The German Energiewende

A transition towards an efficient, sufficient Green Energy Economy

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Industrial Environmental Economics

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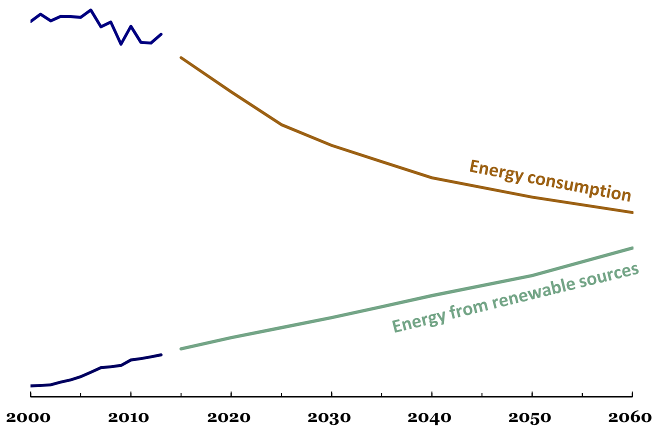

An effective energy transition means closing the gap between energy consumption and the supply of energy from renewable sources. This requires the serious commitment of actors across the entire society and the rapid implementation of ambitious technology and behaviour-oriented policies.

Content

Abbreviations

CDU	Christian Democrats Germany
CFL	Compact fluorescent light bulb
CHP	Combined heat and power
CO2eq	CO2 equivalent
COP21	21st Conference of the Parties (to the UNFCCC)
DSM	Demand side management
EEG	Renewable Energy Sources Act (“Erneuerbare Energien Gesetz”)
ETS	Emissions trading system
FDP	German liberal party
GDP	Gross domestic product
GHG	Greenhouse gas
GW	Gigawatt (109 watts)
ICT	Information and communication technology
IGCC	Integrated gasification combined cycle
IMF	International Monetary fund
LED	Light emitting diode
NGO	Non-governmental organization
NPP	Nuclear power plant
PJ	Petajoule (1015 joule; 1PJ = 0.278 TWh)
PV	Photovoltaic
SME	Small and medium-sized enterprise
SPD	Social Democrats Germany
toe	tons oil equivalent
UBA	German Environmental Protection Agency (“Umweltbundesamt”)

Preface

The German “Energiewende” (energy transition) is meant to be a contract between generations. The rebuilding of the whole energy system is designed and financed today in order to safeguard our children and grandchildren against fundamental risks: the enormous economic, social and environmental costs of a fossil-nuclear energy system, the risks of the nuclear fuel-cycle and the impacts of climate change, as well as energy import dependency, price shocks and geopolitical disputes over scarce resources. In contrast, a successful Energiewende creates new business areas and qualified jobs and increases competitiveness in the ‘green race’ – in particular on the lead markets for efficiency technology and renewable energy.

Accordingly, the Energiewende is described in this book as the collective effort of post-war German history and as a unique learning arena for a positive socio-economic transformation with international relevance. As such it should be understood to be a dynamic formation process rather than the implementation of a grand master plan.

The Energiewende is more than the mere substitution of fossil and nuclear energy carriers with renewable energy and energy efficiency. It is a socio-economic transformation, an arena for experimenting with the transformation of a highly industrialized country in a globalized world. Hence, the effects of the Energiewende in Germany are of great importance for the interplay with European neighbouring countries as well as other industrialized and emerging economies. A successful transition has the potential to catalyze sustainable energy use, climate change mitigation and environmental protection around the world. However, it should not be forgotten that there are often crucial enabling conditions under which such a transformation can take place. The Energiewende would not exist in today’s form without its roots in the strong social movements against nuclear power in the 1970s and 80s, which triggered a search process for alternative energy paths.

The unprecedented Energiewende can only succeed as a collective effort. This effort is based on the public perception of a long-term, foresighted transition process, which in turn requires an active and ambitious state. So far the Energiewende has benefited strongly from the considerable engagement of actors at all levels, from individual citizens to municipalities, companies, and regions. National policies have produced some impulses, but there still is a clear lack of long-term planning and concerted political effort. Technological and social innovation as well as accelerated market transformation demand vivid entrepreneurship across all levels of society – including our political systems. And let’s not forget that the active participation of citizens – resulting from the democratization and decentralization of the energy system – is by no means a nice-to-have side-effect, but the key pillar on which the Energiewende and its public acceptance rest.

1. Energiewende – From social movement to political and scientific consensus?

- The Energiewende has its roots in the anti-nuclear social movement of the 70s and 80s.
- Today there is broad social consensus about the need for the Energiewende as well as broad scientific consensus about its technical feasibility in Germany.
- The official target system of the Energiewende implies ambitious reductions of both energy consumption and CO_2 emissions.

Until now, any form of industrialization has been heavily based on finite energy resources – first coal, later oil and natural gas. The finite character of fossil fuels, pollution caused by extraction and combustion and, finally, man-made climate change emerged as inherent problems of an energy economy based on coal, oil and natural gas.

There was, for a short historic period only, the illusion that civil use of nuclear energy provides an inexhaustible, cheap energy source. The price society had to pay for this illusion were two catastrophic accidents (Chernobyl and Fukushima), a radiating heritage that lasts thousands of years, massive social distortions and, not least, massive barriers to innovation and investments in alternatives. And still, new nuclear power plants cannot compete economically with low-cost alternatives – above all energy efficiency – on the market for energy services.

Coal, oil, natural gas, and also nuclear energy ruled the post-war energy economy by offering (mostly subsidized) cheap energy, by shifting all external costs to the future and by benefiting from a seemingly unlimited abundance of energy resources. While the specific energy bases of the two parts of Germany each developed differently, there was unity in the misjudgement of how to secure energy supplies and minimize risks. It was clear that the era of fossil fuels will come to an end and that replacement is needed. Due to the sheer scale of the damage that a nuclear melt-down would cause, nuclear was in fact a rather poor replacement for fossil fuels. However, the "residual risk" attached to nuclear energy was presented as so small that it appeared as a reasonable burden for the economy and society.

1.1. The roots of the transition – Social movements in the 70s

Spotlight December 1975. Tens of thousands protest in West Germany against the construction of a new nuclear reactor in the village of Whyl at the French border. The causes behind the vast expansion plans for nuclear power can be found in an economic crisis (a doubling of unemployment) and the impact of the oil crisis a couple of years earlier. Oil crises began with the coup in Iran and the Suez Crisis in the 50s. After the collapse of the Bretton Woods System and the rise of monetary policy, the Yom-Kippur War triggered the first oil price shock in 1973. OPEC reduced oil supplies by 5% to put pressure on the supporters of Israel. In just a few days the oil price increased by 70% and this had a strong impact on economies around the world. The oil embargo highlighted the economic dependence on cheap fossil energy and in particular fossil motor fuels.

The German government under Chancellor Helmut Schmidt responded in the mid-1970s by supporting the development of coal liquefaction technology and increasing power generation capacities. An exceptional law allowed power companies at that time to build power plants and get the costs reimbursed without carrying any risks. This policy to increase supply seemed to be justified by the "iron law" of a doubling demand every ten years, i.e. the constant annual growth of power consumption by 7% in the post-war era.

If implemented, this exorbitant build-up of nuclear power plants (50GW additional capacity were envisioned) would have led to a situation comparable to the status quo in France, where nuclear power has a share of more than 70% ("SPD/KERNKRAFT Großer Irrtum," 1977). The resistance against this prospect was strong and just in time. It came both from risk-averse citizens and from within the power sector, which had a more realistic assessment of due efficiency improvements and the slowdown of demand.

The conflicts around the construction of the nuclear power plant (NPP) 'Brokdorf' further catalyzed the growing resistance against nuclear energy. The federal association of environmental citizens' initiatives coordinated major demonstrations. However, demands for a nuclear phase-out only became capable of winning a majority after the nuclear meltdown at Three Mile Island (Harrisburg) had occurred in 1979. Further key protests by the anti-nuclear movement took place in Kalkar (1977-1985), where a fast breeder was under construction, and later in Wackersdorf (1981-89), where a reprocessing plant for nuclear fuel was planned. Neither of the two facilities ever went into operation. The power plant in Kalkar was sold to an investor who turned it into an amusement park; the "Kernwasser Wunderland" (nuclear water wonderland) was opened in 1996.

Since 1985, when the final decision was made not to take the fast breeder in Kalkar into operation, nuclear power generation in Germany has been in retreat. In 1986 the Social Democrats (SPD) decided after the Chernobyl catastrophe to enact a nuclear phase-out (once in power). It still took until the year 2000, when the red-green government of Gerhard Schröder and Joschka Fischer finally managed to reach an agreement between all stakeholders. The nuclear phase-out – stretched over 20 years – became law.

But the fight against nuclear energy was not over. The postponement of the nuclear phase-out shortly before the Fukushima catastrophe and the re-enactment of the phase-out shortly after the accident created a hole in legislation which may result in billions of compensation payments to NPP operators. German policymakers did not have the courage to push through legally viable alternative phase-out pathways, e.g. an ordinance that the consequences of an accident have to be limited to the site of the NPP, the cancellation of privileges such as limited liability or tax clearance of capital reserves, or the closure of NPPs due to the lack of evidence that waste has been safely disposed of.

The protest movement of recent years goes against the watering-down of the agreed nuclear phase-out and turns increasingly towards a positive transition as represented by the Energiewende. No topic has ever seen such stable opposition as the public opposition against nuclear energy – despite the attempts of the financially powerful proponent to turn public opinion around. That nuclear power is still a hot political topic in Germany could be seen after the Fukushima Daiichi nuclear disaster, when the largest demonstration against NPPs in German history took place.

While the anti-nuclear movement was absolutely crucial for the formation of German environmentalism, there are several other social discourses that developed in parallel and that are also important for understanding the origins of the Energiewende. The anti-nuclear movement in West Germany benefited from close ties to the peace movement, which was targeted against the positioning of nuclear missiles in Germany. Civil and military uses of nuclear fission were rightly seen by the social movements as being interconnected. Another hot environmental topic of the 1980s was the *Waldsterben* (forest dieback), which was related to acid rain caused by power plant emissions. Further issues that entered the public discourse of the energy system include (cf. Jacobsson & Lauber, 2006): resistance against open-cast mining for lignite (and the required resettlements), the dependency on natural gas imports from Russia, the Iraq wars (which were often framed as wars for oil), suspicion against large energy corporations and, more recently, also positive aspects such as job creation and export opportunities in the renewable energy sector.

1.2. A change of perspective from “Eco-dictatorship” (1980) to broad consensus (2010)

In the historic analysis of the nuclear phase-out, the interplay between scientific analyses and the anti-nuclear movement has to be unravelled. However, it is a fact that as far back as 1980 a phase-out scenario was presented to the government committee inquiry “Future Nuclear Energy Policy”. In spite of closely reflecting actual developments, this scenario was criticized heavily and was only supported by a very small minority. The scenario up until 2030 even anticipated the main elements of what has become today’s scientific phase-out consensus. Has science since then been driven by social movements and how have real developments been affected?

In 1975 Amory Lovins coined the expression “Soft Energy Path”, which showed the way from centralized fossil and nuclear energy towards an energy efficiency revolution and renewable energy. One year later his book entitled “Soft Energy Path. Toward a Durable Peace” was published (Lovins, 1979). One central message in this concept study was to focus on energy services such as heating, light or mobility, rather than energy carriers. Energy services are the useful effect resulting from energy-efficient technology and energy-saving measures.

In Germany the Öko-Institut published the study “Energy transition. Growth and welfare without oil and uranium” (1980), which illustrated an alternative energy future following Lovins’ scenarios in his soft energy path. This study became the basis for the so-called “Path 4” of the government committee inquiry “Future Nuclear Energy Policy”. While “Path 1” – the favourite of the energy sector – implied an exorbitant increase in nuclear power (50% of which would be provided by breeders) and a necessary increase of primary energy supply to 560Mtoe until 2030, “Path 4” described nuclear phase-out and a reduction of primary energy supply to 220Mtoe.

At that time this was a novelty for the established energy science community and a provocation for the energy sector, which shared the mainstream view that energy consumption is coupled to economic growth. Accordingly, the government committee classified Path 4 as “extreme”, its technological feasibility as “very debatable” and the costs as “incalculable”. Some even saw in Path 4 a direction that would lead to an authoritarian eco-dictatorship.

In contrast, as far back as the 1980s, the Öko-Institut showed in scenarios and analyses of technological potential how economic development is feasible without increasing consumption of coal, oil, gas and uranium. Savings and efficiency were regarded as key for the decrease in energy demand. The focus was not only on renewable energy, but combined heat and power (CHP), district heating and efficiency technologies also played important roles.

A second consecutive study by the Öko-Institut called "Die Energiewende ist möglich" (Hennicke, Johnson, Kohler, & Seifried, 1985) went beyond technological feasibility and demonstrated both the socio-political and economic feasibility of the transformation to a mainly decentral energy economy with municipalities as key actors ("re-municipalization").

These concepts and scenarios were taken up and further developed throughout the 1980s and 90s. Climate change mitigation appeared more and more on the scientific and political radar. First suggestions were made (by opposition parties) to strive for significant GHG emission reductions and nuclear phase-out at the same time. The plan was to achieve this mainly by a massive increase in energy productivity. This was, however, far from being the mainstream among energy experts. Phase-out of nuclear and fossil fuel use in Germany until 2050? For the majority of energy economy studies, this was still unthinkable in the 1990s.

It is encouraging and at the same time exciting that the vast majority of energy experts in Germany now consider an "energy transition path" to be technologically feasible. This is not the case in many comparable countries. It is certainly not going too far to claim: without the long scientific controversy around the feasibility of a soft energy path for Germany and the slow convergence towards scientific consensus, the "conservative revolution" of 2010/11 would not have taken place.

