. Consequently, it becomes the least attractive option for heat production in new private buildings in 2050.

Summary and Conclusions

In this paper, the scenario comparison showed a strong decrease in natural gas demand until 2050, especially in the building sector, with a shift towards electrification of heat production. Furthermore, an economic comparison showed that there are higher grid expansions in the natural gas distribution grid performed at a lower investment than for the electricity distribution grid. Today the share of charges for the network on the energy price is on a similar level for natural gas and for electricity. Furthermore, a simple comparison of network charges or price is difficult for the three different grids, due to the different market structures. The technical comparison clarified that coupling technologies are on similar grid levels (low pressure and voltage grid) only in the building sector, which favored a more detailed exemplary comparison on this level.
Based on the exemplary comparison, heat produced by heat pumps is nowadays the most expensive solution. Nonetheless, excluding taxes and allocations bring the three heat production options on a similar expenditure level. In 2050, heat production by heat pumps becomes the cheapest option, even when including higher shares of taxes and allocations on the electricity price. By neglecting taxes and allocations, the gap between heat from heat pumps to heat from natural gas boilers and heating grids increases in 2050. Considering a future fuel switch to synthetic methane in 2050 would lead to an even higher increase in expenditures for heat produced by gas boilers. Consequently, it can be concluded that the natural gas distribution grid will become the least relevant grid for suppling heat in new private buildings in 2050

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Critical reflection

This analysis provides a first insight into the different components influencing the different energy distribution grids without the aim of being conclusive. The assumption of constant shares of network charges neglects the effect that a strong decrease in natural gas demand might lead to higher network charges in the natural gas grid. Considering this aspect would lead to even higher prices for heat produced by gas boilers. Furthermore, the projection of price developments and efficiency changes include high uncertainties, opening up a broad span of solutions. The exemplary comparison of heat production with different technologies only includes a standard average house. In reality, the variation of buildings in size, age and insulation differs strongly. Furthermore, the regional differences, such as villages or cities, lead to different challenges for the infrastructure. This analysis only considers new buildings in which the heating technologies does not exist. Further research should also include existing buildings with its limitations to include new heating technologies. Additionally, more detailed research is needed considering hydrogen feed into the gas distribution grid or the switch from natural gas to hydrogen on the gas distribution grid level taking into account the limitations of the demand technologies and the necessary transformation steps towards a hydrogen grid. Considering these additional restrictions and options for the gas distribution grid is necessary to better understand the role of the gas distribution grid in the future energy system in 2050.

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NATO'S ENERGY SECURITY IN THE ERA OF HYBRID WARFARE"

Arnold C. Dupuy, Daniel Nussbaum, Sarah Lohmann, Stefan Pickl, Andreas Attenberger and Paul Michael Wibhey

Abstract

Hybrid warfare, which includes cyberwar methods, provides states, terrorist organizations or criminal actors a low cost, yet effective method to influence the poliinatics and policies of other states without the use of conventional military force. This entails the use of innovative technologies coupled with low risk/deniability calculus, resulting in high rewards from the audacious use of unconventional tactics and weaponry, whereby a weaker adversary can outmaneuver a more powerful opponent.

An important component of hybrid warfare is the ability of aggressors to attack civilian energy infrastructures. In fact, hybrid warfare operations have already been directed against the energy sector, both the power grid, as well as fuels production and distribution. As energy is a critical enabler to maintaining a technologically advanced civil society and state viability, the flow of affordable energy is critical. More specifically, the dependence of the world's military activities on the civilian energy infrastructure cannot be overemphasized, where virtually every aspect of the global supply chain is owned and operated by the private sector.

NATO acknowledges the threat posed by hybrid warfare, particularly as it relates to the energy industry, whereby an experienced practitioner in hybrid warfare could impact mission assurance with potentially devastating results to Alliance military effectiveness. Yet, while the Alliance has embraced hybrid warfare as a relevant security threat to the broader energy infrastructure, there has not been a systematic and rigorous analysis of this nexus. This paper introduces the work of a community of subject matter experts who have convened under the NATO banner to address the energy-centric perspectives of hybrid energy warfare or HEW.

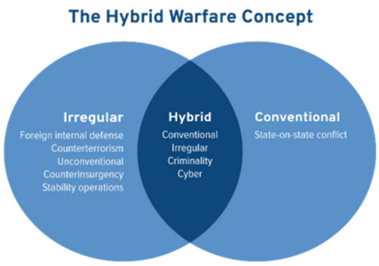
***Keywords**: NATO, hybrid warfare, cyber security, energy, Russia, NATO Science and Technology Organization*

Introduction

There has been much discussion of hybrid warfare, the nebulous and ill-defined area between real and virtual conflict, kinetic and non-kinetic action, or war and peace. Much of the basic components of hybrid warfare are traced to insurgencies and asymmetrical conflict, so it can be argued that its fundamentals are as old as human conflict itself. Hybrid warfare epitomizes the notion of a managed and limited conflict, using multi-domain effects to achieve specific goals such as coercive resource acquisition and territorial expansion. There is a focus on signaling, casualty avoidance and astute market and geopolitical calculations, whereby a weaker adversary can outmaneuver a more powerful opponent using low-cost, innovative technologies, balanced with a low risk/deniability calculus. Ultimately, high rewards are derived from the audacious use of unconventional tactics and weaponry. There are plentiful historical examples of one side leveraging its relative strengths against a larger or more powerful adversary's political, military or economic weakness. The US experience in Iraq, prior to the 2007 surge, is a sobering example of such asymmetric posturing.

With hybrid warfare's humble beginnings, it is the inclusion of rapidly changing modern information communication technologies (ICT) which creates such a unique threat with the potential to impact large segments of society. The speed, quantity and efficiency with which information moves around the world has increased enormously over the last four decades, effectively altering the dynamics of warfare, and blending the edges of peace and war.

It can be stated the cyber threat is the defining component of contemporary hybrid warfare. With the development of cyber operations centers and the rapid expansion of cyber capabilities



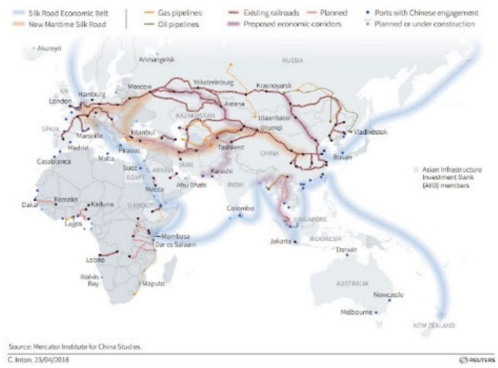
within foreign governments, conflict in cyberspace is growing in importance for nation-states. A critical aspect is difficulty in assigning attribution for such attacks, therefore providing the aggressor a veil of deniability, which makes it difficult to implement effective retaliatory measures.

As is often the case, when confronted with a complicated and multi-varied problem, there is difficulty agreeing upon an acceptable terminology and definition, and hybrid warfare is no different. For our purposes, we prefer the European Center of Excellence for Countering Hybrid Threats definition:
"*…an action conducted by state or non-state actors, whose goal is to undermine or harm the target by influencing its decision-making at the local, regional, state or institutional level. Such actions are coordinated and synchronized and deliberately target democratic states' and institutions' vulnerabilities. Activities can take place, for example, in the political, economic, military, civil or information domains. They are conducted using a wide range of means and designed to remain below the threshold of detection and attribution*[1]."

While the name and definition of hybrid warfare are debated, there is no doubt that we are in the midst of a dramatically changing environment in how states and military forces address threats.
Russia is an active perpetrator of hybrid warfare. In an attempt to avoid direct confrontation with the West, Moscow implemented it most effectively in its 2014 annexation of Crimea and continues to employ it today to influence its desired political outcomes in, for example, Ukraine. There has also been pressure on the Baltic States through direct intimidation, notably the 2007 Bronze Soldier event, which, arguably, ushered in the era of modern hybrid warfare, and elevated Estonia to the top tier of cyber defense expertise. It is not by accident that NATO's Cooperative Cyber Defence Centre of Excellence is located in Tallinn, Estonia.

China's growing influence in Eurasia and Europe proper through its 'Belt and Road Initiative,' has the potential for generating hybrid threats. As it has invested heavily in critical infrastructure including railways, roads, airports and ports, and ICT infrastructure, Beijing has the potential for generating hybrid threats. Europe's reliance on China, such as its investment of $2 billion in ICT--including cross-border optical cables, communications trunk line networks, transcontinental submarine optical cable projects, and spatial and satellite information passageways--makes Europe increasingly vulnerable[2].

Reviving the Silk Road



[1] The European Center of Excellence for Countering Hybrid Threats, located in Helsinki, Finland, began in 2017, under collaboration by the European Commission and the High Representative to the European Parliament and the Council https://www.hybridcoe.fi/what-is-hybridcoe/
[2] Patrick, Council on Foreign Relations, July 2, 2018.

The US Office of the Director of National Intelligence reported in early 2019 that China has the ability to launch world-wide cyber-attacks that could cause disruption of a natural gas pipeline for days to weeks[3].
As the premier security guarantor in Europe, NATO must adapt and derive ways to meet these new realities. Indeed, NATO has taken the hybrid threat seriously, elevating it to the highest levels in the Alliance's leadership structure, and ensuring the collective security of its 29 members, many of which share a border with a Russia forcing its way back to great power status at the expense of its neighbors.

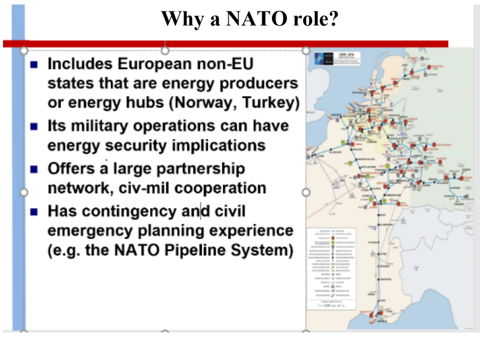
The Energy Nexus
As energy is a critical component to a technologically advanced civil society and state viability, the unimpeded flow of affordable energy is vital. Energy security has become a topic of concern by many nations, in what can be termed as the hybrid-energy warfare (HEW) dynamic, to include the availability and delivery of both fossil fuels and renewable sources. The latter point is particularly relevant; as Europe makes the deliberate shift from fossil fuels to renewable resources, it is important to understand the broader energy security vulnerabilities inherent in this process. Therefore, an important aspect of HEW is the ability of aggressors to attack and negatively impact the civilian energy infrastructure. In fact, it is because of this vulnerability and heavy impact that many hybrid warfare operations have been directed against the energy sector, both the power grid, as well as fuels production and distribution.

For instance, cyber-attacks on Ukraine's power generation in recent years have highlighted hybrid warfare's potentially devastating impact as well as the overall vulnerability of this sector. Also, there was the September 2019 drone attack on the Saudi Aramco facility, so, in a changing and interdependent world, energy is not only an economic commodity but also a "securitized" strategic resource, affected by a variety of kinetic and non-kinetic actions[4].