1.3. The "Conservative Revolution"

When the conservative government of Christian Democrats (CDU) and Liberals (FDP) came to power in 2009, its explicit goal was to decide against the massive opposition of civil society and a large share of energy experts and prolong the operation of NPPs. While there was consensus not to build any new NPPs, there was the attraction to prolong "cheap" nuclear power generation in depreciated NPPs. Some people just could not imagine that a significant transition of the energy system could take place before 2050.

This temporary extension of the operational life of NPPs is very important for the German energy transition as it was accompanied by much more comprehensive and progressive long-term targets for the energy system. These targets gained even more significance after the lifetime extension had been taken back as a reaction to the Fukushima nuclear catastrophe.

In 2010 Merkel's conservative government agreed on the future energy concept, which sets "revolutionary targets" (chancellor Merkel) for the reduction of GHG emissions, renewable energy and energy saving (Federal Government of Germany, 2010). No government in the world has so far had the courage to publish such ambitious targets.

They present a roadmap for energy policy until 2050 (see Table 1). The energy concept is a first important step in the German Energiewende. It shows that the target system does not only have a long-term time horizon, but that it is also more ambitious than the lead targets of the EU (20-20-20).

Table 1:
Target system of the German Energiewende

	2013	2020	2030	2040	2050
GHG emissions (base year 1990)					
GHG emissions	-22.6 %	-40 %	-55 %	-70 %	-80 to 95 %
Renewable energy					
Share in gross final consumption	12 %	18 %	30 %	45 %	60 %
Share in gross electricity consumption	25.3 %	35 %	50 %	65 %	80 %
Share in heat consumption	9.1 %	14 %			
Share in transportation	5.5 %				
Energy efficiency and saving (base year 2008)					* (base year 2005)
Primary energy consumption	-3.8 %	-20 %			-50 %
Energy productivity (final consumption) per year	0.2 % (2008-13)				2.1 % (2008-50)
Gross electricity consumption	-3.2 %	-10 %			-25 %
Primary energy supply	-5.5 %				ca. -80 %
Heat supply	0.8 %	-20 %			
Final energy consumption in transportation*	1 %	-10 %			-40 %

What moves a conservative government to publish such progressive targets, where there is a realistic "risk" that business and civil society will take them seriously? One explanation might be that it was a political deal to gain public acceptance for the heavily criticized extension of nuclear power generation. Revolutionary long-term targets may have been used to cover up the departure from the social-democrat nuclear phase-out roadmap.

The extension for NPPs implied that the last reactor would not be taken from the grid until 2036. It was a very controversial issue among experts whether cheap electricity from NPPs would constitute too large a barrier to investment and innovation to allow for dynamic growth of energy efficiency and renewable energy. There was, however, consensus in the modelling community that the "revolutionary" targets laid out in the energy concept are technologically feasible.

In spring 2011 the situation changed dramatically when the Fukushima Daiichi nuclear catastrophe tragically illustrated the technology-hubris of nuclear experts. The accident rebutted once more the idea that the "remaining risk" of nuclear energy can be easily managed in a highly industrialized country. An earthquake and tsunami triggered a nuclear melt-down in several reactors, which resulted in radiation leaking out into the environment. The costs deriving from the health impacts and resettlement of people in the whole region were and still are immense. The International Atomic Energy Agency estimated that the damage amounts to USD 83 billion, but the true costs are likely much higher (Hennicke & Welfens, 2012).

This event affected energy policy around the globe, not least in Germany. The German government had to react to public pressure and adopted the Energiewende bill. The extension for the operation of NPPs was taken back and the nuclear phase-out even accelerated. Eight NPPs were shut down at short notice and the roadmap for the irrevocable exit from nuclear energy by 2022 was determined. Decades of controversy were suddenly overcome and the implementation of the Energiewende moved into the centre of political attention.

1.4. The scientific Energiewende consensus

It is of great importance whether Energiewende targets are seen as symbols of goodwill or as serious guidance for energy policy. This depends not least on the positioning of scientific authorities in the energy field. There is a risk that ideological inertia and vested interests in economy, society and politics lead to a questioning of the direction and the objectives of reforms of the energy system. Currently, there is broad consensus about the key elements of the Energiewende, a consensus that is based on a comprehensive knowledge base. This combination of knowledge base and consensus cannot be found in many other countries. It is a key enabling factor of the German Energiewende today, but it has been a long and bumpy road to get there.

Various institutes representing different scientific disciplines in Germany have brought about a multitude of thoughts, scenarios and data analyses which document without a doubt: nuclear phase-out, climate change mitigation and resource conservation can be achieved with justifiable macroeconomic effort in the medium term, and will in the longer term create significant benefits for the German economy. However, implementation requires a paradigm shift towards a creative and (pro-)active State and a larger policy focus on energy efficiency.

Figure 1 presents three representative long-term scenarios for Germany. They all imply large efficiency improvements, a radical shift towards more renewable energy, and they also calculate with consistent economic growth.

Total primary energy supply decreases from about 13 000 PJ in 2014 to between 6 000 PJ and just below 8 000 PJ in 2050. All scenarios display a reduction of CO_2 emissions from fuel combustion by at least 80% compared to 1990. Thus, there is strong scientific evidence that absolute decoupling of energy consumption and CO_2 emissions from a moderately increasing GDP is feasible by 2050. Furthermore, many risks of the current energy system (import dependence, climate change, and nuclear radiation) can be drastically reduced. Unfortunately, current German energy policy has its largest shortcomings in respect of one of the key assumptions of all scenarios: that primary energy supply will decrease to half of its current value.

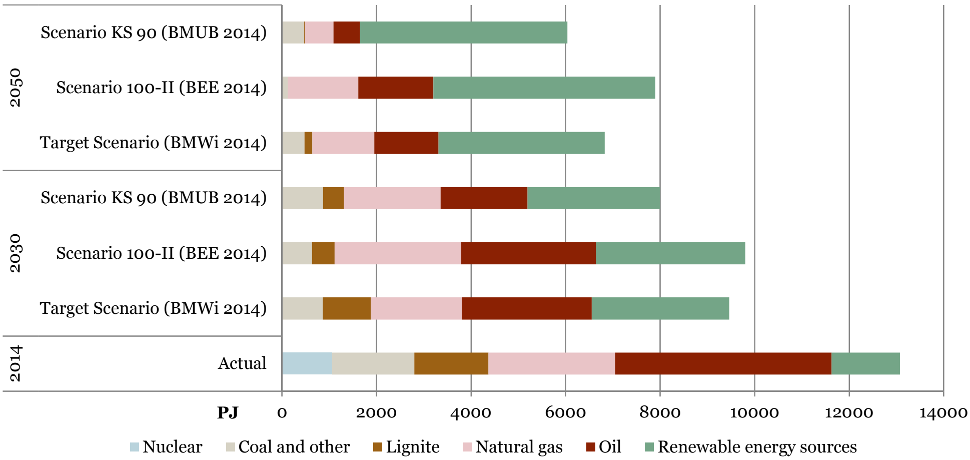

Figure 1:
Comparison of primary energy supply in 2014 and representative scenarios for German primary energy supply in 2050 (in PJ/a) (source: Sascha Samadi, Wuppertal Institute)

2. The Energiewende is feasible – key features of the transition

- The Energiewende in the electricity sector has had a very dynamic start, while the heat and transportation sectors have been lagging behind.
- Quantitative scenarios show that the deployment of renewable energy technology must be accompanied by large energy savings on the demand side in order to achieve the ambitious targets of the Energiewende.
- Current policy programmes – in particular in respect of energy efficiency – are not sufficient to trigger the required short-term (2020) and long-term (2050) developments.

In 2015 it is clearer than ever: the Energiewende is ecologically necessary, technically feasible and economically beneficial. However, structurally and politically it is still in its infancy. The multitude of existing scenario analyses have been used here to synthesize some key structural elements that are needed for a successful transition. Furthermore, one current representative study is presented (Nitsch, 2014). This study was also the basis for the lead scenarios that guide the work of the Ministry for the Environment.

It is important to consider that the following statements are based on modelling work that builds on "what-if" assumptions. Quantitative results should neither be seen as empirical facts nor as a probable projection. They constitute scientifically backed and technically feasible "room to manoeuvre". It is up to us all, which options become reality.

2.1. Basic structural elements of the transition

The Energiewende is based on a broad political consensus for the comprehensive restructuring of the German energy system. This consensus is the first milestone on the way to a sustainable energy and climate policy. The overall target of reducing GHG emissions by 80-95% by 2050 implies a virtually emission-free energy supply by that time. This transformation of the energy system rests on two pillars: increased energy efficiency in all sectors and covering the remaining demand with renewable energy.

The quantitative targets for both energy efficiency and renewable energy over time are the result of a large number of scenario calculations, simulation and systems analyses. They have modelled with increasing complexity the potential pathways towards a sustainable energy system. Taking into account only the most important studies over the last 15 years, there is a long list including publications from the German Environmental Protection Agency (UBA), Fraunhofer Institute for Solar Energy Systems (ISE), Federal Ministry for the Environment, Renewable Energy Research Association (FVEE), Research Centre for Energy Economics (FfE), Institute of Energy Economics (EWI), German Advisory Council on the Environment, WWF and Greenpeace.

The latest studies confirm that the targets of the Energiewende are reasonable and that the achievement of the desired energy efficiency improvements and expansion of renewable energy will warrant the steep reduction in GHG emissions that is needed (cf. EWI, GWS, & Prognos, 2014; Nitsch, 2014; UBA, 2014). There is no need to change the target system. When it comes to the design of the future energy system, scenario analyses provide general orientation for the key success factors:

- The Energiewende in the power sector has been accelerated with the decision for nuclear phase-out and the support for electricity from renewable energy sources. This momentum has to be sustained, while the Energiewende in the heat and transport sectors is still much too slow and requires more effective public intervention.
- Tapping into energy efficiency potentials is needed in all sectors, but in particular the heat and transport sectors need further attention as the lion's share of reduction in energy consumption is planned there. Moreover, structural adaptations in these sectors are a precondition for optimal use of renewable energy (e.g. expansion of district heating, modal shift in transportation, and new mobility concepts).
- The power system will take an even more prominent role in the whole energy system. The challenge to integrate large amounts of intermittent power from solar and wind is another strong argument for energy saving. Renewable electricity will become the main "primary energy source" and both the structure and the market design of the power system need to be adjusted to the dominance of intermittent energy with near zero marginal costs. The remaining load has to be taken on by highly efficient, flexible fossil fuel plants (e.g. CHP with heat storage).

- Sufficient capacity for balancing and transporting energy (especially in power grids), as well as the interplay between different sectors of the energy system are crucial for the efficient usage of increasing volumes of power from renewable energy sources. Systems such as “Power to heat”, “Power to mobility” and “Power to gas” will become increasingly important. These have to be optimized in connection with the existing storage options.
- In contrast to energy use in the heat and transport sectors, an absolute decrease in electricity consumption cannot be expected. While efficiency at the point of final consumption of electricity is of utmost importance, the replacement of fossil fuel with renewable power will trigger an absolute increase in power consumption in the long-run.
- Complexity of energy supply will increase and the relation between central and decentral energy supply will change fundamentally. Despite decentral renewable power generation, there will still be central building blocks, such as large offshore windfarms or renewable power imports. Interconnection at all levels will be crucial for balancing supply and demand (“smart grids”).
- There is a constant need to adapt the energy system and its network to changing conditions and further develop it at local, regional and interregional levels. This requires a large number of capable actors at all levels, ideally operating under equitable, fair conditions. In order to achieve a market driven optimization, price signals that reflect the full external costs, including the cost of climate change, are absolutely necessary.

2.2. Two pillars: increased energy efficiency and renewable energy

In order to better understand the challenges of the Energiewende, it is useful to compare a target-fulfilment scenario (“what needs to happen”) with a reference scenario (“what will happen *if* nothing changes”). The scenarios used for this purpose are labelled “Scenario 100”, which represents the successful decarbonization of the energy system, and scenario “GROKO” (GROKO stands for “Große Koalition”; Eng. “grand coalition”), which models the continuation of trends that are evolving from the coalition agreement of the current government (see Figure 2). Both scenarios build upon the models used by the Federal Ministry for the Environment (Nitsch, 2014).

Scenario 100 illustrates well that by 2030 structural change of the energy system will have had to take place and the Energiewende will need to be in full swing, if targets are to be achieved. The scenario results in a CO_2 emissions reduction of 43% in 2020 and

86% in 2050 (base year 1990). As the government is committed to the Energiewende, credible energy policy measures have to be enacted in the near future. This is the only way that the deep decarbonization of the energy system, as reflected in scenario 100, can be commenced.

The need for additional political intervention becomes even clearer when analyzing the GROKO scenario, which clearly misses the climate change mitigation targets. The scenario displays CO_2 reductions of 32% in 2020 and 42% in 2030. This reflects a continuation of the reduction trajectory in the 2000-2011 period. Climate targets are missed in this scenario as energy efficiency potentials cannot be activated. Furthermore, current policy has slowed down the dynamics in the growth of electricity from renewable sources and does not succeed in creating new incentives for the stagnating renewable heat sector.