NATO has a strong interest in this arena, particularly as it relates to the energy industry; the Energy Security Section has recently taken on the hybrid threat portfolio and was rebranded as "Hybrid Threats and Energy Security." Yet, while the Alliance has embraced hybrid warfare as a relevant security threat to the broader energy infrastructure, there has not been a systematic and rigorous analysis of this nexus, notably within a military operational context. More specifically, the dependence of NATO's military activities on the civilian energy infrastructure cannot be overemphasized, where virtually every aspect of the supply chain is owned and operated by the private sector. Ultimately, it is this lack of emphasis on HEW, particularly in the military operational realm which prompted the authors to look more deeply in this matter.

[3] Coats, Senate Select Committee on Intelligence January 29, 2019
[4] See the Booz Allen Hamilton paper on the Dark Power attack of December 2015: "When the Lights Went Out.: https://www.boozallen.com/s/insight/thought-leadership/lessons-from-ukranians-energy-grid-cyber-attack.html

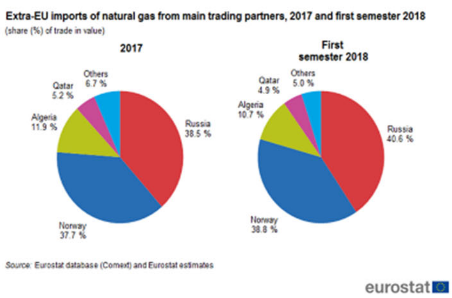
Military Relevance
The dependence of NATO's military activities on the civilian energy infrastructure is significant, while an adversary's ability to negatively affect military operations through a hybrid warfare posture is profound. For example, the delivery of natural gas, crude or refined product to Europe is vulnerable to numerous kinetic or non-kinetic threats. Moreover, the delivery of bulk fuel to forward deployed units, or the so-called 'last tactical mile', via pipeline, road, rail, air or barge can be challenged through any number of attack vectors. Therefore, it is safe to say that an experienced practitioner in hybrid warfare could impact mission success with potentially devastating results to Alliance military effectiveness, highlighting the importance that energy is a critical component across all aspects of the battlespace. Any impediment to energy distribution will inhibit the ability to operate seamlessly across the five domains (land, sea, air, space and cyber) and will also undermine interoperability among the NATO allies.

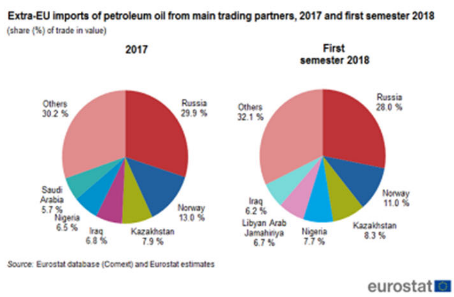


The key question that remains to be asked is: "What role can NATO play in addressing these energy dependencies and vulnerabilities?" As an actor in international security, NATO has a vital role to play in the nexus between energy security and hybrid warfare. This is particularly important considering the Alliance's ability to address dependencies and vulnerabilities among its members and act as a platform to build a common understanding of complex operating systems. However, the Alliance must contend with the member states or the European Union before implementing NATO-wide solutions, indicating that its role is still largely undefined and subject to wide interpretation and pushback from members wishing to protect sovereignty.

Nevertheless, military and civilian planners must understand the unique energy security dynamics found within NATO. The continued dependence on fossil fuels, which are imported mostly from outside of the Alliance borders, leads to a vulnerability where large exporters may use energy to exert political, economic and military pressure on small or dependent member states.

Russia's role in European Energy: Brief Review





The reliance on natural gas as a cleaner substitute for petroleum products introduces new threat variables into the equation, such as the fact that Russia supplies approximately 30% of Europe's gas. Additionally, as much of NATO's member states are promoting large-scale electrification of the infrastructure, how this will affect military operations demands further scrutiny. Finally, the ability of an aggressor to attack and disable large segments of the power grid, and thereby impact civilian security, as well as military operations, should be understood.

The HEW research roadmap or analytic framework in a NATO context

The primary aim of this article is to raise awareness of the energy-hybrid warfare nexus by understanding its component parts, identify its broader impact in the civilian and military realms, and define courses of action. The authors are part of a loosely organized community of stakeholders and subject matter experts with an interest in addressing this growing threat and propose a rigorous analysis of NATO energy sector's vulnerability in a hybrid warfare environment. Ultimately, we believe there is a need to define courses of action and create tools to mitigate the impact on civilian and military infrastructure and interests and develop countermeasures and analytic rigor to this vital topic.

Because of the European-centricity of this effort, we submitted a proposal for a Systems and Analysis Studies (SAS) to the Alliance's Science and Technology Organization (STO) in Neuilly-sur-Seine, France. The proposed activity will elevate the profile of this topic within NATO and among the member countries, to include Partnership for Peace (PfP) states, in which the results will be delivered to decision-makers and policy specialists among the NATO member and partner states. This will entail collaboration with public and private security experts, to include academia and the member states' governments, to determine common understandings, as well as define the parameters and countermeasures' goals. This activity will conduct both qualitative and quantitative analysis, accomplished through a series of workshops and conferences dedicated to the free and open exchange of ideas, as well as the use of methods and tools for operational analysis as applied to energy security and hybrid warfare. This intellectual foundation will support the analysis throughout the conduct of this activity and will encompass the full spectrum of threats as identified by the European Center of Excellence for Countering Hybrid Threats in Helsinki. Notably, this will include the social, economic, political and military threats to both the liquid fuel supply chain, as well as the grid.

We have developed an analytic method which looks at four key 'pillars', notably:

- What are the main threats to the civilian infrastructure?
- Data acquisition, analysis and modeling
- Understanding the adversary; acknowledging the Russian and Chinese threat
- What are the current and future mitigation efforts and countermeasures?

Our primarily focus will center on Russian hybrid warfare tactics, as well as to identify commonalities and determine unified responses. The recent growth of Chinese investments in European infrastructure will also be addressed with consideration to the energy sector. Moreover, emphasis will be placed on those areas most vulnerable to energy sector attacks among the NATO member states; primarily in Eastern Europe and Eurasia[5]. The initial findings will be produced in time for the 2022 summit.

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[5] Coats, Senate Select Committee on Intelligence January 29, 2019. For instance, the Office of the Director of National Intelligence reported earlier this year that China can launch world-wide cyber-attacks that could cause disruption of a natural gas pipeline for days to weeks.

The culmination of this activity will include methodologies and new research related to a prototype-operating model providing early warning on attacks to the energy grid, an analytic framework that addresses the inherent challenges associated with the energy-hybrid warfare nexus, a literature review and published body of knowledge. A final technical report will be provided, which outlines the basic aspects of the HEW dynamic, determines the threats to civilian and military infrastructure, and provide lessons learned, best practices and clearly defined courses of action.

Conclusions

HEW has the potential to destabilize many NATO and PfP member states and negatively impact Alliance cohesion. The authors believe this concept makes for a strong argument in favor of the potency of HEW as an unconventional war-fighting and balance of power concept. Additionally, we believe this activity will help initiate a comprehensive review by NATO as to what 'modernizing the force structure' into the 2020's really means, and why adaptability rather than stasis is the only option NATO has, if it intends to remain a viable, functional alliance. We welcome comments and participation from the broader NATO security community at large and anticipate impactful results for national Alliance-wide leadership.

THE CHALLENGES AND PROSPECTS OF JAPAN'S ENERGY SECURITY IN EAST ASIA SINCE THE 1990s

Hideaki Fujii, Kyoto Sangyo University, Japan

1. Overview

After the US-Soviet Cold War ended due to the collapse of the Soviet Union in 1991, market opening of information and communication technology to the private sector have progressed, and rapid demand expansion and technological progress of ICT services have been realized. The globalization has triggered the expansion of the market economy and the convergence of economic levels on a global scale. The movement of the geographical center of energy demand has also changed the global energy supply and demand structure. On the other hand, it has been pointed out that this phenomenon has been the cause of new isolationism, protectionism, and regionalism.

Japan needs to rethink new energy security after accurately observing reality; instable international order, and uncertainty in the energy transition policies and connectivity. This is because the environment surrounding Japan has changed dramatically since the Cold War in the United States and the Soviet Union, and East Asia now accounts for about one-third of global energy consumption. This paper examines Japan's non-traditional energy security issues since the 1990s, and it discusses the new energy security issues to be recognized in the first quarter of the 21st century.

2. Methods

First, the method of defining the concept of energy security[1] is reviewed([19][20]), and then it is divided into three eras according to the changing concept of energy security in Japan (*Table 1*.) ; 1) *Traditional Energy Security Concept*: the 1950s to 1991, characterized by national energy security and oil supply security([5][16][18]), 2) *Non-traditional Energy Security Concept*: 1991 to 2011, in addition to the feature of 1), characterized by multi-layered structure of risks in the process of globalization, regional energy security and multilateral cooperation, technology reliability([1][2][8][9][10][14][17][21]), 3) *New Energy Security Concept*: 2011 to present, in addition to the feature of 1) and 2), characterized by energy system transition (new risks from the decentralization and democratization of energy), Middle East instability (new risks from shale revolution and resource nationalism) and instable international order (new risks from Chinese expansionism and America first policy).

This paper aims to clarify the challenges of Japan's energy security issues and strategy by comparing the concept of *Traditional Energy Security*, *Non-traditional Energy Security* and *New Energy Security*.

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[1] This paper uses the following four elements that define the concept of security; Security targets (what to protect), Risks to be guaranteed (from what to protect), Security measures (how to protect it), "Who protects whom", according to [19] and [20].

Table 1. *Transition of Energy Security Concepts in Japan*

1. Risks to be guaranteed 2. Security measures 3. Who protects whom?		**Traditional Energy Security Concept** (US-Soviet Cold War structure) Before 1991	**Non-traditional Energy Security Concept** (Post US-Soviet Cold War) From 1991 to 2011	**New Energy Security Concept** (US-China tensions) From 2011 to present
Security targets	**Oil supply**	1. Soaring prices, Supply disruption, Resource depletion 2. Alternative energy, Oil reserve, Friendly diplomacy with oil-producing countries, Military action 3. National energy security	1. Soaring prices, Supply disruption, Resource depletion 2. Alternative energy, Oil reserve, Friendly diplomacy with oil-producing countries, Military action 3. National energy security	1. Soaring prices, Supply disruption, Resource depletion 2. Alternative energy, Oil reserve, Friendly diplomacy with oil-producing countries, Military action 3. National energy security
	+ **Environment**		1. Acid rain, Climate change, Radioactive waste, Marine pollution 2. Multilateral cooperation beyond national framework 3. Multilateral cooperation	1. Acid rain, Climate change, Radioactive waste, Marine pollution 2.Multilateral cooperation beyond national framework 3. Multilateral cooperation
	+ **Technology**		1. Advanced technology risks 2. Multilateral cooperation beyond national framework 3. Multilateral cooperation	1. Advanced technology risks 2. Multilateral cooperation beyond national framework 3. Multilateral cooperation
	+ **Energy Demand**		1. Demand fluctuation risks 2. Multilateral cooperation beyond national framework 3. Multilateral cooperation	1. Demand fluctuation risks 2. Multilateral cooperation beyond national framework 3. Multilateral cooperation
	+ **Socio-cultural elements**		1. Socio-cultural risks (NIMBYism, Environmental justice, etc.) 2. Establishing public confidence from grassroots 3. Governments guarantee for own country, Multilateral cooperation	1. Socio-cultural risks (NIMBYism, Environmental justice, etc.) 2. Establishing public confidence from grassroots 3. Governments guarantee for own country, Multilateral cooperation
	+ **International relations**		1. International risks, Military risks, Nuclear fuel cycle risks, Proliferation risks 2. International cooperation, Information disclosure and exchange, Understanding of nuclear problems 3. Governments guarantee for own country, Multilateral cooperation	1. International risks, Military risks, Nuclear fuel cycle risks, Proliferation risks 2. International cooperation, Information disclosure and exchange, Understanding of nuclear problems 3. Governments guarantee for own country, Multilateral cooperation
	+ **Energy system transition**			1.Energy system transition risks, Centralization risks and decentralization risks, Risks of democratization of energy, Connectivity risks and non-connectivity risks 2. Stable policy/investment, Public acceptance, System resilience, Business continuity plan(BCP) 3. Governments guarantee for own country, Multilateral cooperation
	+ **Middle East stability**			1. Middle East instability risks from shale revolution and resource nationalism 2. Transition to a dehydrocarbon society, Friendly diplomacy with oil & gas-producing countries 3. Governments guarantee for own country, Multilateral cooperation
	+ **Stable international order**			1. Global energy regime risks from Chinese expansionism and America first policy, Rulemaking risks 2. Multilateral negotiations and dialogue 3. Multilateral cooperation

Sources: Prepared by the author based on [1] [5] [8] [9] [14] [16] [17] [18] [21].

3. Results

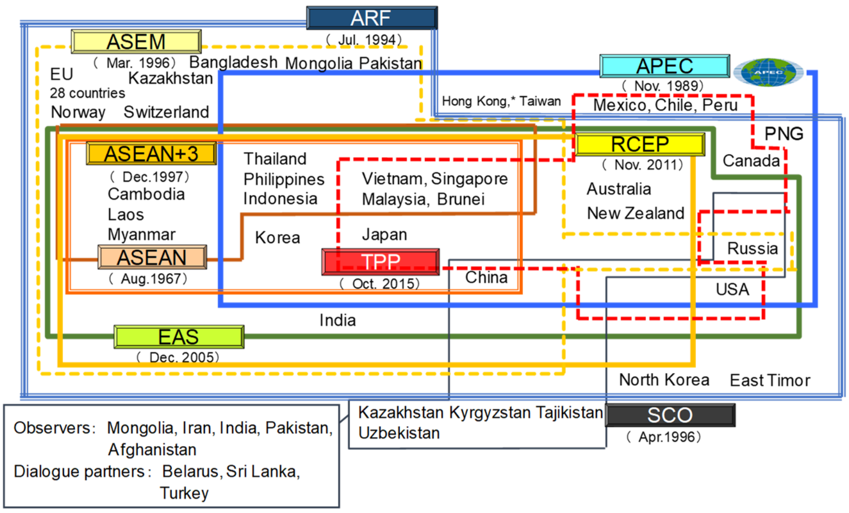
3.1 **Multi-layered multi-forum and frameworks for multilateral cooperation**

Since the end of the US-Soviet Cold War, "Risks to be guaranteed" have expanded and become multilayered, the demand for a framework for such multilateral cooperation has been becoming stronger. Under *Non-traditional Energy Security* concept, many multi-layered multi-forum and many frameworks for multilateral cooperation have been established (Fig. 1.).

The East Asian Energy Environment Community Initiative that affects survival rights, property rights, and democratization of democracy would be very unlikely to be realized without trust between Japan, China and Korea, and without sharing the same values. Already in East Asia, functional integration has progressed in the fields of trade, investment, finance, and non-traditional security, which is sufficient for the strategic reciprocity that aims at the interests of trade transactions.

The European Union is evaluated as a community formation based on the top-down Gemainshaft (community) concept as a precedent example of a community. On the other hand, a community concept in East Asia that does not yet share the same values had priority given to the method of building up a collection of economic and energy-environment cooperation by multiple bottom-up approaches ([9], [10]). In East Asia, energy-environment cooperation has been carried out in the framework of international organizations, multilateral cooperation, and bilateral cooperation within a range where actions of each country / region can be decided independently without any restrictions.

However, if there are some restrictions on the relationship between players and they cannot act based on their own decisions, an international regime consisting of principles, norms, rules and procedures is necessary ([14]). It is generally difficult to continue the sectoral cooperation framework in the energy and environmental sector, as shown by the fact that the APP (Asia-Pacific Partnership) established in July 2005, was abolished in April 2011 due to US budget constraints.



Note: * Hong Kong returned to China on July 1, 1997 as the Hong Kong Special Administrative Region of the People's Republic of China.
The dates in parentheses indicate the time of establishment of each Forum/Meeting/Agreement/Negotiation.
Source: Prepared by the author based on [10].

Figure 1. **Multi-layered multi-forum and member countries in East Asia**

(as of December 2019)

3.2 Uncertainty in the energy transition policies and connectivity

In considering Japan's *New Energy Security* strategy, the following five high priority energy security issues should be noted.

(1) Nuclear policy issues after The Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant accident.

1) Design and deployment of multi-layered measures to prevent the recurrence of the nuclear accident by various risks (human error, natural disasters, terrorist acts, cyber-attacks, high-altitude nuclear explosions, and electromagnetic pulse attacks by high-power microwaves ([11]).
2) Decontamination of radioactive materials in Kanto and Tohoku regions, disposal of contaminated waste (isolation/storage), and nuclear damage compensation.
3) Domestic power generation dependency on nuclear power.[2]
4) Nuclear back-end business (decommissioning of nuclear reactors, final disposal of radioactive waste, nuclear fuel cycle, prevention of diversion from nuclear power to military technology for non-proliferation and nuclear non-proliferation.
5) Selection of nuclear power business operators and human resource development (including avoidance of human resources and information outside the country).

(2) Upward revision of global resource reserves assessment and progress of shale revolution.

The impact of the upward revision of oil resource reserve assessment and the progress of the shale revolution on crude oil prices is complex. The following six main impacts are expected.

1) The principle of supply and demand is applied, and a new equilibrium is sought in accordance with price changes and quantity adjustment of supply and demand.
2) When the proportion of unconventional oil resources whose production conditions are difficult in oil supply increases, the marginal production cost of the entire oil supply increases, and the oil supply curve shifts to the upper left.
3) Larger oil and natural gas capital and investment will be required than before ([12][13][15]).
4) Since the establishment of the social cost of carbon raises the total supply cost of oil, the supply amount will not increase as much as the upward revision of the resource reserve assessment ([7]).
5) The United States will join the net oil and gas exporters (suppliers), and the oil and gas markets will become more competitive.
6) As shale gas production progresses around the world, demand for liquefied natural gas (LNG) will increase and competition with crude oil will intensify. On the other hand, Japan's bargaining power, which has been monopsony by LNG buyers in the Asia-Pacific region, will be relatively weak ([6]).

[2] As of August 5, 2019, there are nine units of nuclear power plants in operation (2 units are stopping) (Kansai Electric Power Takahama Power Station Units 3 and 4; Kansai Electric Power Ooi Power Station Units 3 and 4 (stopping); Shikoku Electric Power Ikata Power Station Unit 3; Kyushu Electric Power Genkai Power Station Units 3 and 4); Kyushu Electric Power Sendai Power Station Units 1 (stopping) and 2), and total output is 7.06 million kW. 24 reactors that have been decommissioned (17.43 million kW), 6 reactors that have been approved to change the reactor installation (6.31 million kW), and 12 that are under review for compliance with new regulatory standards (12.18 million kW), 9 that have not yet been filed (9.64 million kW). Kansai Electric Power Company Takahama Power Station Unit 1 (44 years of operation) and Unit 2 (43 years of year) have been permitted to change the reactor installation. Restarting a nuclear power plant after the 2011 earthquake required "decisions made by energy policy authorities and locals based on the judgment of the Nuclear Regulatory Commission and operators' explanations". Taking account that the location conditions of Takahama Power Station (the risk of impact on the Kinki and Tokai areas), we should note that the extension of operation of these old nuclear power plants requires more careful deliberation and judgment. As of March 11, 2011, there were 54 nuclear power plants in Japan, and around 30% of the electricity used in Japan was covered by nuclear power.

(3) Expansion of renewable energy generation

Like many countries that have introduced the FIT (Feed-in tariff) system[3], Japan has also benefited from expanding renewable energy power generation facilities (doubled in 5 years) and reducing costs (purchase price of residential solar power; \48/kWh in 2009 to \26/kWh in 2019). On the other hand, new problems of public burdens (2.1trillion yen/year) and grid constraints (Kyushu area in 2018) are emerging, and the continuing burden of public costs and the technical problems of grid connection are increasing the uncertainty of renewable energy policies ([3][4]).

At present, there is no significant input-output spillover effect due to the increased introduction of solar power in Japan. This is because imports of solar panels made in China have been increasing, Chinese manufacturers accounted for 53% of the Japanese market share of solar cell modules for industry in 2016.

(4) Research and development of new technology and diffusion

Technology is the key to breaking through energy security issues. The Government of Japan humbly acknowledged *the uncertainty of technology development*[4] in the basic concept of the 2014 Energy-related Technology Development Roadmap. Meanwhile, a roadmap for specific energy technology development up to 2050 identifies 36 technical fields based on the energy supply chain.

(5) Economic development and energy supply and demand trends of China that is a population-rich country located in the west of Japan

1) Chinese expansionism

China's political and economic presence in the world has been expanding significantly. China's GDP was 8.2 trillion dollars (2010 prices) in 2014 accounting for approximately 11% of the world's total. China's energy consumption and CO_2 emissions are the largest in the world as a country. It is necessary to observe carefully that the movement of the Belt and Road Initiative (BRI) as a regional economic zone by Xi Jinping regime and the Asian Infrastructure Investment Bank (AIIB, founded in 2014) would make some negative impacts[5] on the "democratization of democracy" in the relevant region.

In order to confront China's strategy of always adhering to *an omnidirectional strategy*, regardless of whether Japan prioritizes a decarbonization strategy, we cannot help but think about the problems of submarine resources with neighboring countries, and territorial issues surrounding oil and gas resources, cobalt rich crust, rare earth resources, methane hydrate.