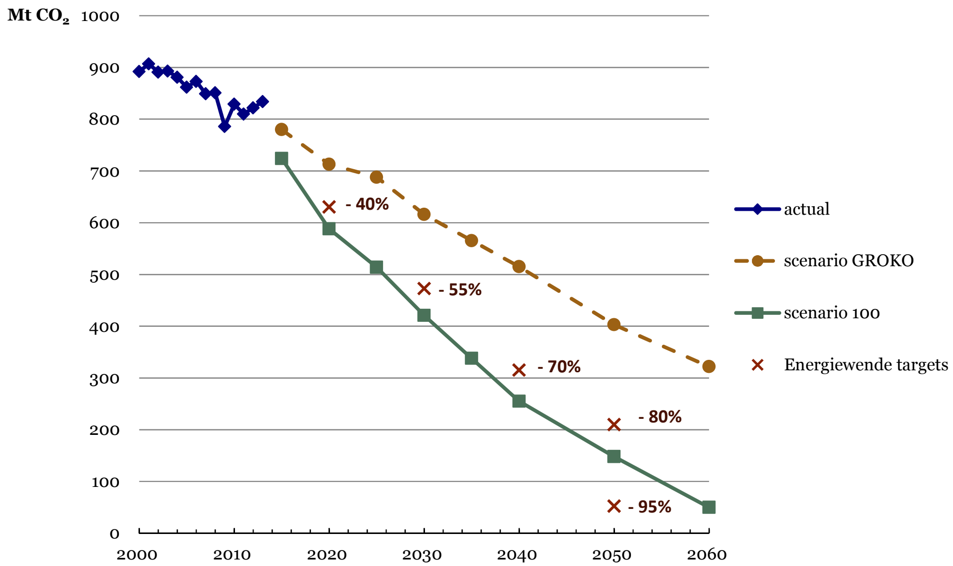

Figure 2:
Development of CO_2 emissions from energy (incl. industrial processes) until 2013 and two scenarios for reduction pathways (source: Nitsch, 2014)

Both energy efficiency and renewable energies are needed to reach the targets. This becomes clear when looking at the development of primary energy supply (see Figure 3). The required reduction in primary energy consumption can only be realized if strong incentives are enacted immediately (e.g. the effective implementation of the EU Energy Efficiency Directive in national decrees and legislation). The continuation of the actual trend of the last decade will lead to energy savings that fall significantly short of the Energiewende targets.

The third National Energy Efficiency Action Plan of 2014 acknowledges this "efficiency-gap" explicitly, but does not make any great effort to fill it. Even if all additional measures of the action plan are to be implemented they are most likely not enough to reach the 20% reduction target in 2020. If continued, the non-intervening energy policy will at best result in a reduction of primary energy consumption by 30% by 2050. In contrast, several studies have clearly shown that the reductions targeted in the Energiewende (as displayed by scenario 100) are achievable (DENA, 2012; Kohler, Joest, Peters, & Stolte, 2013).

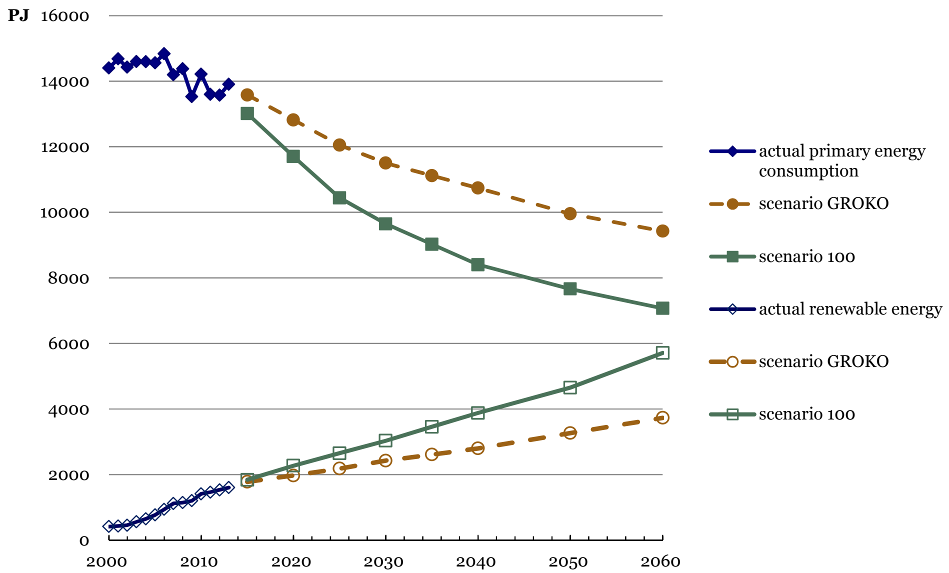

Figure 3:
Development of primary energy consumption and renewable energy supply in two scenarios (source: Nitsch, 2014)

Despite the very encouraging development of renewable energy in Germany in the last decade, the scenario comparison makes it very clear that a slowdown in the growth of renewable energy is not possible if the Energiewende targets are to be achieved. Even if energy efficiency targets are fully achieved, recent growth rates of renewable energy have to be maintained in order to reach the targeted CO_2 emissions reductions. There is a substantial risk that policymakers might take the truly remarkable success of renewable energy in the power sector as a reason to slow down the pace in order to satisfy conservatives who continue to repeat their mantra of electricity shortages and exploding costs.

2.3. The power sector and its challenge of fluctuating supply

The power sector and its growth of the share of renewable energy are currently at the centre of the Energiewende debate. There are two reasons for this. Firstly, it is the only area where an actual transition has already been initiated. Secondly, there is a lot of friction caused by the incompatibility of the current market design and the requirements set by volatile renewable power generation at zero marginal costs.

Moreover, power consumption is also determined by various factors. In the medium-term (until about 2025), reductions in consumption will be driven mainly by tapping energy-efficiency potentials of existing power-consuming sectors and applications. The increasing share of renewable power has, however, an impact on the applications that are run on electricity. Electric vehicles, heat pumps and – in the longer term – hydrogen and other power-to-gas technologies will enter the market as they are suitable for using cheap "excess" power generation from intermittent renewable energy. The share of these applications is expected to grow substantially and reach in the long term a share in overall consumption that is comparable to that of today's existing consumers. Scenario 100 calculates with a share of electricity in final energy of 65% by 2060, of which 95% will be generated from renewable energy sources. This includes both direct and indirect power use via power-to-gas technology.

Thus the sum of future electricity use is a result of income, energy prices, and energy efficiency improvements as well as the growth of renewable power generation. Total electricity consumption is therefore expected to grow despite considerable efficiency improvements in energy transformation and final consumption. Consumption will increase all the more, the faster the transition towards a renewable power sector takes place.

The transformations described above will change the power supply structure completely (see Figure 4). The total capacity of all power plants will increase from 183 GW to 266 GW in 2030 and 370 GW in 2060. The added capacity will be dominated by new wind power and photovoltaics. Their capacity of 78 GW in 2013 corresponded to 35% of total capacity, while their share in power generation was 12%. This will increase to 60% of all capacity and 45% of power generation in 2030, and 70% and 55% respectively in 2060. Integrating peaks of power generation from renewables as well as securing supply in times of very low wind and solar power generation is a substantial but manageable challenge. Production peaks until 2030 can be fully exploited by applying load management, conventional storage systems, by using power for heating as well as electric vehicles. Disconnecting renewable power plants in cases of extreme peaks is another option, which will result in marginal losses. The precondition for dealing with intermittent power from renewable energy is a functioning transport and distribution grid in order to balance spatial differences in the supply with renewable energy.

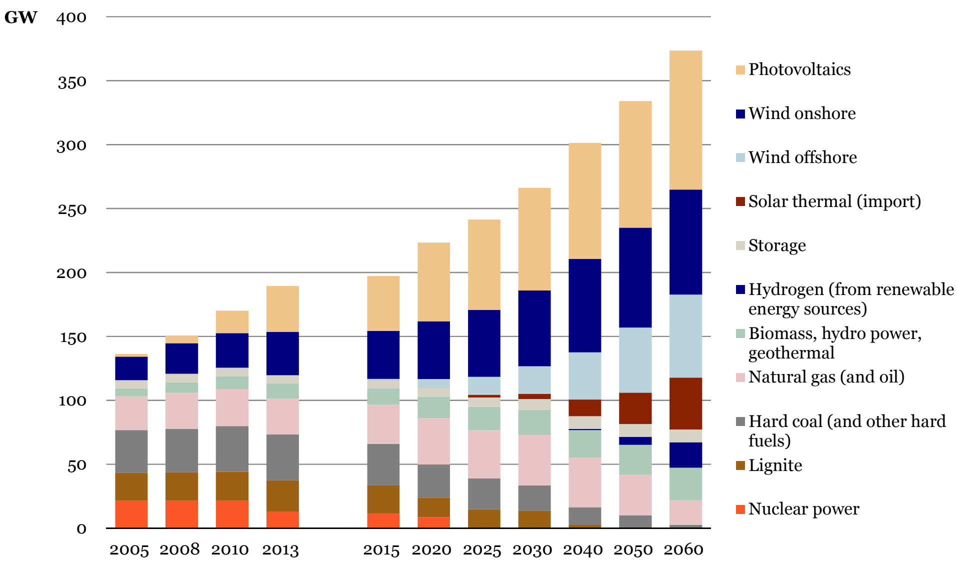

Figure 4:
Development of gross power generation capacity by technology in scenario 100 (source: Nitsch, 2014)

As the share of renewable power generation continues to grow after 2030, excess production will increasingly be turned into storable energy carriers. These energy carriers are subsequently converted back into electricity in efficient CHP plants, or are used as fuel in transport and industry. In 2030 only 2% of renewable electricity will be used for hydrogen production, in 2059 it will be 23%, and in 2060 in excess of a third of all renewable power.

The large increase in total capacity brings with it an increase in intermittent capacity. Nevertheless, the peak load (of about 85-95 GW) is always covered. Until 2040 this will mainly be achieved by thermal power plants, while the share of coal decreases and the share of natural gas increases, increasingly supported by bio energy and geothermal power plants. Later, CHP plants (based on renewable hydrogen or methane) will be added to the mix, with solar thermal power contributing, and a small share of assured capacity also being provided by widely interconnected wind power plants. Furthermore, the capacity of local storage will increase[1]. Scenario 100 foresees a decline in capacity of conventional power plants from 101 GW (incl. nuclear power) to 82 GW in 2030 and 22 GW in 2060. At that time the combined capacity of power from

[1] Another option for using large excess power from renewable energy and providing assured capacity, namely the integration with Scandinavian hydropower and pump storage, is not considered in this scenario.

biomass, geothermal energy, storage sites, and CHP plants (based on hydrogen/methane) will be 50 GW (see Figure 4).

In order to remain on the trajectory of scenario 100, the reorganization of thermal power generation towards natural gas has to be initiated and pushed ahead as soon as possible. Power generation from coal is supposed to decrease by 2020 by 40% as compared to 2013, and its capacity will decrease from 61 GW to 42 GW. This means, of course, that no new coal-fired power plants can be built and several old plants have to be retired. At the same time the capacity of (heat and) power plants that run on natural gas has to increase from 8 to 36 GW. As a continuation of this trend, lignite will no longer contribute to power generation from 2040 onwards.

Actual developments in recent years do not reflect the trend needed. The contribution of coal (and lignite in particular) has not yet started to decline. There is a clear need for further political intervention, which has to include a revival of the emissions trading system (ETS). The ETS has not managed so far to give the incentives to switch generation from coal to natural gas. As a consequence of low emission allowance prices, modern natural gas plants are idling or even being shut down and investment in additional capacity is being delayed. Additional incentives for the provision of conventional power-generating capacity (e.g. capacity markets) should be limited to highly efficient, flexible gas-fired CHP plants.

2.4. The Energiewende in the heat sector

Currently, 58% of final energy is used as heat (heating, warm water, process heat) which causes about 50% of energy-related CO_2 emissions (420 Mt in 2013). Hence, a successful transformation of the heat sector is absolutely crucial for the success of the Energiewende. This is a commonly ignored factor in the current debate. As long as there are no comparable dynamics in the heat sector as those initiated in the power sector, talking about an Energiewende is out of question. Structural adjustments and changes will be at least as radical as in the power sector and will depend on two key building blocks. Firstly, the deep, comprehensive energy renovation of existing buildings needs to be accelerated, requiring at least a doubling of the current annual renovation rate. Secondly, stronger incentives are needed for the pick-up of the renewable heat market, e.g. for solar collectors. If these elements of energy policy are implemented in the near future, a development as illustrated in Figure 5 is feasible.

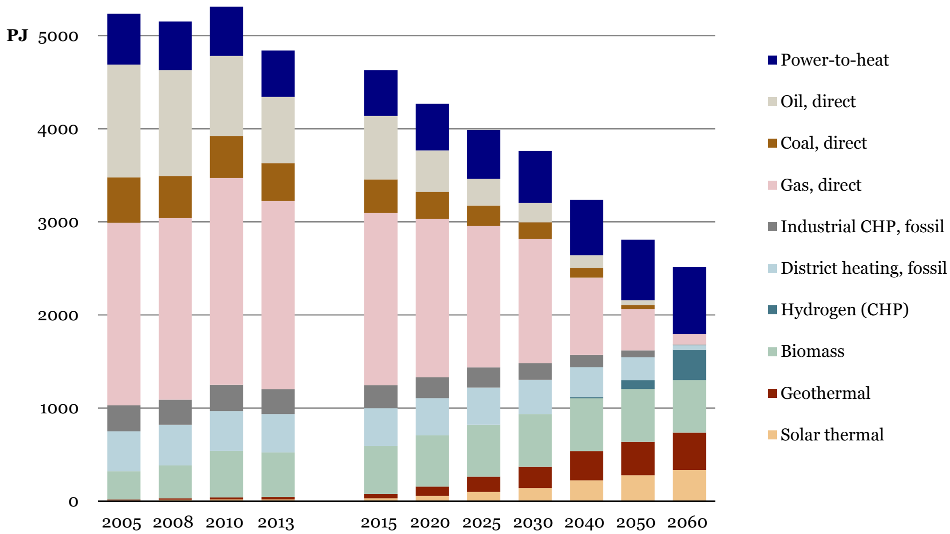

Figure 5:
Development of heat generation by technology in scenario 100 (source: Nitsch, 2014)

In scenario 100 the energy demand for heat decreases by 15% until 2020, by 28% until 2030, and by 50% in the longer term. The main share of this reduction will be achieved by increasing efficiency and decreasing energy consumption for space heating, e.g. by the replacement of today's individual oil and natural gas heating systems with small-scale district heating based on renewable energy sources.