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[3] With the implementation of FIT in 2012, the existing RPS (renewable portfolio standard) system will be phased out in five years from FY2017. Prior to the FIT, a surplus purchase system for residential solar power was introduced in 2009, and from 2019 onwards, there will be power sources that end the fixed price purchase period for residential photovoltaic power generation under the FIT system.

[4] On December 21, 2016, the Ministerial Meeting on Nuclear Energy decided that the Fast Breeder Prototype Reactor "Monju" of the National Research and Development Organization of Japan would not resume operation as a nuclear reactor, but would shift to decommissioning and it would position itself to take on a new role in future fast reactor research and development.

[5] The Chinese government's overseas investment already has problems in Zambia, Myanmar, Vietnam, Brazil, Sri Lanka and other countries. See "Sri Lankan government sells interest in a large port to Chinese company" (Nihon Keizai Shimbun, December 9, 2016).

2) Recognizing the failure of the Kyoto Protocol Clean Development Mechanism (CDM)

Although China is currently the world's largest emitter that emits much more greenhouse gases than the United States, its dependence on coal in total primary energy supply remains over 60%. Based on the "Kyoto Protocol Clean Development Mechanism (CDM)" of the United Nations Framework Convention on Climate Change, environmental technology cooperation was provided to China. However, as shown by the Jevons Paradox, the adverse effects of environmental technology cooperation have rather significantly increased China's greenhouse gas emissions. This means that a more compelling international regime is needed to ensure East Asian energy security.

4. Conclusions

Under *Non-traditional Energy Security Concept* (1991 to 2011), functional integration had been established in the fields of trade, investment, finance and nontraditional security by multiple bottom-up approaches in East Asia. The East Asian Energy Environment Community Initiative[6] had been studied and discussed among Japan, China, Korea and ASEAN countries. During this period, little progress was made in the framework. If we wish to advance the various East Asian community initiatives further, we will have to secure a situation in which things can be decided by each country, ensure the reliability of technology, ensure trust among countries[7], and establish common rules.

Under *New Energy Security Concept* (2011 to present), priority has been given to building a decentralized energy system to secure various options for domestic energy supply and demand by emphasizing technology and investment in Japan.

The following three points as additional Japan's energy security strategies should be emphasized in the first quarter of the 21st century under *New Energy Security Concept*.

(1) Japan's energy policy should focus on promoting energy technology development, and it should be necessary not only to "get out of the fossil energy-dependent hydrocarbon society" but also to have an innovative strategy of "full management of energy demand".

(2) There are other possible options than Japan's domestic optimization strategy (Fig. 2.). A connectivity strategy among East Asian economies would include the Asian Super Grid initiative and an energy bridge (oil & gas, electricity) initiative between Russia's Sakhalin

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[6] The central role of civil society is private non-profit organizations (NPOs), non-governmental organizations (NGOs), think tanks, etc., but "social and governmental bridge" is required based on citizenship. For example, in Japan, the "East Asia Community Council" (CEAC: The Council on East Asian Community, established in 2004) provides a place where industry, government, and academia gather together to discuss the concept of the East Asia community. A research group such as the CEAC that accepts pros and cons of the East Asian community concept and is made up of people with different ideas (note that it is not a promoter group of the East Asian community) is a few examples.

[7] In East Asia, there are sovereignty issues on the East China Sea (Senkaku Islands (Diaoyu Islands)) and Takeshima (Liancourt Rocks, Dokdo), North Korea's nuclear warhead missile issue, abduction issue, and history issue. Also, although Japan recognizes that the comfort women problem and the issue of former civilian workers from the Korean Peninsula have been settled by the Agreement on the Settlement of Problems concerning Property and Claims and on Economic Co-operation between Japan and the Republic of Korea (1965), the comfort women issue and the issue of former civilian workers from the Korean Peninsula have been used for political use every time the president changes in Korea. If promises under the law are not guaranteed in constitutional countries, the relationship of trust could not be established forever. Needless to say, the Japanese reflect on Japan's harm to Asians during World War II and the Japanese have been educated, at least since I was born (1961), to reflect, and still believe that I should reflect.

Island and Japan. These projects have positive effects (energy saving through the regional optimization, increase of available transfer capability in the transmission line by the export of electric power[8], stable supply in the event of a disaster or accident) and negative effects (cost burden and profitability, mutual dependence would be fixed by connecting the power grids or pipelines).

(3) In East Asia, a comprehensive and enforceable multilateral legal framework should be needed, and East Asian countries and regions should need to seek the formation of common values that could be shared regarding order, justice and peace. It is necessary to think about when and how to understand that politics and economy cannot be separated among Japan-Russia, Japan-Korea, and Japan-China. Therefore, a comprehensive and enforceable multilateral legal framework such as existing Energy Charter Treaty and International Energy Charter, or a new East Asia Energy Charter Treaty should be considered more positively.

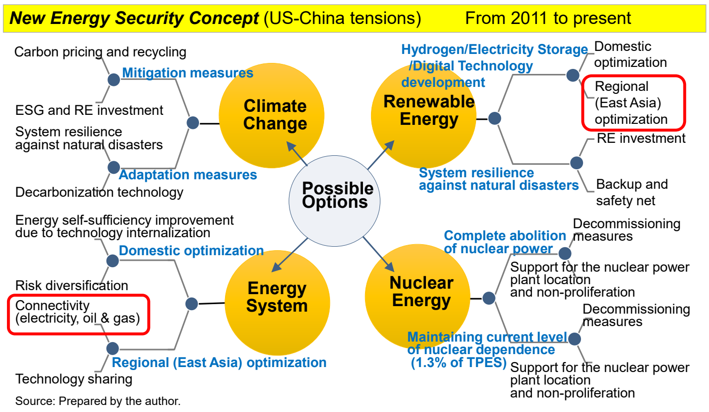

Figure 2. **Other options for Japan's energy security strategy**

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OIL AND THE DOLLAR COMOVEMENTS: IS SHALE OIL A GAME CHANGER?

François Benhmad, Associate Professor Université de Montpellier

Abstract:
In this paper we explore the relationship between oil prices and US dollar before and after the shale revolution and its impacts on international oil markets.
As the two markets are linked through various channels which may have impacts at different frequencies, we should investigate this relationship from a time-frequency perspective. Indeed, the wavelet transform enables us to decompose oil and US dollar time series into their respective frequency components, and to run tests of Granger causality on these components on a time scale (frequency band) by time scale basis during two periods. The first period occurs before US shale revolution (2000-2007), the second one comes after this revolution and runs from 2008 to 2018.
Our main findings suggest that for to a time horizon running from 9 months to 64 months, representing approximately the business cycle frequency band, the Granger causality that was running from US dollar to Oil prices during the period 2000-2007 had switched its direction during the period 2008-2018. The US shale revolution was the main reason behind this switching according to its large effect on oil markets.

Keywords: Shale oil, Oil, US Dollar,Wavelet Granger causality JEL codes: E32, Q43

1. Introduction:

Since the oil prices collapse in mid-2014, the conversation about oil markets has been dominated by the shale oil revolution in USA. Indeed, after a steady decline since the mid-1980s, US production began to increase in 2008. The horizontal drilling and hydraulic fracturing or "fracking" used to produce oil enables US oil output to break records by surpassing 10m barrels a day in 2017 after its low point of about 5m b/d in 2008 . As the shale oil boom continues, the United States will overtake Russia as the world's biggest oil producer by 2019 at the latest, according to International Energy Agency (see figures 1 and 2).

Figure 1. **US field production of crude oil (thousands barrels per day)** (Author, data source EIA)

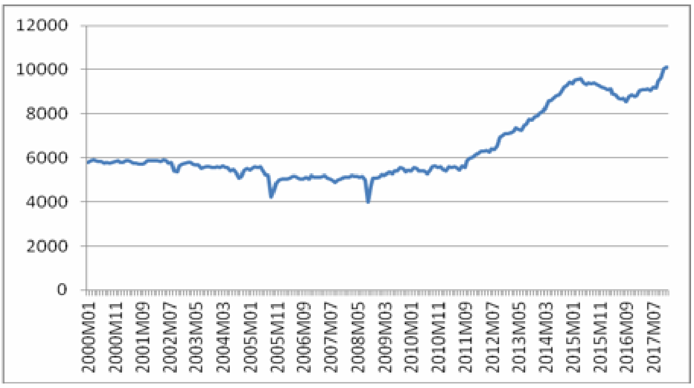
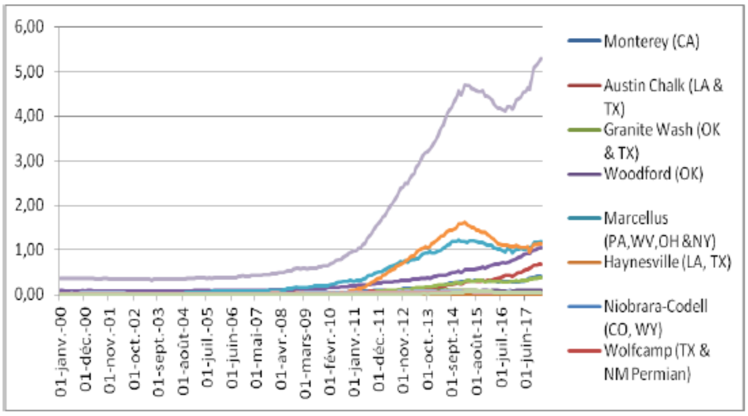
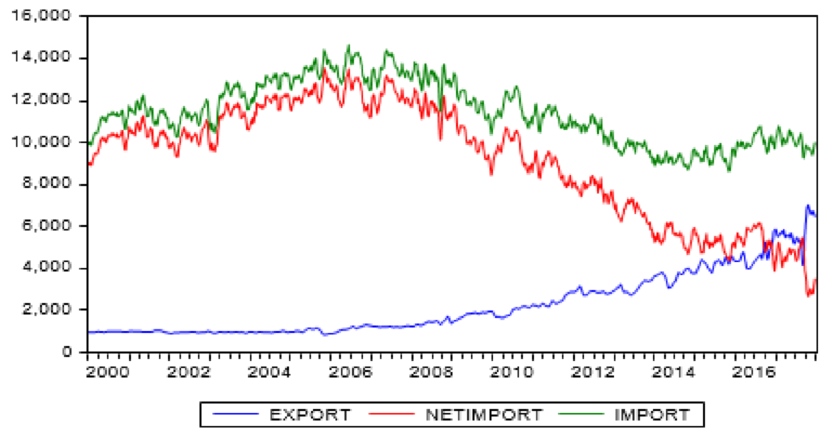


Figure 2. **U.S tight oil production** (million bbl per day) (Author, data source EIA)



Is worth noting that the dramatic increase in U.S. oil production from shale formations over the past decade has been a remarkable change for a country that for decades was the world's largest importer of crude. Indeed, the country's net imports (imports minus exports) of crude oil and petroleum products from foreign countries fell below 2.5m b/d in late 2017, from a peak of 13.4m b/d in 2006, the lowest level since 1970. Moreover, restrictions on crude oil exports, put in place after the first oil crisis in 1973/74, were lifted at the end of 2015, allowing growing volumes of oil to be exported around the world, ranging from the world's top importer (China), to India and Europe.
The figure 3 below shows the U.S. imports and exports of crude oil and petroleum products. There has been a clearly visible sustained increase in exports over the last few years and a substantial drop in imports. Furthermore, some of oil imports are being used to create refined products such as gasoline, which are then exported.

Figure 3. .**U.S. Oil: Imports and Exports** (Thousand Barrels per Day) (Author, data source EIA)



It is worth noting that after being interrupted by the oil prices collapse from mid-2014 to late 2016, U.S. net energy imports have resumed their declining trend since late 2016, showing a sharper collapse.

The US shale oil "revolution" has had a major effect on the global oil market supply and have, to some extent, contributed to putting downward pressure oil prices. Consequently, most producers reaction, especially those that depend on high oil export revenue for social spending or those having low buffers, consisted on producing as much as they can to defend market share and maximize revenue.

However, a year after their decision not to cut production, the market remains oversupplied, oil prices have sunk so much that its caused majors producers-including Russia and members of OPEC (Organization of the Petroleum Exporting Countries)- to reconsider their decision and go into policy reversal. Indeed, in November 2016, they reached an agreement to reduce production, after losing a price war with U.S. shale producers that created a global oil glut. Withholding output induced an oil price rebound such that the US shale drillers decided to re-activate rigs and complete more wells, at the risk of sending the price tumbling again. Thus, the U.S. shale oil industry has become the swing producer (marginal supplier) of crude oil to the global market and the driver of oil prices.

Since the U.S. is such a big consumer of crude oil and related products, the shift to producing more of its own oil has raised concerns that U.S. oil crude output will left substantial fuel supplies available for other buyers. Indeed, U.S. producers are not only displacing foreign oil at home, but also making new customers out of some of the world's biggest oil-importing nations in Asia and Europe, posing a serious competitive threat to oil producing countries. Therefore, the U.S. crude oil flowing to the world's biggest and fastest growing markets in Asia, especially China and India, is a major trend in global oil trading, allowing the US shale oil to take increasing market share from OPEC members and Russia.
This major shift is global oil markets that has taken place in USA, making the United states to become the world's leading oil producer overtaking not only Saudi Arabia, but also Russia.
The oil production surge in the United States is impacting oil trade flows and lowering imports of oil and related products. Indeed, the share of petroleum in total goods imports representing 16 percent in 2006, accounted just about 8 percent in 2017 , while the share in total goods exports almost tripled. This improvement in the U.S. petroleum trade deficit has prevented the total U.S. trade deficit from widening further.
This new U.S. oil trade balance will certainly have a strong impact on US dollar. Indeed, the U.S. was such a major importer of crude oil from abroad that oil imports accounted in some times as much as 40% of the U.S. foreign trade deficit. That was a large reason of US dollar outflows.
Thus, at the long run, the change in the import/export mix of energy-related products could have an impact on the U.S. dollar. Each decrease in oil imports will lower the supply of dollars that have to be sold , and an increase in exports of refined products will create more demand for U.S. dollar.
Thus, the shale oil revolution could have a far-reaching implication for the U.S. dollar. By preventing the U.S. trade deficit from widening further, the oil trade balance will contribute to a sustained improvement in the U.S. current account deficit.
Although this deficit remains fairly large, it has recently shown improvement, as it stood at lesser percentage of GDP. This could be supportive for a stronger U.S. dollar.

In this paper, we explore the relationship between oil prices and U.S. dollar before and after 2008 corresponding to the beginning of shale oil revolution in USA, in order to study the US

shale oil effect on this relationship. Indeed, until 2008, USA had the largest market share of crude oil imports all over the world (about 20%), the increase in shale oil production induce a reduction of US dependence on oil imports. The impact of this fundamental change in crude oil market was not felt and truly priced, the oil prices remain stable around 100 $ after the great financial crisis during 2009-2013. However, the weakening of the world oil demand due to weak fundamentals and sluggish recovery is USA, Europe and China putted more downward pressure on the prices of crude oil that finished by their collapse since June 2014
OPEC under the leadership of Saudi Arabia, instead of cutting its oil production as it had historically done to stabilize oil prices,it instead refused to play the swing producer and claimed its market share defense against shale oil.
Our main contribution to the empirical literature consists first, on exploring the oil-dollar relationship before shale oil revolution (time period corresponding to 2000-2007) and after this revolution (time period corresponding to 2008-2018).
It consists secondly on studying this relationship at different time scales. Indeed, the wavelet transform enables us to decompose oil and US dollar time series on their respective frequency components. We can then run the Ganger causality tests on a time scale by time scale basis(trend, cycle, season, and noise).
The results will allow us to disentangle the comovement between the two variables and to shed more lights on frequency bands where these variables could impact each other.
Our main findings consists on the non constance of the relationship nature between oil prices and US dollar along different frequency bands. Thus, before the shale oil revolution (time period from 2000-2007), for a time horizon from 2 to 4 months (D1 frequency component) - a short investment horizon corresponding to speculative trading or noise traders- we can find, a Granger causality running from US dollar to oil prices. This finding was confirmed for the period running from 2008 to 2018, showing that shale oil revolution had no impact at high frequency band D1 (a time horizon of 3 month) on the relationship between oil prices and US dollar.
However, for seasonal frequency D2 (a time horizon about 6 month), we can find a Granger causality between oil prices and US dollar and a reverse causality running from US dollar to oil prices (bidirectional causality) during the period running from 2000-2007.
In contrast, during 2007-2018 period, the reverse causality from oil to US dollar did not happen. The US dollar is still the leading variable. The Shale oil had then stopped the feed-back from oil price to US dollar.
Lastly, from a time horizon running from 9 months to 64, which can be considered as frequency band corresponding to the business cycle, the results are quite different during the period 2000-2007 and 2008-2018. Indeed, the causality that was running from US dollar to Oil prices had switched due to the impact of shale oil revolution. This switch in causality relationship between oil and US dollar is a long run phenomenon as it was found at business cycle frequency band. It is a regime change in one the must studied relationship: the oil-dollar link. Shale revolution provides a reasonable explanation to the reversed causality link between oil and the dollar as the international oil markets were heavily affected by shale oil revolution.

The paper is organized as follows. Section-II provides an overview of the empirical literature about the relationships between real oil price and the real effective US dollar exchange rate. In section-III, we carry out an empirical analysis based upon wavelet analysis and causality tests and discuss the main findings. Section-IV provides some concluding remarks.

2. Literature review on oil-dollar link:
An important number of studies in the empirical literature suggest that oil price and US dollar have a positive relationship. On one hand, some studies have evidenced that oil prices variations contribute to the explanation of exchange-rate changes. Amano and van Norden

(1998) showed that real exchange rate adjusts to oil prices in the long-run and not vice versa,and indicated that while oil prices Granger-cause real exchange rate, there is no evidence to support the converse. Chaudhuri and Daniel (1998) used cointegration test and showed that the nonstationary behavior of U.S. dollar real exchange rates over the post- Bretton Woods period is due to nonstationary behavior of real oil prices. Similarly, Chen and Chen (2007) used a panel cointegration theory to test the long-run relationship between real oil prices and real exchange rates of G-7 countries; they suggested that real oil prices may have been the dominant source of real exchange rate movements and that real oil prices have significant forecasting power. Bénassy-Quéré et al. (2007) provided evidence for a cointegration relationship between the two series and for a causality running from real prices of oil to real effective exchange rate of the dollar, over the 1974-2004 period. Lizardo and Mollick (2010) concluded that oil prices significantly contribute to the explanation of movements in the value of the U.S. dollar in the long-run against major currencies from 1970s to 2008.

On the other hand, some authors found that movements in the U.S. dollar contribute to the explanation of oil prices movements. Sadorsky (2000) suggested that exchange rates transmit exogenous shocks to energy futures prices, and, therefore, that movement in commodity prices may be a response to movements in the U.S. dollar. Zhang et al. (2008) concluded that the U.S. dollar depreciation drives up the international crude oil prices. Zhang and Wei (2010), by using cointegration and causality analysis, found that the U.S. dollar index may Granger-cause the change of both the crude oil prices and the gold prices.

Benhmad (2012) studied the relationship between oil prices and US dollar exchange rates using wavelet multiresolution analysis. The study characterized the oil price-exchange rate linear and nonlinear relationship for different time-scales. The empirical analysis reveals a strong bidirectional causal relationship between the real oil price and the real dollar exchange rate for large time horizons, i.e. corresponding to fundamentalist traders, especially fund managers and institutional investors. However, for the first frequency band which corresponds to a class of traders whom investment horizon is about 3-months and whom trading is principally speculative (noise traders), the causality runs only from the real oil prices to real effective U.S dollar exchange rate.

Uddin et al. (2013) studied the relationship between oil prices and exchange rates within the time-frequency space in Japan. Over the time horizon, they reported that the strength of the relationship between oil prices and exchange rate keeps changing.

Furthermore, many authors, for instance Fratzscher et al. (2014) showed that the correlations between oil prices and the USD exchange rate have turned negative since the early 2000s, whereas being positive beforehand. Turhan et al. (2014) applied the DCC model to compare the dynamic correlations between oil prices and exchange rates of G20 members. Their empirical evidence confirms a strengthening of a negative correlation in the last decade, especially after only two events; US invasion of Iraq in 2003 and the 2008 global financial crisis. Brahmasrene et al. (2014) examined relationship between U.S. imported crude oil prices and exchange rates from January 1996 to December 2009. Their empirical findings indicate that exchange rate shock has a significant negative impact on crude oil prices.

Jammazi et al. (2014), using a wavelet-based nonlinear autoregressive distributed lags model (W-NARDL), found that in the long-run, the dollar depreciation exerts a greater impact on oil prices than appreciation , even though effect has a negative sign of the in both cases.

Similarly, Jawadi et al. (2016) investigated the interactions between the oil market and the US dollar/Euro exchange rate by using recent intraday data, and found that a US$ appreciation decreases oil prices.