2.5. And what about transport?

The Energiewende has not started in the transport sector either. At 185 Mt CO_2 per year, 22% of CO_2 emissions are caused by transportation and there is no trend of emission reductions yet. Furthermore, the share of renewables in final energy consumption of transport is still very low at about 6%. In scenario 100 the contribution of bio fuels to final energy remains very limited, as the domestic bio energy potential is more efficiently used in stationary plants (i.e. for heating) and the German government restricts the import of biomass. That means that besides efficiency improvement, electricity from renewable energy will become the main fuel for transportation, either directly in electric vehicles or indirectly via transformation into hydrogen or methane.

Future energy consumption in the transport sector will be significantly determined by the growth of freight transport, which – in contrast to passenger transport – still involves increasing energy consumption. In the short to medium term, emission reduction will be achieved mainly by substantial efficiency improvements, a modal shift between means of transport and the changing mobility needs. Thus, final energy consumption in the scenario will decrease by 10% by 2020, 22% by 2030 and 41% by 2050 (see Figure 6).

Until 2030 the main contribution of renewable energy to the energy needs in the transport sector will come from bio fuels, whose share will increase to 12.5%. After that it is only electricity from renewable energy sources and hydrogen from renewable energy that will take significantly increasing shares. Until 2050 half of personal transport will be based on electric and hybrid electric vehicles, the rest being covered by biofuels and hydrogen. Thus, passenger transport on the roads will then be free of CO_2 emissions and freight transport to a large extent. Renewable energy sources will cover 57% of energy needs for transport. This share will increase to 83% by 2060. Only aviation will still consume significant amounts of fossil fuels. The overall achievable emission reductions will be 75% in scenario 100. Hence, transportation can make its contribution towards achieving climate targets.

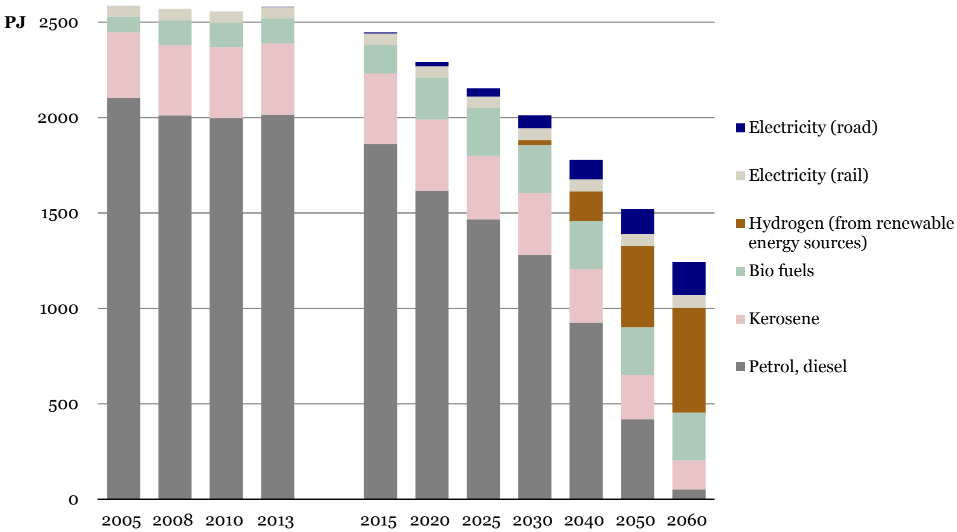

Figure 6:
Structure of energy supply in the transport sector in scenario 100 (source: Nitsch, 2014)

2.6. Synthesis of Energiewende scenarios

There is currently no comprehensive political strategy to cope with the major challenges that are connected to the total restructuring of various sectors in the energy system within the space of a few decades. It is not credible to stick to the target system of the Energiewende, which includes both nuclear phase-out and deep decarbonization, but not to agree on additional efforts to implement it. It is very clear that for several years the transition dynamics in respect of energy efficiency (in particular energy renovation of buildings), heat supply, CHP plants and transportation will at best be insufficient. There is a dire need for additional activities and measures. In this context neither the measures under the National Energy Efficiency Action Plan nor the Climate Action Plan (both 2014), are sufficient.

3. Is the Energiewende on track?

- Strong decoupling of CO_2 emissions from GDP in Germany in the past was mainly driven by the decreasing energy intensity of the economy, while the carbon intensity of the energy mix only decreased a little and has remained stable over the last decade.

- Positive achievements of the Energiewende include the nuclear phase-out, an increased share of renewable energy in power generation, job creation and municipal value added.

- The largest challenges of the Energiewende include reducing energy consumption, reducing CO_2 emissions more quickly, keeping electricity tariffs within limits and adapting power grids.

There is clear social and scientific consensus about the need for the Energiewende, which comprises both the phase-out of nuclear energy and the decarbonization of the economy. While this consensus took decades to form, political and institutional steering has to start immediately so that the ambitious targets can be achieved. In order to illustrate the state of the Energiewende, current developments of key indicators are put into their historic context and the main Energiewende achievements and challenges are briefly summarized.

3.1. The Energiewende indicators in a historic context

Future scenarios clearly illustrate the feasibility of reaching Energiewende targets by combining large energy savings with the deployment of renewable energy technology. While the nuclear phase-out is agreed and unlikely to be altered, the decarbonization of the German energy economy remains an enormous challenge. In order to get a better grasp of the challenge ahead, it is useful to look back at the development of key macroeconomic drivers of CO_2 emissions, including GDP, the energy intensity of the economy and the carbon intensity of energy.

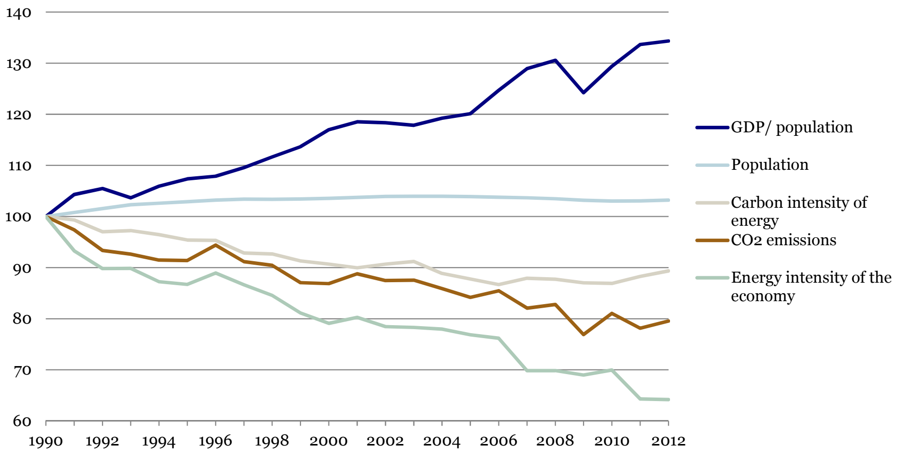

Figure 7:
Macroeconomic drivers of CO2 emissions from fuel combustion 1990-2012 (IEA, 2014b)

The first interesting finding when looking back at the development since 1990 (see Figure 7), is that CO_2 emissions decreased by about 20% while per capita GDP grew by 35%. When looking at the drivers that enabled this strong decoupling effect, decreased energy intensity stands out as the main factor. Since 1990 there has been a consistent trend of less and less primary energy being needed to generate GDP.[2] There are two possible explanations for this trend. Firstly, a structural change in the economy may have occurred, i.e. proportionately more GDP is generated from economic sectors with low energy intensity today than 25 years ago. These sectors include, for example, the service sector and trade. Secondly, individual sectors may have deployed more energy-efficient technologies and processes. Quantitative analyses reveal that structural change has not been driving energy intensity improvements. Germany is not in the process of de-industrialization. On the contrary, in the first decade of the 21st century structural change *increased* energy intensity (Löschel, Pothen, & Schymura, 2015). This is an effect that is not visible in Figure 7 as it was outbalanced by enormous improvements in energy-efficiency technology.

While the German national economy is increasingly efficient in turning energy into GDP, it has not yet achieved a significant total reduction in final energy consumption. The consumption of energy has remained more or less constant at around 9000 PJ throughout the last 25 years and a modest reduction trend has only started in the last decade. The limited success of achieving an absolute reduction of energy use (despite large efficiency improvements) is also the reason why the concept of "decoupling" should be viewed critically. While the influence of GDP on energy use may have been

[2] It is important to note that the years immediately after 1990 were heavily influenced by German reunification. Hence, energy intensity improvements in that period can be regarded as one-off events.

"softened" it is still clearly linked, or in other words "coupled", to the development of economic activity.

The reason why CO_2 emissions from energy dropped significantly while energy use remained constant is that the carbon intensity of energy supply improved. The carbon intensity of the energy mix has decreased as cleaner fuels (low carbon intensity) have replaced dirtier fuels (high carbon intensity). Renewable energy and natural gas have replaced coal and oil. The effect that more renewable energy in the electricity mix has on overall carbon intensity will become even more visible when the nuclear phase-out is finalized and coal-based power generation is replaced.

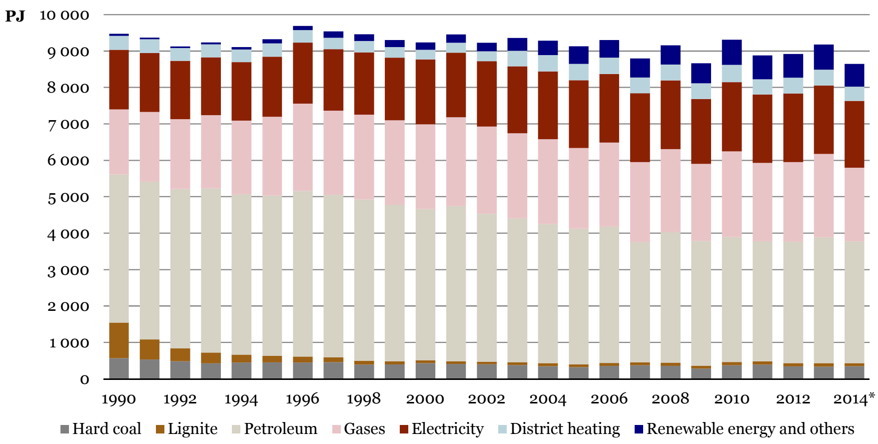

Figure 8:
Final energy consumption by energy carrier 1990-2014 (AG Energiebilanzen, 2015)

Several key lessons have been learned from the study of energy-economy indicators over the past 25 years:

- The former strong decoupling of GDP from CO_2 emissions was mainly driven by improvements in energy efficiency. Policies for the even stronger decoupling that is needed until 2050 need to take account of this and should not focus too much on adding renewable energy to the mix.
- The second main driver of changes in energy intensity, i.e. the structural change of the economy, is often forgotten. So far it has not been a major driver of decarbonization of the German economy, but it has great potential. Shifting industrial production to less energy-intensive sectors, strengthening the service sector as well as greening the structure of energy-intensive sectors all have the potential of reducing energy consumption while maintaining a high level of employment and incomes. It must be made clear, however, that merely shifting energy-intensive production abroad does not reduce overall environmental

impacts. Shifting for example efficient German steel production abroad may even increase environmental impact ("carbon leakage"). On the other hand, shifting business models from the mere manufacturing of cars to an integrated offering of mobility services is an example of structural change that reduces overall energy consumption and CO_2 emissions.

- The carbon intensity of the energy mix has not improved throughout the last ten years and, even before that, changes in the energy mix were not the main driver of decarbonization. As the nuclear phase-out has been agreed and enacted, the coal phase-out is the next major challenge that needs to be addressed as soon as possible, so that the carbon intensity of the energy mix can be reduced.

3.2. State of the Energiewende 2015

The German government monitors the progress of the Energiewende and publishes an annual report with progress indicators in the areas of renewable energy, energy efficiency, transport, GHGs, electricity market, costs, grid, innovation and economy. Despite the consultancy of an independent group of experts, the monitoring report and the follow-up required are completely in the hands of the Ministry for Economics. Rather than summarizing the government publication (Federal Ministry for Economic Affairs and Energy, 2014), a snap-shot of the Energiewende in mid-2015 is presented below. It illustrates substantial progress on the one hand and several unsolved challenges on the other. The Energiewende can be credited with the following achievements so far:

- Up to 2015, nine NPPs have been shut down for good; if prototypes, trial and demonstration plants are considered, 19 NPPs have also been taken off the grid. The further nuclear phase-out (eight NPPs by 2022) is neither questioned by any relevant group in society, nor by any political party. Once nuclear energy was wrongly seen as a sustainable, cheap energy source, but after 40 years of heavy conflicts nuclear energy has become history in Germany. Other countries have now the opportunity to avoid this costly as well as dangerous technological path and develop their energy systems from start without nuclear energy – and this is also due to the German Energiewende.
- Gross power generation from renewable energy sources increased from 20 TWh (3.6%) in 2000 to nearly 160 TWh (27.3%) in 2014 (AG Energiebilanzen, 2015). The actual development exceeded by far all the previous projections of scenario experts. In particular, the assessment of German power corporations was drastically refuted. In a media campaign from 1993 they still claimed that, even in the long run, sun, water and wind cannot provide more than 4% of our power demand (see Figure 9).

Wer kritisch fragt, ist noch längst kein Kernkraftgegner.

Viele junge Leute empfinden Kernkraftwerke als bedrohlich. Wir, die deutschen Stromversorger, haben ihre Kritik nie leichtfertig abgetan. Im Gegenteil: Wir stellen uns dieselben Fragen, die sie bewegen.

Kann Deutschland aus der Kernenergie aussteigen? Ja. Die Folge wäre allerdings eine enorme Steigerung der Kohleverbrennung, mithin der Emissionen des Treibhausgases CO_2. Denn regenerative Energien wie Sonne, Wasser oder Wind können auch langfristig nicht mehr als 4 % unseres Strombedarfs decken.

Können wir ein solches Vorgehen verantworten? Nein. Der steigende Energiebedarf der dritten Welt verpflichtet die reichen Staaten, ihre CO_2-Emissionen zu mindern.

Schaffen wir das ohne Kernkraft, allein durch Energiesparen? Nein. Kernkraftwerke liefern 34 % des deutschen Stroms und ersparen der Atmosphäre jährlich 160 Mio. Tonnen CO_2 – bei einem international vorbildlichen Sicherheitsstandard. Also: Treibhaus oder Kernkraft? Das ist hier die Frage!

Viele junge Leute stellen kritische Fragen. Wir auch. Denn unsere schärfsten Kritiker sind wir selbst.

Ihre Stromversorger

Badenwerk Karlsruhe · Bayernwerk München · EVS Stuttgart · Isar-Amperwerke München · Neckarwerke Esslingen · PreussenElektra Hannover · RWE Energie Essen · TWS Stuttgart · VEW Dortmund

Figure 9:
Newspaper campaign by German energy corporations from 1993: "Asking critical questions does not mean you're an opponent of nuclear power". The marked text translates: "Renewable energy sources such as sun, wind or water will not even in the long run be able to cover more than 4% of our power demand."

- Learning effects and cost digression for electricity from PV and wind energy also exceeded expectations: in 2013 the average cost for electricity from PV was 7.3 ct/kWh and from wind (onshore) 5.6 ct/kWh. It is estimated that the cost for electricity from PV will decrease further and reach 3-5.5 ct/kWh in southern and central Europe by 2035 (Fraunhofer ISE & Agora Energiewende, 2015). With PV in particular, the German Energiewende and fierce international competition brought about "power for the world" that is affordable, decentral and sustainable, and can drive rural electrification.
- Gross employment in the renewable energy sector reached its all-time high in 2013 at 400 000 people employed. Despite the significant crisis in the solar economy, employment still stood at about 370 000 in 2014 (DIW, 2015). By comparison, employment in the coal and lignite sector is estimated to be about 40 000 (DIW, 2014).
- Even although net electricity exports increased in 2014 to 34TWh, CO_2 emissions decreased significantly after an intermediary increase between 2009 and 2013. The temporary increase was clearly not driven by the Energiewende but was a result of the extremely low price for emission allowances in the European Emissions Trading Scheme (EU ETS), which fell to about 5 €/t CO_2 in 2014.
- From 1990, GHG emissions decreased by more than 250Mt CO_2eq to about 990Mt CO_2eq (estimation for 2014). In order to reach the target of 40% reduction by 2020 an annual reduction rate of 3.4% would be needed, which is three times the rate of the last 15 years (Agora Energiewende, 2015).
- Public acceptance of the Energiewende is high. In a 2015 opinion poll 93% of Germans stated that they find the further use and expansion of renewable energy sources important or very important (Renewable Energies Agency, 2014). Key factors for public acceptance are the large increase in the number of energy cooperatives (nearly 1000 in 2015) and the increasing share of citizens' financed decentralized renewable energy (Müller & Holstenkamp, 2015). This might reflect a decentralization trend that is driven by the renewable energy technology and the economics behind it, and hence can be replicated elsewhere by opening the market through a feed-in tariff, a diversity of supply and direct competition.
- Total municipal value added by renewable energies was EUR 6.95 billion in 2011 and a doubling is expected to take place by 2020 (Hirschl, Heinbach, Aretz, & Salecki, 2012). In that respect the Energiewende has already contributed significantly to the strengthening of the municipal economies; and the trend still points upwards. Considering the strained financial situation of

many German municipalities and the lack of investment, this is an important success factor of the Energiewende.

On the downside, the following challenges remain:

- Primary energy consumption decreased only slightly from 14 905 PJ in 1990 to13 132 PJ in 2014 (AG Energiebilanzen, 2015). The reduction targets of the German government for 2020 (11 504 PJ) and for 2050 (7 190 PJ) require a paradigm shift towards an accelerated energy-saving policy. Germany is still far away from a systematic approach for primary energy reduction.
- The lack of energy savings is partly due to the lack of ambitious Energiewende policies in the building and transport sectors. Current regulation and support for building efficiency does not reflect at all the planned doubling of the energy renovation rate. Besides policy *ambition* there is a great need for the *development* of new policies and their *integration* across sectors. The Energiewende needs the support of a comprehensive and structured set of policies.
- Compared against the binding targets of the EU Energy Efficiency Directive (reduction of 20% by 2020) and the ambitious targets of the German energy concept (see Table 1), a clear implementation deficit of the energy savings potential can be observed. The neoliberal idea that market-based instruments are sufficient for reaching ambitious energy-saving targets still dominates official energy policy. The EU parliament is more progressive by demanding a binding energy-saving target of 40% by 2030.
- In order to reach the GHG reduction targets by 2020 (40%) and 2050 (at least 80%) a complementary phase-out of power generation from coal is necessary. The 30 largest German coal-fired power plants alone emit 239Mt CO_2 per year. The estimated shortfall of GHG emissions reduction of 62-78Mt CO_2eq by 2020 was initially planned to be diminished by 22Mt CO_2eq from the shut-down of three older coal-fired and six lignite-fired power plants (DIW, 2014).
- However, the German States („Länder") and labour unions opposed the closure, so that new estimates now reckon on an additional GHG reduction in the coal sector of only 12.5Mt CO_2eq (Oei, Kemfert, & von Hirschhausen, 2015). The measures to reach this modest reduction would most likely be much more expensive than the levy planned initially. The gradual phase-out of coal and in particular lignite in the German power mix remains an immense challenge for the Energiewende.
- There is a critical public debate about increased electricity tariffs for households and SMEs and the exemptions granted to large industry players. The average electricity price for households increased from 13.9 ct/kWh (2000) to a maximum of 29.1 ct/kWh (2014). The maximum contribution of

the renewable energy surcharge has been 6.2 ct/kWh in 2014. A large redistribution effect towards industry could be observed as the sum of exemptions from the surcharge, reduced transmission costs and the free allocation of emission allowances increased from EUR 9.4 billion in 2007 by political intervention to EUR 16.8 billion in 2013.

- Management challenges of fluctuating power generation from PV and wind have so far been mastered without any power shortages or even black-outs. However, considerable challenges in the development of more flexibility in the system remain. The extension of the high-voltage grid is under way but far from finished. Currently the construction of north-south grid interconnectors and the connection of offshore wind parks to the grid are particularly challenging. Moreover, additional power storage is needed. The development of smart grids and load management needs further advancement. The integration and wide deployment of combined heat and power plants has not yet come very far. And the stationary and mobile use of renewable electricity needs to be better integrated.
- Local acceptance for the new construction of wind parks and electricity grids is facing resistance. In order not to jeopardize the broad support for the Energiewende, it is absolutely crucial to allow public participation and have a truly transparent dialogue. The “not in my backyard” attitude (NIMBYism) is often the result of planning deficiencies rather than a more fundamental opposition. Keeping parts of the economic benefits within the respective municipalities is a success factor for increased acceptance.

4. What are the benefits of an integrated Energiewende?

- Multiple quantitative studies illustrate the macroeconomic benefits of the Energiewende in general and energy-saving measures in particular.
- The large synergies between resource efficiency and energy efficiency mean that integrating policies in these two areas is very beneficial.
- Co-benefits of the Energiewende include conservation of fossil resources, strengthening of regional value added, job creation, and reducing the concentration of market power.

The remarkably high, stable public acceptance of the Energiewende project may be explained by the desire to contrast the large crises and failures of our time with a positive vision, which goes beyond the current generation. Wide identification with the project can trigger unused potential for creativity and motivation. A previous example of this type of project is the American Apollo Programme of the 60s, which within a decade achieved the unthinkable: the first human on the moon.

The German Energiewende has almost achieved its first milestone, the phase-out of nuclear energy. While the last NPP will not be taken off-grid until in 2022 and the challenge of managing nuclear waste has still not been solved, the "nuclear problem" has certainly been solved from society's perspective as another pull-out from the phase-out is virtually impossible. From its roots in the anti-nuclear movement the Energiewende has now evolved into a constructive project that centres on economic performance and climate change mitigation.

From a psychological perspective it is understandable that the argument of risk-minimization slowly loses relevance and economic arguments become more important. Exploding costs and the fear of "de-industrialization" accompany almost every economic debate about the Energiewende. It is important to differentiate between purposeful attacks against the Energiewende and justified worries of low income households and SMEs. Motivation for and acceptance of the common Energiewende project would only dwindle if it entailed costs that are perceived to be unacceptable and unequally distributed. So far the debate has not reached this point.

The unequal development of power tariffs for households and small-scale consumers on the one hand (large increase) and energy-intensive industry on the other hand (constant level) may challenge the considerable public support, if and only if the Energiewende debate is not transparent and narrowed down to temporary price developments in the power sector. Thus, a thorough public examination of the costs and benefits of the Energiewende is absolutely necessary.

4.1. Estimating economic benefits

It is a commonly repeated myth that the Energiewende costs exorbitant sums of money and cannot be financed. A good example of this is the claim by former Minister for the Environment Peter Altmaier in 2013 that the Energiewende will come at a cost of a staggering one trillion Euros. This counterproductive statement was not very convincing as Altmaier did not confront his (controversial) summing up of costs with economic and social benefits, suggesting a wastage of public money without the creation of real benefits (Reuster & Küchler, 2013). Accordingly, the following remarks will illustrate that money put into the Energiewende is well invested from a purely economic perspective.

The general macroeconomic cost dynamics of the Energiewende are as follows: an energy system based on a high share of renewable energy and massive energy efficiency improvements, hence substituting most fossil and all nuclear fuels, will in 20 years be "cheaper" than the continuation of the current system. This is certainly the case, if avoided external costs of fossil-nuclear energy supply and the potential cost increase of fossil fuels are also considered. Still, the economic costs will probably exceed the immediate benefits for a limited transition period. The system costs for energy supply are modelled in annually updated studies for the Ministry of the Environment.

A comprehensive long-term evaluation of the economic effects of the Energiewende has not yet been carried out. This is not surprising as long-term scenarios (2030 and 2050) of monetary costs and benefits are inherently uncertain as they depend on many assumptions regarding the development of key factors (e.g. energy prices and financing costs). Moreover, it is virtually impossible to model the structural change that is triggered by the Energiewende, including the development of new business fields ("Cleantech"), the dynamics of innovation ("disruptive innovation") and the accompanying social transformation ("sustainable consumption and production").

The large number of sectoral studies and plausibility considerations leads to the conclusion that the Energiewende pushes ahead with beneficial ecological modernization, including the creation of new enterprises and new jobs as well as increasing competitiveness on the global markets of the future ("the green race"). In the following section we argue that energy savings are necessary to realize the full economic benefits of the Energiewende (section 4.2) and present selected studies about the economics of energy efficiency.

4.2. Priority to energy savings

Electricity from renewable sources is not only at the centre of public perception and political debate, but is also the main subject of economic analysis. This is understandable considering the visibility and dynamics of change in the power sector. Still, it risks losing sight of the initial comprehensive target system of the Energiewende – a world without nuclear, coal and oil. If, however, the visionary perspective of a “soft energy path” (cf. Hennicke et al., 1985; Lovins, 1979) guides the transition, the demand side of the energy market has to move back into the centre of analysis and policy-making; priority should be given to policy for energy saving.

Saving energy and fostering the efficiency revolution is the cheapest, most comprehensive and potentially quickest element of the Energiewende. Hence, it is at the very core of this study. Energy saving and efficiency improvements create new governance challenges in the policy process and the initiation of social transformation processes. The central paradigm shift in the redesign of the energy system can be found in the primacy of rational energy consumption and consumer needs for energy services. The formation process behind the Energiewende should be guided by following principles:

- Phase out the use of nuclear and fossil fuels as soon as possible.
- Make sure socially useful consumer needs are satisfied.
- Deploy as much renewable-energy technology as needed, but as little as possible – always in accordance with social and environmental standards.

It is important to keep all three aspects in mind when shifting towards a fully renewable energy system, as the massive new renewable energy capacity comes along with considerable interference in the natural environment and cultural landscapes, and requires the use of large amounts of strategically important metals.

If the economic potentials for efficient energy-saving technology are not tapped more consistently, the implementation of the Energiewende, if then still feasible at all, will come at a significantly higher cost and with lower public acceptance. This includes questioning both the amount and type of energy services we are consuming today. Even the most efficient use of energy can coincide with higher total consumption that is driven by effects of rebound, comfort and growth (see also chapter 5.1). Hence, the Energiewende also includes changes in lifestyle and the development of new models and understanding of prosperity. Do we actually need larger and larger dwellings, shopping arcades that mutate into temples of consumption, bigger flat-screens in our households, more powerful cars and excessive long-distance travel? Or can we live well and run the economy without all of the above, i.e. have an energy-sufficient lifestyle?

Note that asking "how much is enough" and arguing for sustainable consumption and production patterns does not undermine energy efficiency and saving. It is rather a call to combine efficiency and sufficiency policies, in order to avoid efficiency improvements being nullified by increased consumption of more energy services. The combination of energy efficiency and sufficiency can:

- make the transition towards an energy economy based 100% on renewable sources quicker and cheaper. If primary energy consumption can be cut by 50% by 2050, the current amount of energy from renewable sources "only" needs to be tripled. This reduces costs significantly, not least for grid integration and storage;
- maximize macroeconomic benefits, because energy-efficient buildings, appliances, machinery and solutions are typically cheaper at full-cost pricing than the non-optimized alternatives. Furthermore, energy sufficiency saves not only energy but also acquisition costs;
- strengthen the global example that the Energiewende can be, as Germany shows – in particular towards countries in transition – that targets can be achieved more quickly and cheaply if wasteful patterns of production and consumption are abolished (or not adopted in the first place); and
- accelerate the Energiewende altogether, because combined energy efficiency and sufficiency can be put into effect more quickly, and "time is our scarcest resource".