Recently, Wen et al. (2017) examined the nonlinear Granger causality using the Hiemstra and Jones (HP) test, the Diks and Panchenko (DP) test, and found that crude oil prices are the nonlinear Granger-cause of exchange rate, but not vice versa. Lu et al. (2017) studied the dynamics of co-movement between crude oil prices and exchange rate in the time and frequency domain by using the wavelet coherence framework. They found strong but not homogenous links around the year 2008.
Very recently, Kim and Jung (2018) investigated the relationship between daily crude oil prices and exchange rates by using functional data analysis and copula functions. They showed that the rise in the West Texas Intermediate (WTI) oil price returns is associated with a depreciation of the US dollar. McLeod and Hughton (2018) studied the dynamic relationship between real oil prices and US real effective exchange rate using an approach that accounts for the potential of asymmetric cointegration and multiple structural breaks. They applied the Threshold Autoregressive (TAR) and Momentum TAR (MTAR) models. Their empirical analysis indicated that variables are cointegrated with significant asymmetric error- correction, and that long-run causation is unidirectional, going from the US real effective exchange rate to real oil prices, however causation in the short run is bidirectional.

However, although the empirical literature on oil-dollar link is quite large, the studies that addressed the topic of the impact of shale oil on this relationship are still rare. The most interesting one was done by Baumeister and Kilian (2015). They noted that more than half of oil prices decline was predicted in real times as of June 2014. Manescu and Nuno (2015) employed a general equilibrium model of the world market and concluded that most of expected increase in US oil supply due to shale oil revolution has already incorporated into oil prices, and referred the mid-2014 collapse in oil prices to positive unanticipated supply shock.

Kilian (2016) examined how the increased availability of shale oil has shaped U.S. oil and gasoline prices and also why domestic crude oil trading at a discount relative to international oil prices has not translated into lower U.S. gasoline prices and what the role of shale oil has been in causing the 2014 oil price decline. He cautioned against the view that the United States will become independent from oil imports, that the shale oil would induce a rebirth of U.S. manufacturing, and of net oil exports offsetting the U.S. current account deficit.

3. Methodological Framework and Data

3.1 Methodology:

The conventional time domain approaches of economic data analysis do not enable us to identify the different frequency components of a given time series (low, medium and high frequency) and quantify their respective importance.

Therefore, transforming data to frequency domain can be used to get a clear distinction between frequency fluctuations of time series (e.g. trends, cycles, seasonalities, noise).
The Fourier transform, based on a stationary assumption, seems to be too restrictive due to existence of regime shifts, jumps, volatility, outliers, or long-term trends in economic times series. To overcome these drawbacks, the wavelet transform was introduced. It consists on dividing a time series into segments of the time domain called ''scales'' or frequency ''bands''. The scales, from the shortest to the largest, represent progressively high, medium and low frequency fluctuations. It thus enables us to decompose a given time series into its time scale components, each reflecting the evolution of the signal trough time at a particular frequency (Percival and Walden, 2000).

As continuous wavelet transform (CWT) is computationally complex and contains a high amount of redundant information, many authors use the more parsimonious discrete variant of the wavelet transform (DWT) as it uses a limited number of translated and dilated versions of the mother wavelet to decompose a given signal (Gençay et al. 2002). Indeed, the DWT is based on two discrete wavelet filters which are called mother wavelet $h_l = (h_0, \ldots, h_{L-1})$ and the father wavelet $g_l = (g_0, \ldots, g_{L-1})$. The mother wavelet, associated with a difference operator, is a high-pass filter whereas the father wavelet is a low-pass (scaling) filter.

The mother wavelet h integrate to zero, $\sum_{l=0}^{L-1} h_l = 0$, has unit energy, $\sum_{l=0}^{L-1} h_l^2 = 1$, and is orthogonal to its event shifts; $\sum_{l=0}^{L-1} h_l \, h_{l+2n} = 0$ for all integers $n \neq 0$.
On the other hand, the father wavelet coefficients are determined by the quadrature mirror relationship: $g_l = (-1)^{l+1} h_{L-1-l}$ for $l = 0, \ldots, L-1$

Its basic properties are $\sum_{l=0}^{L-1} g_l = \sqrt{2}$, $\sum_{l=0}^{L-1} g_l^2 = 1$, $\sum_{l=0}^{L-1} g_l \, g_{l+2n} = 0$, for all nonzero integers n, $\sum_{l=0}^{L-1} g_l \, h_{l+2n} = 0$ and for all nonzero integers n. Therefore, father wavelets satisfy the orthonormality property as they have unit energy and are orthogonal to even shifts.

Thus, a wavelet decomposition consists on applying recursively a succession of low-pass and high-pass filters to a given time series, in order to separate its high frequency components from the low frequency ones. The father wavelets represent the smooth or low frequency parts of a signal, and the mother wavelets capture the details or high-frequency components.
Thus, father wavelet reconstructs the longest time-scale component of the series (trend) and mother wavelets extracts the cyclical components around the trend (Gençay et al. 2002)

Thus, wavelet decomposition of a time series x(t) in L2 (R) consists on a sequence of projections onto father and mother wavelets through scaling (stretching and compressing) and translation. The projections give the wavelet coefficients $S_{J,k}$, $d_{J,k}$, ... $d_{1,k}$. The coefficients SJ ,k (approximations) represent the smooth behaviour of the signal at the coarse scale 2 J (trend). The coefficients $d\, j ,k$
(details) represent deviations from the trend; $d_{J,k}$, $d_{J-1,k}$ ...., $d_{1,k}$, capture the deviations from the coarsest to finest scale.)
The wavelet representation can be expressed as follows:

$$x(t) = \sum_k s_{J,k}\phi_{J,k}(t) + \sum_k d_{J,k}\psi_{J,k}\ (t) + \sum_k d_{J-1,k}\psi_{J-1,k}(t) + \ldots\ldots + \sum_k d_{1,k}\psi_{1,k}(t) \quad (1)$$

where J is the number of multiresolution levels, and k ranges from 1 to the number of coefficients in each level where:

$$S_J(t) = \sum_k s_{J,k}\phi_{J,k}(t) \quad (2)$$

$$D_j(t) = \sum_k d_{j,k}\psi_{J,k}(t) \text{ for j=1, 2,}\ldots, J \quad (3)$$

We can thus achieve the "reconstruction" the original time series or multiresolution analysis (MRA) (Mallat, 1989), as follows:

$x(t) = S_J(t) + D_J(t) + D_{J-1}(t) + \ldots + D_1(t)$ (4)

Each term in equation (4) represents an orthogonal component of the signal x(t) at different resolutions (scales or frequency ranges). At scale *j*, the detail components D_j captures frequencies $\frac{1}{2^{j+1}} \leq f \leq \frac{1}{2^j}$ f which represent the cycles with periodicity between 2j and 2^{j+1} and the wavelet smooth S_j captures cycles with periodicities greater than 2^{j+1} periods. According to the preservation of energy property of wavelet transform, the variance for returns series is reconstructed from variance estimates at each scale *j*.

3.2 Data Description

The data covers the period of 2000 M1-2018 M12 and consists of monthly observations on the two variables: oil prices and US dollar. Oil prices of West Texas intermediate crude oil (WTI) are converted to real variables by using US consumer price index (CPI) as a deflator, all data are obtained from Federal Reserve of Saint Louis. The US real effective exchange rate data, obtained from Bank of International Settlement (BIS), is a geometric weighted average of the bilateral exchange rates of the US dollar against the currencies of a selection of trading partners taking into account developments in relative prices. It provides a measure of international price competitiveness of the US economy. An increase in the REER indicates an appreciation. Both real oil and REER are transformed by a natural logarithm.

Figure 4. **Real Effective U.S. Dollar Exchange Rate** (dollar) and US Real Price

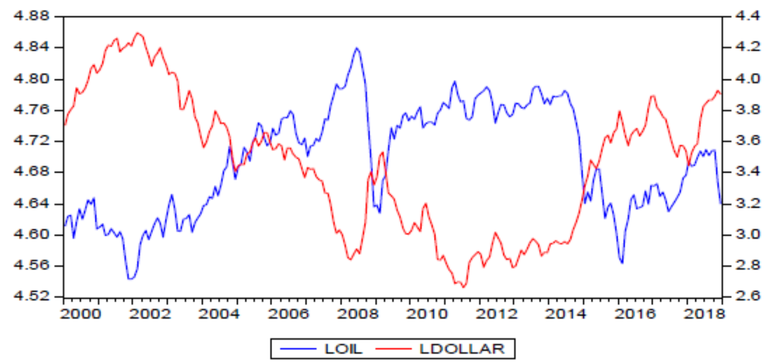


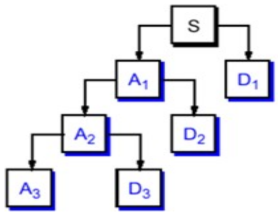
Figure 4 reveals that for some short periods oil prices and US dollar moved at the same direction, but during most time periods, they move at the opposite direction. It also shows tow large oil depreciation during 2008 and 2014, and two pics of US dollar appreciation during 2003 and 2017. This suggests rich dynamics in the co-movements between the two variables that incentivize our study to explore the causality in their relationship.

4. Empirical Results

4.1 Oil and Dollar Wavelet Decomposition

We use symmlet wavelet (symlet 6) to decompose real effective exchange rate (REER) of US dollar and real oil prices. It is an orthogonal symmetric wavelet filter, which has a linear phase (zero phase when centered), sufficiently long to avoid undesirable artifacts in the filtered series. The time series are decomposed into a set of five orthogonal components D1, D2,….D5 which stand for different frequency bands of time series representing the deviation from the trend, and a frequency component A5 representing time series' long trend. Figure 5 shows the tree decomposition of the wavelet transform

Figure-5. **Wavelet Tree Decomposition (J Level)**



$$S = A_1 + D_1$$
$$= A_2 + D_2 + D_1$$
$$= A_3 + D_3 + D_2 + D_1$$

For J=6, the signal

$$S = A_6 + D_6 + D_5 + D_4 + D_3 + D_2 + D$$

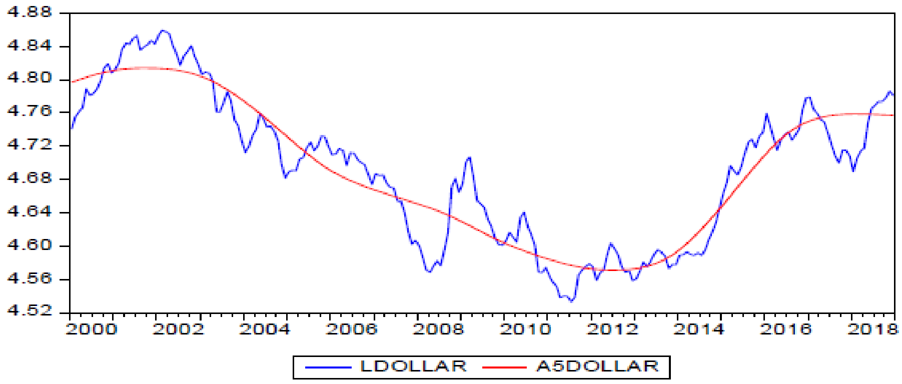
Table-1. **Frequency Interpretation of MRA Scale Levels**

Scale crystals	Monthly frequency
D1	2-4 months
D2	4-8 months
D3	8-16 months
D4	16-32 months
D5	32-64 months
D6	64-128 months

This decomposition provides a representation of the time series. The time-frequency interpretation of MRA scale levels is given in Table1. To accommodate the dyadic scale of wavelet decomposition, we define the business cycle as cycles with periodicity of 16-64 months (D3+D4+D5) whereas for Burns and Mitchell (1946), the 'business-cycle' components have a waveband ranging between 6 and 32 quarters. Therefore, level 1 detail (D1) accounts for high frequency noise. The level 2 details (D2) account for the seasonal components. Finally, the level 5 approximation (A5) accounts for the long-run trend. Indeed, the wavelet decomposition enables us to decompose any economic time series into components -trend, cycle, and noise -whose sum is the original series (by the perfect reconstruction property of the wavelets).