4.3. Studies of the macroeconomic effects of the Energiewende

The Energiewende has triggered a multitude of mainly sectoral cost-benefit analyses of its economic impact. Here we only present a few key publications and findings that illustrate well the main economic aspects of energy efficiency improvements:

- The DIW (German Institute for Economic Research) researched in 2013 the required investment into the Energiewende and its economic impact on the power and buildings sectors until 2020. It concludes that without a considerable increase in energy efficiency, the Energiewende targets are out of reach. Between 2014 and

2020, additional annual investments of EUR 31-38 billion are required. The macroeconomic effects of this investment are clearly positive. The DIW model specifies further that EUR 17-19 billion must be invested annually into power and heat production as well was EUR 6 billion into the extension of the power grids and (as far as required until 2020) into grid integration (e.g. energy storage and load management). For the pursued doubling of the energy renovation rate of the building stock, DIW calculates with additional investment costs of EUR 6-13 billion per year. (Blazejczak et al., 2013)

- In the building sector, efficiency potentials are particularly large, but challenges and barriers are also tough. Support programmes are necessary to overcome these barriers, and solid economic arguments are needed to convince politicians and taxpayers that support programmes are beneficial. The development bank KfW reported in 2012 that EUR 1.5 billion of taxpayers' money triggered total investments of EUR 19.4 billion in energy-efficient construction and renovation by private people (Prognos, 2013). Considering the positive multiplier effects of this support programme on investment, employment and tax income, such a programme of a development bank presents itself as a win-win instrument for improving energy efficiency. It should be continued and ramped up. In this context it is important to consider the low investment rate in Germany, which is clearly below the EU and OECD average in the 21st century. Low investment rates contribute to the ageing of the capital stock and weaken technological progress. This results in weaker growth and employment dynamics, also in the sectors that are important for the Energiewende.
- The Prognos think tank shares this view that the support programme should be ramped up (Prognos, 2013). The study concludes that the continuation of the KfW programme and a higher financial volume (EUR 5-10 billion per year to double the renovation rate) will result in significant positive economic effects. Even if the state is debt-financing the programme, a "self-financing ratio" of more than 1 can be expected due to higher tax income.
- The German Advisory Council on the Environment considers lowering power demand through energy efficiency as the least costly "bridging technology" and a necessary condition for keeping the costs for renewable energy as low as possible (SRU, 2011). The potential energy savings in industry alone amount to an estimated EUR 65 billion by 2030 and require investment of about EUR 9 billion (Bauernhansl, Mandel, Wahren, Kasprowicz, & Miehe, 2013).
- Another study investigates the total economic effects of a strengthened efficiency strategy (IFEU & Fraunhofer ISI, 2011). In comparison to a reference scenario, the main indicators of the studied scenario "Ambitious Efficiency" will develop until 2030 as summarized below:

- GDP and private consumption increase
- Investment increases significantly
- Government consumption expenses are lowered
- Energy imports are reduced by EUR 4 billion per year (91 billion in 2010)
- A net employment increase of 130 000 jobs in manufacturing can be achieved.

4.4. Increased efficiency reduces the need for back-up capacity

A particular benefit of increased efficiency in the consumption of electricity is that power grids are unloaded and a contribution to the security of supply is made.

Measures to improve electricity efficiency result in lower consumption of electricity. To the extent that this reduction takes place at the time of peak consumption, the peak load that power grids have to handle can be reduced. This effect has not been utilized systematically, but it is very relevant for the costs and the capacity of grid extension, considering that a reduction of one to two percent per year is feasible. If the 2020 target of a 10% reduction in power consumption is achieved and if the reductions are realized along the current load profile, peak load will be reduced by more than 8 000 MW.

In addition to this effect, efficiency measures can even be steered in a way so that the load profile is adapted to temporal and spatial specifics. Changing from electric night-storage heating to another type of heating (ideally CHP) can, for example, reduce power demand in winter when power generation from PV is very low. Furthermore, electric ventilation, cooling and pumping often run continuously around the clock, while in most cases pauses in the time of peak demand are feasible without compromising the quality of the respective energy service.

Against this background, the suggestion arises of investigating further the strategic utilization of energy-efficiency measures to strengthen the security of power supply. What is the potential of electric efficiency to complement other measures subsumed under the headings of load shifting and demand side management (DSM)?

A current study estimates that the DSM potential for absorbing excess electricity is about 9 000 MW and for reducing the load on the grid up to 3 000 MW (Krzikalla, Achner, & Brühl, 2013). This shifting potential persists for several hours. Between half and two thirds of it can be contributed by industry and the remaining potential depends on households (both with and without heat-pumps). The load-shifting potential for shorter periods is even higher in industry.

As far back as the 1990s, Hannover's energy utility company showed what is possible in respect of DSM. It contracted load-shifting in large companies that corresponded to about two percent of peak load, in order to minimize the need to purchase power when it is most expensive, i.e. during peak hours (Thomas et al., 2003).

4.5. Controversy regarding electricity prices

During the last 15 years the price paid for electricity has undergone different developments in the household sector and in the power-intensive industry sector respectively. It was a political decision to use a transfer mechanism that puts the temporary burden of significant additional costs related to wind and solar power onto private households and SMEs, while at the same time an increasing number of energy-intensive companies (currently 2 200 companies) were exempt from this transfer (BAFA, 2015).

This exemption has been debated as it includes many companies that do not need this privilege to be competitive on the international market. Furthermore, increased tariffs for households and SMEs were taken as an opportunity to criticize the Energiewende and the Renewable Energy Sources Act (EEG) in general. The surcharge for renewable energy is, however, only responsible for a small proportion of the overall price increase. Moreover, it is expected to remain on the current level of around 6.3 ct/kWh and will decrease in the 2020s. Whether and when the electricity price trend turns also depends on other political decisions about the financing of grid infrastructure and reserve capacity provided by large power plants (e.g. coal).

If no counter measures are initiated (such as targeted energy-saving programmes), the high electricity price for households and SMEs and its negative distributive effects on low-income households may become the Achilles heel of the Energiewende.

4.6. Synergies of an integrated energy and resource efficiency policy

For both economic and environmental reasons the Energiewende should be accompanied by a resource transition and a more innovative resource efficiency policy. Synergies could thus be tapped that would amplify the macroeconomic benefits of energy efficiency policy.

In 2002 an expert commission researched for the first time the energy-saving potential of closing material loops more effectively and of improving the use of materials and products. Compared to a reference scenario, the following (additional) energy savings could be achieved in Germany by 2030 if a more active material efficiency policy were to be adopted:

1. More recycling of materials (128 PJ).
2. Lower specific material demand (193 PJ).
3. Substitution of materials (118 PJ).
4. Increased intensity of usage (65 PJ).

The expert commission estimated at that time that in the reference case 465 PJ would already be saved (corresponding to 5% of total energy demand) and the same amount again with a dedicated resource efficiency policy.

These figures still do not capture the full (cost) savings potential of an integrated resource and energy efficiency strategy. About 45% of the costs in the manufacturing industry are material costs, while energy costs make up about 2% and costs for staff about 20%. Total material input costs were EUR 858 billion in 2013, which illustrates that policy interventions for integrated material and energy efficiency have great potential (Destatis, 2015).

Recent simulation exercises show that the integration of an active climate-change mitigation pathway with material efficiency measures will add further benefits to a 54% reduction of GHG emissions by 2030 (Distelkamp, Meyer, & Meyer, 2010):

- Material consumption decreases by about 20%.
- GDP increases by about 14%.
- Employment increases by 1.9% (considering also demographic factors and a wage development that reflects productivity improvements).
- Government debt can be reduced by about EUR 250 billion.

The simulation concludes that a comprehensive material efficiency policy will strengthen Germany's competitiveness on international markets. This pioneering study provides evidence that a high-tech country like Germany can achieve absolute decoupling of economic growth from resource consumption by combining climate-change mitigation with progressive material efficiency efforts.

4.7. Co-benefits of the Energiewende

A narrow monetary cost-benefit analysis of the Energiewende cannot capture the more comprehensive social benefits derived from a nuclear-free, decarbonized energy system. Assuming for a moment that climate change itself does not provide sufficient justification for the Energiewende, there are numerous additional benefits that are commonly summarized as the "co-benefits" of climate change mitigation(cf. Höhne, Day, Hänsel, & Fekete, 2015; IEA, 2014a). Several actual co-benefits and future opportunities of the Energiewende are summarized in Table 2. Some of these are discussed in more detail below. Note that co-benefits are not limited to monetary benefits, but typically still have a significant positive economic impact. Even though they are labelled co-benefits, these factors can in many cases be the main reasons why the Energiewende is moving forward and widely accepted by many actors.

Table 2:
Co-benefits of the German Energiewende

(Co-)Benefit	Description/explanation
Conservation of scarce fossil fuels	Substitution of oil and natural gas and reduction of import dependence
Climate change mitigation and clean air (in particular in countries in transition and developing countries)	Reduction of CO_2 emissions and air pollution from the combustion of fossil energy carriers
Strengthening of local/regional value added and job creation	Substitution of energy imports by regional chain of economic value added
Reducing the concentration of market power and assuring a diversity of actors	Erosion of the superiority of large energy corporations and strengthening small-scale investors (citizen-financing, energy cooperatives)
Lowering the risk of wars for resources	Decreased dependence on the group of countries in the strategic energy ellipse that stretches from the Arabian Peninsula to the north of Russia
Minimizing risks related to national energy supplies	Avoiding scarcity, technical risks and price volatility
Creating export opportunities in the 21st century	Export of renewable energy technology and further sustainable energy systems
Strengthening social cohesion	More accessibility, participation and manageability

Conservation of scarce fossil fuels

A key reason for the fundamental change of our energy supply systems is the awareness that the energy reserves that have built up over millions of years are finite; in particular oil and natural gas will become scarce in the foreseeable future. The *Club of Rome* warned of energy resource scarcity as far back as 1973. Until today the general finding of scarce resources still holds – despite new technologies, new explorations and new discoveries. The "peak of fossil fuels" will occur sooner or later, but it is not going to be a sufficient driver for achieving the target to keep global warming below two degrees.

It is now more certain than ever that at most a quarter to a third of all carbon-energy reserves can still be burnt if climate change is to be kept within limits (IPCC, 2014; Meinshausen et al., 2009). This "planetary boundary" leaves little room and time for manoeuvre when deciding and putting into effect a global regime for the management of climate change. Hence, the restrictions that were once identified by the *Club of Rome* have been replaced: the boundary is not limited energy reserves in the ground, but the "sky", i.e. the limited capacity of the atmosphere to cope with an increasing volume of GHG emissions.

Germany's energy import dependency is particularly high in respect of oil and gas, while coal consumption is mainly covered by domestic resources (see Figure 10). From a national resource conservation perspective, lignite mining is at the core of the debate. The calls to 'keep it in the ground' are getting ever stronger. From an energy-security perspective, imports of oil and natural gas (in particular from Russia) are of geopolitical importance. Energy security can in this context be regarded as one of the additional drivers of the Energiewende.

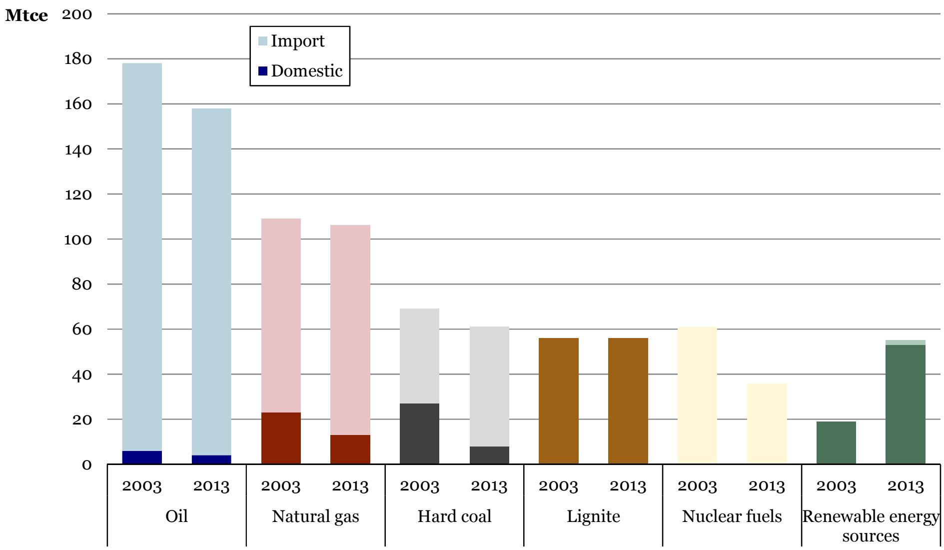

Figure 10:
Import share in primary energy consumption by fuel in 2003 and 2013 (BGR, 2014)

There will eventually be sufficient economic reasons to move globalized markets away from fossil fuel exploration and combustion and towards competitive renewable energy solutions and energy efficiency technology. For this to happen, the steep cost digression of power generation from PV and wind has to continue, which requires technology and knowledge transfer between countries (cf. Fraunhofer ISE & Agora Energiewende, 2015). Furthermore, external costs of fossil fuel based power generation should be fully internalized, e.g. by enacting a global emission trading scheme or a CO_2 tax. In Germany the external environmental costs are at least 9 ct/kWh, with the exception of natural gas at around 5 ct/kWh (UBA, 2012). Exorbitant subsidies for fossil fuels need to be phased out quickly and the global movement towards divestment from coal and other fossil fuels has to gain traction. National energy policy has limited influence on these global processes. Hence, the focus should be on what can be done nationally in the context of the Energiewende.

Strengthening of regional value added and job creation

Energy demand in Germany is covered by imports to the extent of 70%. Mainly oil and natural gas are imported. These imports come at a cost of EUR 90 billion per year. By using domestic renewable energy sources, an increasing share of this money remains in the country. At the municipal level alone, EUR 10.5 billion of value was added by renewable energies in 2011 (Hirschl et al., 2012).

So far, about 370 000 jobs have been created in the renewable-energy sector, spreading roughly equally into the sub-sectors wind power, solar energy and biomass (DIW, 2015).