Figure-6 plots monthly log real US dollar and its long-run trend since 2000.

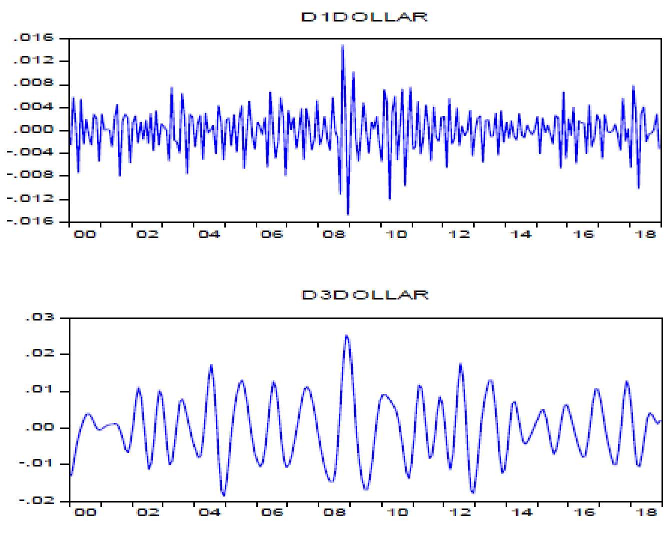
Figure-6: **US Dollar and its Extracted Trend by Wavelet Fitler**

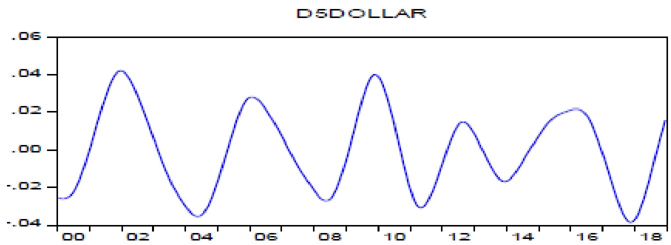


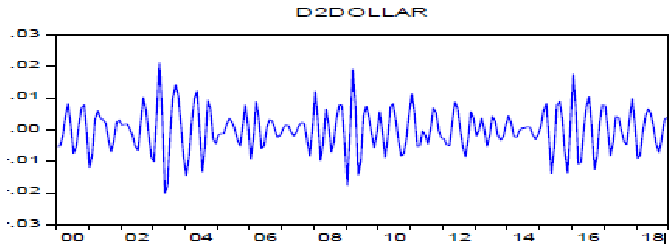
We can observe the impacts of the housing price buble burst in 2006 and Leman Brothers' bankruptcy annoucement leading to a global financial crisis in 2008, followed by a quantitative easing (QE) policy of the Fed (Fawley and Neely, 2013). The depreciation of US dollar during this period may be limited due to similar easy monetary policies followed by other major central banks in the world (e.g. UK, EU, and Japan). The US dollar becomes stronger with the end of QE in 2015.

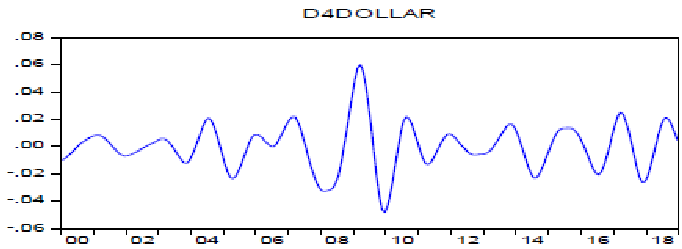
Figure-6 shows the five levels U.S dollar (REER) wavelet decomposition since 2000.

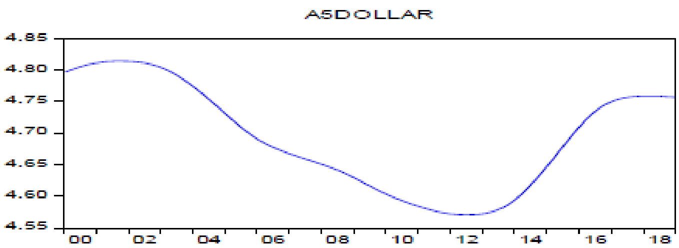
Figure-6. **US Real Dollar Wavelet Decomposition** (5 Levels)







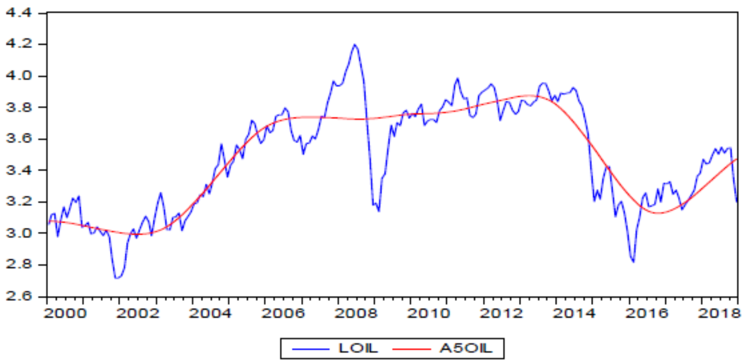




Levels 3 through 5 (D3+D4+D5) represent the business-cycle components. Level 1 detail (D1) is the high frequency noise, Level 2 detail (D2) stands for seasonal component and level 5 approximation (A5) stands for the long run trend

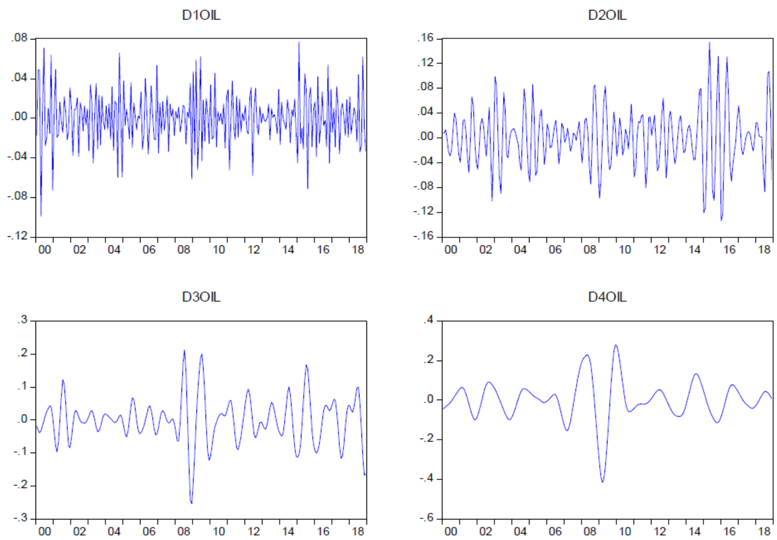
Figure-7 plots the monthly log real oil price and its long-run trend since 2000. The long-run trend is the level 5 approximation of the wavelet decomposition, corresponding to cycles with periodicity greater than 64 months.

Figure-6. **Real Oil Price and its Extracted Trend by Wavelet Filter**



After the oil prices collapsed during the Asian crisis, it began an increase from 2003 due to the high demand especially from emergent economies (China and India). However, the 2008 sharp slowdown in the global economy was accompanied by a collapse in oil price before a quick recovery. The 2008 global financial crisis induced a deviation of oil prices far from its long-run trend. The recovery after the subprime crisis was interrupted by a deep counter- shock of oil markets which began in mid-2014. It is a natural outcome of an excess supply (oil glut) due to US Shale oil revolution and the end of the "swing producer" role at oil markets historically played by Saudi Arabia. However, in November 2016, in an effort to arrest the decline in prices to its lowest levels in a decade, OPEC and non-OPEC producers led by Russia agreed on November, 2016, to cut oil output by about 1.8 million barrels per day. This agreement, which induced a sluggish recovery of oil prices around 50 dollars per barrel, was extended, in November 2017 until the end of 2018. It thus allowed oil prices to hit four-year high in October 2018 at 76.90 dollar before plunging more than 20 percent and ending 2018 around 60 dollars

Figure-7. **Real Oil Price Wavelet Decomposition** (5 Levels)



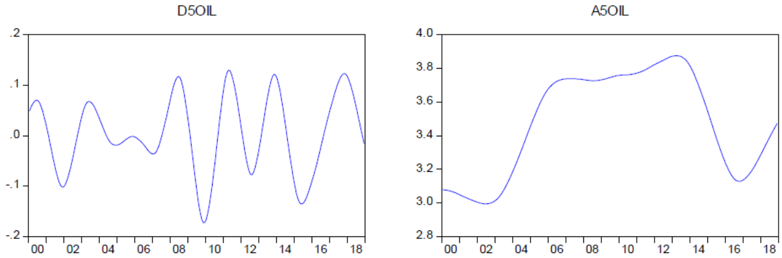
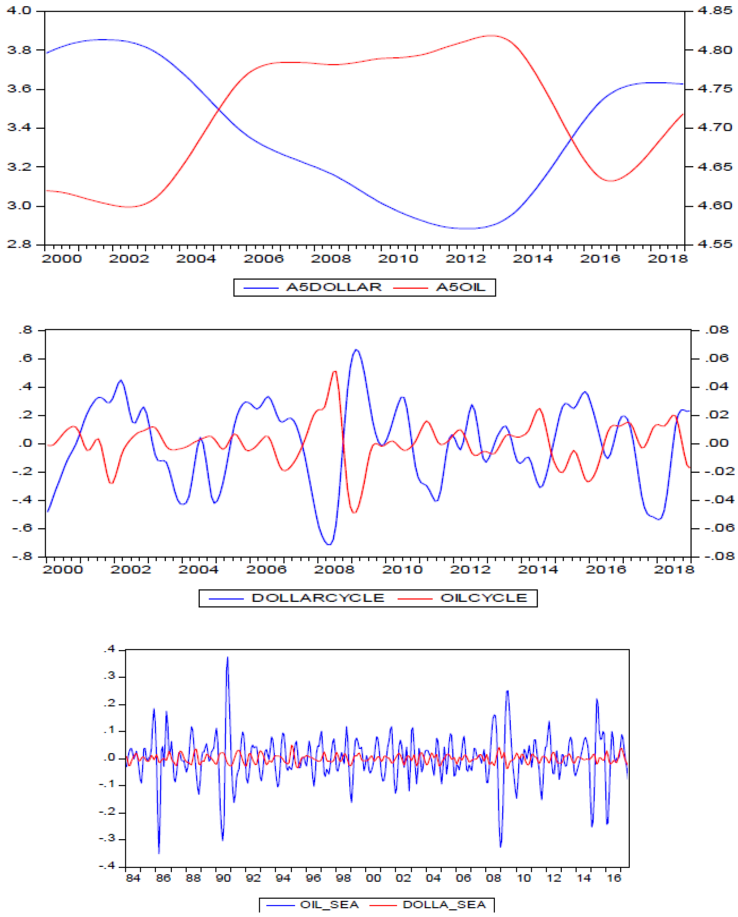
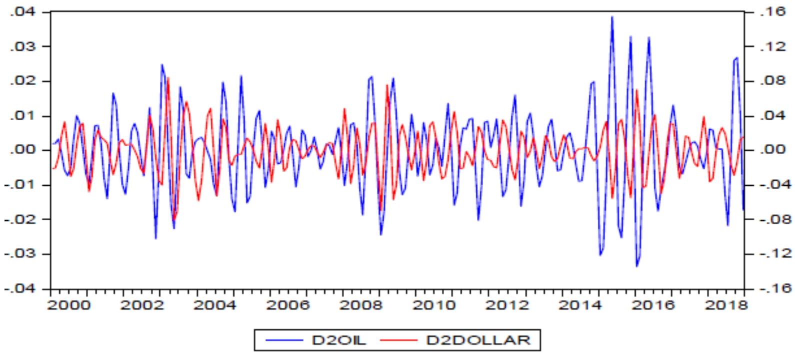