Reducing the concentration of market power and assuring a diversity of actors

Until recently the four large energy corporations in Germany had a dominant market position and significant influence on political decisions at the federal and state levels (BKA, 2011). This dominance is waning as renewable energies expand and the decentralization of the energy system advances. The German Monopolies Commission supports this conclusion in a recent special report (Monopolkommission, 2013). Installations under the Renewable Energy Sources Act are mainly owned by citizens, while the "large four" own only 5% of the installed capacity, which is even less than municipal utilities (see Figure 13).

The low participation of large energy corporations in the decentral restructuring of the power market is combined with the contraction of conventional power generation in large thermal power plants (chiefly nuclear and coal). In response to this trend E.ON made an announcement to split the company into two parts. The management identified the coexistence of the old energy world with a new energy world as a challenge and opportunity: "This new world, which is emerging around customers and their changing needs, is fundamentally different from the conventional energy supply system which is based on large-scale systems." (E.ON CEO J. Thyssen, 1.12.2014).

How long the coexistence of the two energy worlds will last is an open question. It is clear, however, that the new world, which is characterized by decentral power generation, new business models, smart grids, and the integration of power, heat and mobility sectors, will grow.

5. Socio-economic effects of the Energiewende: Both sufficiency and efficiency are needed!

- Direct and indirect rebound effects of energy-saving measures exist, but they are difficult to research and tend to be overestimated.
- Distributional impacts, economic growth and lifestyle changes are important economic aspects of the Energiewende and have to be discussed together to avoid simplification.
- Only an effective mix of information, financial incentives, governing with taxes, but also directives and bans can lead to the required economic and social processes of change.

The strong decoupling of moderate economic growth (about 1% per year) from primary energy supply (reduction of about 50% by 2050) is at the core of Energiewende and will probably be its most important success factor.

If energy efficiency improvements are outweighed by increased energy consumption, the Energiewende would only be possible if the economy stagnated or even shrank. Moreover, decarbonization could only be achieved by a very large expansion of renewable energy installations. Both options are faced with many problems. Hence, both the discussion about the meaning and extent of rebound effects and about the feasibility and potential outcomes of sufficiency policy are relevant for the implementation of the Energiewende.

5.1. Rebound effects as argument for, not against, ambitious efficiency and sufficiency policy

Do we drive more if we have fuel-efficient cars and do we keep the lights on longer if we have energy-saving light bulbs? Do the energy savings of a passive house motivate the members of the household to fly more, so that the overall energy consumption of the household increases (so-called “backfiring”)? And if all of the above is the case, does it challenge the need for a much more progressive energy efficiency policy in Germany and the EU?

No! Rebound effects have so far carried a lot of weight due to an unambitious efficiency policy. Therefore, it is more important than ever to enact progressive energy-saving policies in combination with complementary sufficiency elements. While rebound effects may abate, some (but not all) of the efficiency improvements in appliances, vehicles and buildings, climate change and resource scarcity mean that every kilowatt hour saved counts. What then are the strategies and the policy mix to minimize unwanted rebounds? This is a complex question that requires a balanced answer.

Opponents of public intervention for energy efficiency argue that, due to the rebound effect, energy-efficiency measures cannot possibly make a rapid, substantial, cheap contribution to climate-change mitigation. On the other hand, critics of economic growth argue that energy and resource efficiency cannot lead to an absolute reduction of energy and resource consumption if economic growth continues. Hence, stagnation or degrowth is needed to achieve an absolute reduction of GHG emissions and other environmental impacts, which can be supported by historical analyses.

Does this mean that efforts to increase energy efficiency do not work at all, that they may even be harmful? Or does it rather imply that energy-efficiency policy has not yet been sufficiently ambitious?

What are rebounds?

The concept of rebound effects requires a precise definition and a solid empirical base. Otherwise, there is a risk that the term is used as a dummy for (often justified) criticism of economic growth, technological optimism and excessive consumption.

To begin with, it is important to differentiate between actual rebound effects (efficiency improvements as the cause of energy savings that are lower than expected) and a whole bundle of drivers of economic growth that is largely independent of efficiency improvements, including catching-up effects in consumption as well as comfort, luxury and lifestyle effects. In literature, three types of rebound effects are typically mentioned:

1. **Direct rebound effects** occur if more of the same energy service is consumed, i.e. more efficient buildings, appliances and vehicles are used less sparingly. The more efficient flat-screen TV runs longer. The fuel-efficient car is driven further and more frequently.
2. **Indirect rebound effects** result from the fact that energy cost savings are typically larger than the investment in energy efficiency. This increases the available income, which can be used for other things than energy. Consumers can purchase additional products and services, for which energy is needed again. Producers gain additional capital for investments into new products or an increase of production capacity. If these additional products do not replace other products, it means that overall production is increased, which requires more energy in total.
3. Both of the aforementioned microeconomic effects also contribute to **macroeconomic rebound effects**. Energy efficiency enhances overall productivity and contributes to higher economic growth, which in turn requires additional energy input – just like any form of increase in the productivity of labour and capital. Furthermore, macroeconomic effects arise from the influence of energy efficiency on the energy price: if energy consumption can be reduced significantly by implementing energy efficiency measures in several countries, the market price for energy will go down, which in turn increases demand (in other countries).

Rebound effects are not only damaging in respect of energy and resource consumption, but may also have socially useful co-benefits. These include: increased prosperity and wellbeing (particularly in developing countries and countries in transition), less energy poverty, increased competitiveness on cleantech markets, and job creation. Hence, it is important to differentiate between unwanted and wanted rebound effects, as long as they are connected to significant co-benefits of energy efficiency improvements.

How large are rebound effects in practice?

Measuring, or rather estimating, rebound-effects is difficult and contested. This is even the case for direct rebound effects because, as with energy savings themselves, they only become apparent when comparing to a hypothetical reference case, i.e. the consideration of what would have happened without an energy-efficiency measure.

The methods for analysis as well as the extent of indirect and macroeconomic rebound effects are subject to ongoing scientific debate. The International Energy Agency (IEA) estimates indirect rebound effects, which occur as money saved on energy is spent on additional goods and services, to be about 9%, which can be further reduced with appropriate policy interventions (IEA, 2012).

As a rule of thumb (and due to the lack of precise data) it can be assumed that about 25% of the energy savings that are connected to energy-efficiency improvements are "eaten up" by overall rebound effects (Thomas, 2012).

How can rebound effects be prevented?

Even though rebound effects are not as strong as frequently claimed, the fundamental principle still holds: "Do not waste any saved kilowatt hour!" A foresighted policy design should incorporate rebound effects by including a robust reduction of the targeted energy savings in the evaluation process. Furthermore, the energy-efficiency policy mix needs to include specific additional instruments that help to minimize rebounds. The following list gives an overview of possible elements of a policy mix that limits unwanted rebound effects.

System adjustments:

Direct:

- Binding energy-saving targets (EU 2011/2012)
- Energy-efficiency obligations for utilities (EU ESD 2012)
- Reduction of subsidies and internalizing ext. cost of nuclear/fossil fuels
- Caps, e.g. dynamic standards for fleet consumption of cars (EU)
- Bonus/malus regulations e.g. for cars ("feebates")
- More ambitious targets for EU ETS
- Progressive standards (e.g. ICT)
- Environmental taxes (incl. energy taxes)

Indirect:

- Structural change to less resource-intensive sectors (i.e. services)
- Promotion of renewable energy in coordination with energy efficiency
- "ProgRess" (German Resource Efficiency Programme)

Behavioural change:

- Sustainable consumption, promotion of common goods, education
- Reducing societal disparities (e.g. income, wealth, access)

Despite the positive effects of a policy package that supports energy-efficiency improvements and reduces rebound effects, the effects of the orientation towards growth maximization remain an unsolved socio-political challenge. Hence, it is crucial not only to research and consider rebound effects better, but also to create a scientific basis for policies to couple energy efficiency and sufficiency.

It is a task for policymakers to decide on targets, criteria and the implementation of a social "sufficiency strategy". Behavioural change of individuals is honourable and can persuade other people to follow, but is not sufficient to trigger a general shift towards sustainable production and consumption. However, individual sufficiency in combination with energy efficiency makes it easier to reach the social targets of the Energiewende.

Growth and affluence are the main systemic drivers of energy and resource consumption, which cannot be limited sufficiently without political intervention, i.e. a coupled efficiency and sufficiency policy. It is not constructive to engage in undifferentiated growth-bashing, as this does not further the understanding of complex interactions between efficiency improvements and sustainable patterns of production and consumption. The "right" amount of sustainable consumption and production and of political intervention can only be found in a long-term democratic discourse.

To conclude, energy efficiency remains crucial for reaching the targets of the Energiewende. Despite rebound effects it is still the quickest, largest and most economical option to mitigate climate change, secure energy supplies and support the green economy. An efficiency revolution is not the driver of unsustainable economic growth, but a necessary condition for a truly green economy. Comprehensive energy savings improve the ecological quality of economic development and structural change. They are the basis for the formation of more sustainable patterns of consumption and production.

5.2. A systems perspective on changes in growth, distribution and lifestyle

Discussing the economic aspects of fair distribution, growth and lifestyle separately from each other does not reflect their close interconnectedness and leads to many misjudgements in the context of a constructive sufficiency policy. Growth critics often neglect distributional aspects and do not answer the question: "How much is enough *for whom*?" For advocates of distributional justice the ecological "limits to growth" are often not a serious challenge, as long as the benefits from economic growth are used to balance income inequalities.

Impact on distribution

It gets you thinking, if sceptics of the Energiewende suddenly demand very loudly that "electricity needs to remain affordable!" Are the 'friends of coal and nuclear' actually advocates of the poor? The sceptics often forget to mention increased heating and fuel costs and do not elaborate on further drivers of electricity price hikes. Despite the populist nature of many sceptics' arguments, the problem of energy poverty is real and deserves attention.

In Germany, more and more people cannot afford to heat their apartments and houses adequately and can hardly pay their electricity bills. People who pay more than ten percent of their available income for energy count as "energy-poor" according to a definition from the UK. This applies to about 14% in Germany.

The main reasons for energy poverty are increasingly unequal distribution of incomes and of capital, as well as unequal opportunities for social participation. These trends cannot be reversed with even the most ambitious social energy policy. The Energiewende should not further intensify existing problems, so that they are not mistakenly presented as being causes of energy poverty.

Energy poverty is caused by low incomes, high energy prices, inefficient buildings, wasteful appliances and unconscious routines of everyday life. A combination of these factors may cause, in the worst case, electricity or gas supplies being cut off. Hundred thousands of people live temporarily without power in Germany.

Socio-political intervention alone is not enough to tackle this challenge. While it is necessary to adapt social transfer payments to rising energy prices, it is at the same time important to advise people locally about energy-efficient behaviour. For an average household the electricity and heat-saving potential of these adjustments alone is between 10 and 30 percent. Correct ventilation and keeping room temperatures at a moderate level can save several hundreds of Euros.

Energy advice to households can be connected to national support programmes for the purchase of energy-efficient appliances, which are implemented at the local level. Replacing the fridge can easily save 100 Euros per year, but the initial costs are too high for many energy-poor households.

Another area for intervention is the socially acceptable energy renovation of buildings. Poor people often live in poorly insulated buildings, which is partly due to the fact that the social welfare institutions only cover a low rent. The German city of Bielefeld covers higher rents too, if the building produces comparatively low heating costs. This is a cost-neutral approach for the city but increases the incentive for landlords to renovate dwellings.

There are numerous options to balance the consequences of high energy prices for poor people. Instead of populism and polemic about "affordable energy" it is more important to develop and implement target group-specific, energy-saving concepts. This creates acceptance among those in need, improves overall welfare and strengthens democracy. While poor people should use energy as efficiently as possible, it also needs to be pointed out that poor people already consume less electricity than the average. The more affluent citizens are, the more energy they consume.

Impact on economic growth

Ever since the oil crises in the 70s, potential limits to growth have been discussed. This discussion is coined by two opposing streams. The first one assumes that production and consumption can be increased almost without any limits. If this increase is halted at some point in the distant future, there will already be alternative "green" technologies. In order to develop these technologies economic growth is needed.

The second stream argues that the maximum limit for extracting finite resources and the capacity of sinks to absorb emissions (e.g. CO_2 into the atmosphere) are lower than often assumed. By developing and deploying new technologies the increase in resource extraction can at best be limited; but it cannot be reduced to a responsible level. Economic growth counteracts climate change mitigation efforts. What is needed are business models and lifestyles that conserve resources and nature.

Which of the two streams is right? The "green growth" perspective sounds very attractive and reassuring, but the proponents fail to explain compellingly how this can be achieved without additional public debt and increased resource consumption.

The interaction of consumers and producers drives a continuous increase in material production, more and more capital is invested and more and more products are bought. The standard of comfort increases every year: cars become heavier; TVs, refrigerators and dwellings larger; and even shrinking cities continuously open new construction and industrial areas. International airports in the vicinity have become the standard, passenger numbers increase, and new runways are planned and constructed. Roads are frequently congested, even although the capacity of many "Autobahnen" has been increased to six or even eight lanes. Many thousand kilometres of roads are still to be built, if everything goes according to plan.

There is still hope that technological and social innovations will in future enable an absolute decoupling of economic growth from environmental degradation. Renewed attention to the circular economy, the emergence of the sharing economy, and progress in the use of renewable materials and energy are first steps towards a comprehensive ecological transformation. Its technological feasibility for a whole economy has so far only been demonstrated in scenarios.

Reduce economic growth dependence

Indeed, it is not a straightforward task to steer economic growth in a way that implies absolute decoupling from resource consumption. Just imagine: municipalities and regions would no longer offer space for new dwellings, industrial parks and roads; at Volkswagen the number of cars produced would stagnate [not such an unlikely scenario any longer as at the time of revising this text the Volkswagen scandal around manipulated diesel engines unfolds]; the port of Hamburg would dismiss expansion plans and freeze the number of containers it can handle. What would happen? The economic crisis in 2008/09 gave a first taste of potential economic impacts. Without an alternative concept, unemployment would rise if the economy stagnates. The social welfare system would be at stake. Social unrest would become more likely.