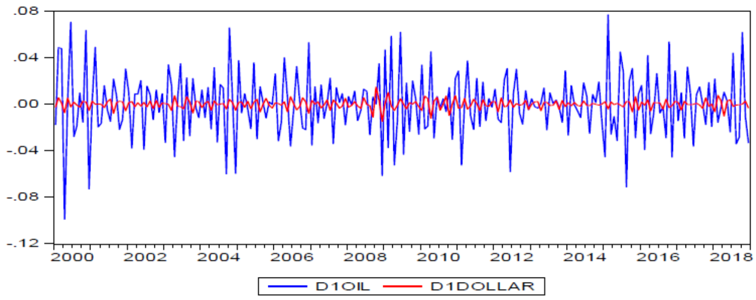
Figure-7 shows the five levels real oil price wavelet decomposition corresponding respectively to high frequency noise, seasonality, business cycle and long term trend.

In order to study the dynamics of relationship between real US GDP and real oil price, on a 'frequency band' by 'frequency band' basis, we have plotted the raw data, the trend (A5), business cycle (D3+D4+D5), seasonal (D2) and and irregular components (D1) of the two macroecconomic variables. The results are shown in *Figure-8*

Figure-8. **Frequency Components of Real US GDP and Real Oil Price**







Overall, the trend and business-cycle components of real oil price and real US dollar appear positively correlated in some periods and negatively correlated in some others, while the irregular components show no consistent pattern.

It is worth noting that researchers, who applied a first-difference filter to the data and used an unrestricted vector autoregressive model or its nonlinear refinements, have studied the link between real oil price and real US dollar at high frequencies as they placed heavy weight on the 'irregular' components of the data (Baxter, 1994). Therefore, they are at risk of failing to uncover a significant link between these variables occurring during business cycles to the nearby low-frequency components of the data.

Therefore, we assume that the correlation between real US dollar and real oil price might be, in fact, much stronger at business cycle to low frequencies. Wavelet decomposition is an ideal statistical tool allowing us to study not only the correlation but also the dynamic comovement between oil prices and US dollar at different frequency bands. The Granger causality tests applied at a multifrequency (multiscale) level could help us to shed more lights on this quite complex relationship.

4. 2 Multiscale Granger causality tests

In order to disentangle the causality relationship between oil prices and US dollar at different timescales, the first step consists on decomposing oil prices and US dollar by wavelet transform. The second step consists on testing linear Granger causality relationships, a frequency band by frequency band basis, each frequency band corresponding respectively to noise, seasonality and business cycles. Some works used the same methodology in economics and finance (Ramsey and Lampart 1998, Almasri and Shukur 2003, Kim and In 2003, Dalkir 2004, Mitra 2006, In and Kim 2006, Benhmad 2012, 2013 among others)

The estimates results are depicted at the following Table-4 and 5. In table 4, the pairwise Granger causality was runned during time period from 2000M1 to 2007 M12 (before shale oil revolution) , the table 5 corresponds to time period after the shale oil revolution from 2008 to 2018.

Table-4. **Pairwise Granger Causality test** (2000M1-2007M12)

Frequency band	D1	D2	D3+D4+D5
Time scale (Months)	2-4(noise)	4-8 (season)	16-64 (cycle)
Ho: US Dollar does not cause OIL (p-value)	**0.0767**	**2.E-06**	**0.0625**
Ho: OIL does not cause US dollar (p-value)	**0.1931**	**0.0253**	0.4187

Note: p-values for the F-test are reported. Rejection of the null of no causality at the 10% significance level (if p-value < 0.10)

Table-5 . **Linear Granger Causality Analysis** (2008M1-2018 M12)

Frequency band	D1	D2	D3+D4+D5
Time scale (Months)	2-4(noise)	4-8 (season)	16-64 (cycle)
Ho: US Dollar does not cause OIL (p-value)	**0.0030**	**0.0864**	0.1989
Ho: OIL does not cause US dollar (p-value)	0.8743	0.1768	**0.0025**

Note: p-values for the F-test are reported. Rejection of the null of no causality at the 10% significance level (if p-value < 0.10)

The main conclusion which can be drawn from our results is that, from 2000-2007 for the high frequency band (2-4 months), there is a linear Granger causal relationship running from US dollar to oil prices. This finding was confirmed for the period running from 2008 to 2018, showing that shale oil revolution had no impact at high frequency band D1 (a time horizon of 3 month) on the relationship between oil prices and US dollar.

However, for seasonal frequency D2 (a time horizon of 6 month) there is a bidirectional causality between oil prices and US dollar during the period running from 2000-2007.
In contrast, during 2007-2018 period, the reverse causality from oil to US dollar did not happen. The US dollar is still the leading variable. The Shale oil had then stopped the feed-back from oil price to US dollar.

Lastly, from a business cycle perspective (time horizon from 9 months to 64 months), the results are quite different during the period 2000-2007 and 2008-2018 as depicted at the Table-4 and 5. Indeed, the causality that was running from US dollar to Oil prices had switched due to the impact of shale oil revolution. This switch in causality relationship between oil and US dollar is a long run phenomenon as it was found at business cycle frequency band. It is a regime change, a paradigm change in the most empirical studied relationship: the oil-dollar link.

We conclude that during the great moderation epoch (2000 to 2007), the linear Granger causality runs from US dollar to oil prices. Therefore, the US dollar was leading the oil prices. This empirical fact was confirmed by many authors (Bénassy-Quéré et al. 2007, Bernanke 2004, Blanchard and Gali 2007). However, during the shale revolution (2008 to 2018), the linear Granger causality runs from oil prices to US dollar. Therefore, the high volatility of oil prices due to shale revolution induced a re-switching of the causality direction between the two variables. The oil price becomes a leading macroeconomic variable. This finding corroborates the results of Coudert and Mignon (2016) on the growing role played by speculators looking for a hedge of their investment and the commodity market financialization hypothesis. It is a kind of flight to quality played in commodities markets, especially in the crude oil market, as a hedge against risks both in the stock and bond markets. Therefore, from the third frequency band up to the fifth one (D3, D4, D5) representing the spectrum of time horizons running from 8 months to 6 months (approximating US business cycle of duration 6-32 quarters), and corresponding to fundamentalist traders, especially fund managers and institutional investors, the shale oil revolution induced a strong causal relationship running from the real oil price returns to the real effective US dollar exchange. Indeed, the institutional investors (i.e. pension funds, portfolio managers etc.) began to treat commodities as an asset class, seen as a "flight to quality" from low returns in other investment classes ((Ordu et al., 2017)).

5. Conclusion and Policy Implications

This paper explores the relationship between oil prices and US dollar before and after the shale revolution and its impacts on international oil markets.
As the two markets are linked through various channels which may have impacts at different frequencies, we should investigate this relationship from a time-frequency perspective. Indeed, the wavelet transform enables us to decompose oil and US dollar time series into their respective frequency components, and to run tests of Granger causality on these components on a time scale (frequency band) by time scale basis during two periods. The first period occurs before US shale revolution (2000-2007), the second one comes after this revolution and runs from 2008 to 2018.
Our main findings consists on the non constance of the relationship nature between oil prices and US dollar along different frequency bands. Thus, before the shale oil revolution (time period from 2000-2007), for a time horizon from 2 to 4 months (D1 frequency component) - a short investment horizon corresponding to speculative trading or noise traders- we can find, a Granger causality running from US dollar to oil prices. This finding was confirmed for the period running from 2008 to 2018, showing that shale oil revolution had no impact at high frequency band D1 (a time horizon of 3 month) on the relationship between oil prices and US dollar.
However, for seasonal frequency D2 (a time horizon about 6 month), we can find a Granger causality between oil prices and US dollar and a reverse causality running from US dollar to oil prices (bidirectional causality) during the period running from 2000-2007.
In contrast, during 2007-2018 period, the reverse causality from oil to US dollar did not happen. The US dollar is still the leading variable. The Shale oil had then stopped the feed-back from oil price to US dollars.
Lastly, from a time horizon running from 9 months to 64, which can be considered as frequency band corresponding to the business cycle, the results are quite different during the period 2000-2007 and 2008-2018. Indeed, the causality that was running from US dollar to Oil prices had switched due to the impact of shale oil revolution. This switch in causality relationship between oil and US dollar is a long run phenomenon as it was found at business cycle frequency band.

The U.S. shale oil boom would have undoubtedly far-reaching consequences not only in oil markets and therefore in oil-dollar relationship, but also in geopolitics. Indeed, the shale revolution can be considered as a game changer with a new emerging balance of power in the global oil market. The policy shift of the OPEC's toward defending market share had pushed crude oil prices to a slump since mid-2014. In November 2016, in an effort to arrest the decline in prices to its lowest levels in a decade, OPEC and non-OPEC producers led by Russia agreed on November, 2016, to cut oil output by about 1.8 million barrels per day. Moreover, the agreement was extended, in November 2017 until the end of 2018. To conclude, all these efforts to stabilize oil prices can not overshadow the shift of power from OPEC to USA as OPEC (and its leader Saudi Arabia) had lost power to set global oil prices, meaning that Saudi Arabia can no longer play the swing producer role in international oil markets. The switch in the direction of Granger causality after the beginning of shale oil revolution in USA had made oil prices a leading variables in its relationship with US dollar.

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