Pushing the topic aside is not a solution as the "growth-question" is not only a challenge of the Energiewende but of all sustainability policy. If it remains unaddressed it will be nearly impossible to establish a set of rules that limits the wasteful use of resources such as zinc, indium, oil, natural gas etc. Requirements that may slow down growth are, so far, often off-limits. Abandoning privileges for company cars, for example, may decrease the sales of large (often German) diesel cars. The same holds true for strict CO_2 emission limits. Even the modest ticket tax on air travel is criticized, because it may slow down the growth of airports; and, of course, taxing kerosene would dampen growth, too. For similar reasons most resources are untaxed, the number of CO_2 emission allowances is too high to result in an appropriate carbon price, there are no stricter regulations for more ethical husbandry, there is no serious tax on financial transactions, the regulation of the financial sector is not as tough as it should be, and so forth. Even a general speed limit on German motorways, a measure that is connected to multiple benefits, fails because it may hamper the growth of car manufacturers or drastically change their model ranges.

Avoid a race to the bottom

The unlimited addiction to economic growth can trigger a severe downward trend. Companies want to make as much money as possible. They do not typically shift round production only to do good for future generations. If ecological concepts make production more expensive this may constitute a competitive disadvantage. Companies on the stock markets will consider climate change and the limited nature of resources only if they pay off. The steel industry has, for example, invested heavily in efficient technology, but with a payback horizon of two to three years. Any investment beyond that threshold is only made if it is required by law, since investors are typically unwilling to wait any longer for their returns.

Why should an energy utility support its customers in improving their energy efficiency if their competitors are not doing it? If, however, there is a general requirement to do so, managers have a much better standing in relation to investors.

Even whole cities are in a comparable situation. There are few mayors who dare to restrict motorized traffic in their cities. One criticism they face is that people from the surrounding regions will go to the neighbouring city to shop, which will be bad for the retail sector, bad for the local economy, bad for employment. Similar arguments are brought forward to develop green space into business areas or dwellings. This is a strategy to secure the municipal tax base, which is made up of the local business tax and the municipal share of the income tax. The underlying thought is: if we do not offer new housing opportunities and easily accessible shopping opportunities, the neighbouring municipality will do it, and they already attract people with low taxes and the dumping of prices for construction land.

This destructive competition drives cities and municipalities further into the construction and expansion of roads and airports. Decision-makers are quite aware that the increase in aviation accelerates global warming and that whole districts are polluted with noise. The perceived risk of missing out on state-of-the-art infrastructure and developments seems to be greater, however. It is a race that most of the participants can only lose. Consultations and agreements between municipalities are one way to avoid destructive competition. Another way is to change the rules of the game, i.e. changes in the national policy framework.

Support Corporate Social Responsibility

Finally, countries too can engage in destructive competition. Economists talk about a "race to the bottom" when social, environmental and labour standards are lowered further and further in global competition. The news is full of reports about companies with astronomic value on the stock market and making minimal tax payments. In the search for tax havens these companies play off countries against each other.

More and more managers have recognized the race to the bottom; and off-the-record they demand a stricter regulatory framework to make progress in respect of various sustainability challenges. The United Nations and the consultancy Accenture surveyed 1 000 CEOs from 100 countries and surprisingly found that eight in ten wish for more radical requirements from policy (United Nations, 2015). Government intervention at international, national and local level is crucial to move from sporadic improvements to a collective transformation process towards sustainability.

Combine the ‘carrot and the stick’ policies

An honest assessment of all relevant socio-economic aspects will come to the conclusion that the promise of green energy technologies alone is certainly not enough. More than 40 years ago the UN Conference on the Human Environment established the guiding concept of “qualitative growth”. In the decades since then, absolute resource and energy consumption in industrial countries could not be reduced. Technology optimists may still oppose and claim that, in the future, electric vehicles will become the standard and aircraft will become more efficient and mainly run on bio fuels. Buildings will no longer consume energy but will generate it.

Yes, much will become technically feasible. Yet, if technological progress remains the only substantial progress, not much will change. Aircraft will become more efficient, but this will remain without effect if air travel also continues to increase. The depth of this challenge becomes apparent when considering that even the avant-garde of the environmental movement can hardly resist long-distance flights to India or New Zealand; due to a notorious lack of time, tumble driers are an unfortunate necessity.

For all sectors of the economy and areas of consumption it is essential to consider that renewable energy and energy efficiency are only sustainable solutions if growth in luxury, size and comfort can be kept within limits. Hence, it remains an open question whether and to what degree the absolute decoupling of economic growth from environmental degradation and resource consumption is feasible in industrialized countries like Germany. What is certain is that it will not be realized through lifestyle changes alone; a policy framework that is both demanding and supportive is required. The most important decisions contributing to more sustainability can be prepared and supported from the bottom up – but they will only reach the whole society if they can also be politically enforced.

Binding sustainability targets

The findings above imply that it is unavoidable to introduce a form of “obligatory sustainability” including regulated sufficiency. This is particularly the case in product areas in which the collective effects of unsustainable production and consumption detract from the quality of life for a majority of people, including rapid land consumption and the unnecessary waste of energy in buildings, vehicles, and appliances. Further directives and regulations will have to set the frame in which free consumption and production decisions can be made. The issue is about limits for horse power and vehicle weight, about the consumption of household appliances, fertilizers, pesticides, antibiotics, residential and commercial areas, roads and runways and so on. Requirements are needed to guide the Energiewende, if the targeted (absolute) decoupling of economic growth from energy consumption is to be achieved.

Furthermore, general requirements have the advantage of being fair. A speed limit, for example, is an obligation for behaviour of solidarity. It applies to all without exemptions. If on the other hand fuel prices would increase further – no matter whether due to scarcity or additional taxes – poor people would no longer be able to drive as much, while the wealthy would not be equally affected. Another measure with equal impact on all is stopping the expansion of the road network.

This approach has already been partly implemented in Germany and the EU. Until end of 2011, for example, the topmost floor or the ceiling above it had to be (re-) equipped with thermal insulation. The EU Eco-Design Directive stipulates that, as of 2012, only fridges with the energy label A+ or better can be sold. The same directive states that the stand-by consumption of electric appliances is now limited to half a Watt and the maximum power of a vacuum cleaner to 900 Watt. Consumers are supported in their deciding between cheap products with high life-time costs and more economical ones. Sufficiency-promoting consumption decisions are encouraged and wasteful behaviour discouraged. This includes the removal of asocial privileges.

Technological innovation and modest economic activity and lifestyle are complementary. Only the effective mix of education, information, financial incentives, steering with taxes, but also directives and bans can lead to the required economic and social processes of change.

6. Governing the Energiewende? A Joint Task

- It is a sustained delusion of energy policy that efficiency improvements can be realized by the market and sovereign consumers alone.
- Significant barriers and market failures imply that there is unfair competition between energy supply (megawatts) and savings through efficiency technologies ("negawatts").
- The dynamic development of the Energiewende has so far been enabled by activities of decentralized actors such as municipalities, regional networks, energy cooperatives

6.1. Energy efficiency pays for itself – or does it?

In principle, energy savings and energy efficiency are the quickest, most comprehensive and most economical way to mitigate climate change and save resources. In order to actually implement the "efficiency revolution" and shift to more sufficient consumption of energy services, several methodological and institutional challenges have to be tackled by energy policy. It requires courageous, forward-looking and innovative politicians – a precondition that is not always fulfilled in reality. In contrast, there is still the tendency to prove the vast energy-saving potential in scenarios, but to treat even official energy-saving targets rather as symbolic policy, as a placebo for the worried public.

The placebo of energy policy

So what exactly is an energy-political placebo? It describes a situation in which both international and national scenarios demonstrate that about 50% of the required climate-change mitigation can (and must) be achieved by increased energy efficiency, but no far-reaching measures for implementation are taken. Scenarios promise a cure but the virus of exceedingly high energy consumption is still spreading.

This is the basis for symbolic policy. Whoever openly rejects the promise of energy-efficiency potentials is fighting a lost battle. On the other, whoever wants to implement relevant and target-group-specific policy measures that go beyond appeals to consumer responsibility and information campaigns is also fighting a losing battle.

It is a sustained delusion of energy policy that efficiency improvements – as everybody wants them – can be realized by the market and sovereign consumers alone. The market for energy services requires regulation and interventions to that it can function. On a free market the perspective of suppliers does not coincide with the perspective of consumers. As long as you make your money from the sales of energy there is no interest in increased efficiency on the demand side. Only if the framework conditions are adapted in a way that the supply of energy services results both in a cost digression for the consumer and appropriate profits for the supplier, will there be a market for energy efficiency. This type of incentive-regulation is practised in several countries but not yet in Germany.

The latest National Energy Efficiency Action Plan from 2014 still builds heavily on voluntary measures and information, and includes very few new interventions that strengthen economic incentives for energy efficiency and tighten the regulatory frame. According to the German NGO *Deutsche Umwelthilfe,* the Action Plan will only achieve one third of the 7% energy savings that are the official government target (DUH, 2014). The reservations of German politicians to actively govern energy efficiency are difficult to grasp – not only because more energy efficiency is a precondition for the success of the Energiewende, but also because of the large macroeconomic benefits of deploying energy efficient technology (see section 4.3).

Taking energy-efficiency potentials and barriers to implementation seriously

Energy-saving policy can be successful if two strategies are followed. Firstly, the misuse of merely symbolic policy should be avoided. Secondly, evidence should be provided that even highly economical energy-efficiency technologies and solutions are not implemented due to a number of barriers.

The starting point of the debate is that national and global energy systems are extremely inefficient energy transformation machines. From 100% primary energy supply, only about a third goes into the use of energy services. The rest is lost on the way from primary energy to useful energy and further to the respective energy service. Some energy services stick out in their efficiency of utilizing final energy. Passive houses use less than 15 kWh/m^2 for heating, which is only 10% of the average heating demand in the German building stock. LED light bulbs with the same lighting performance as 60W incandescent bulbs require only about 10W.

If the inefficient energy transformation machine replaces fossil fuels with renewable energy, it is still – figuratively speaking – a bathtub that is filled without a stopper. Hence, the "first law" of the Energiewende should read: *Avoid losses first and then cover the remaining energy demand as quickly and comprehensively as possible with renewable energy*.

Within ten years GHG emissions can be reduced by more than 20% in addition to the ongoing trend of endogenous efficiency improvements, creating a dividend for companies, consumers and the whole economy. By 2050 energy consumption in the EU can be reduced by 57% against the current trend, including energy-cost savings of EUR 500 billion per year. In this scenario primary energy supply and GHG emissions are even decreased by two thirds through reductions in final energy consumption and savings in the power generation system (Bossmann, Eichhammer, & Elsland, 2012).

The efficient use of electricity in the three sectors – industry, households as well as small business, trade and services – accounts for a third of the total economic potential for reducing GHG emissions by improving energy efficiency (see Figure 11). The most economical reductions can be achieved in the areas of ventilation, air conditioning, ICT, compressed air, pumps, lighting and refrigeration. Furthermore, energy efficiency in production (mainly process heat) and in buildings (mainly floor heating) can each provide a third of the reductions.

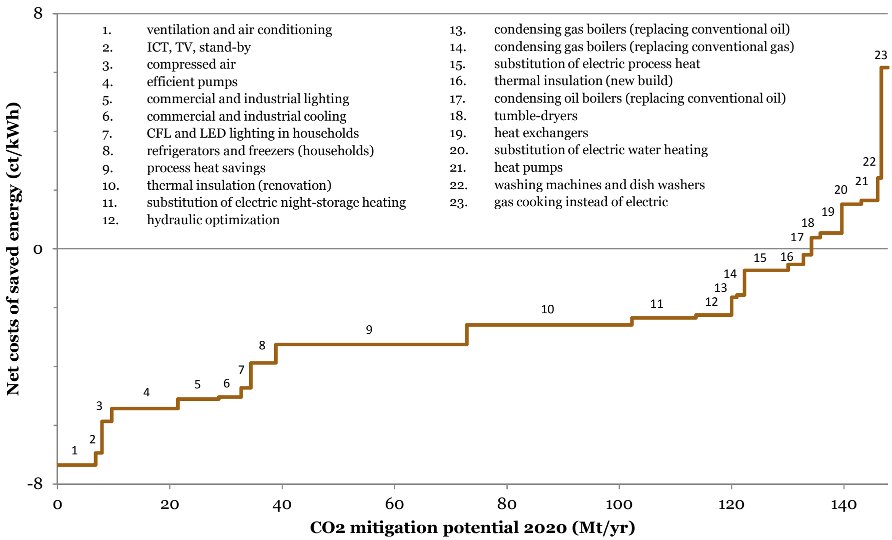

Figure 11:
Theoretical cost-potential curve of GHG emissions reduction through energy savings (based on Berlo et al., 2011)

The figure illustrates the economic potential assuming the ideal of a level playing field, on which efficiency technology and energy supply are interchangeable and, thus, freely compete with each other. A certain energy service (e.g. space heating, force, lighting, communication) can be supplied with low energy input at maximum efficiency and vice versa. For the economy and consumers alike it is important that energy services are provided at minimum cost (including external costs). The costs of efficiency technologies and energy supply are calculated in the same way, which means that the respective technical life-span is taken into consideration and the same interest rate is used.

Actual energy markets are fundamentally different from this level playing field. Significant barriers and market failures imply that there is no free competition between energy supply (megawatts) and energy savings through efficiency technologies ("negawatts"). The multitude of barriers is the main reason that an account of economical potentials for energy efficiency exists at all. They keep the market from tapping into the potentials. Some of the most significant barriers are listed below:

- Continuous subsidies to energy supply as external costs are not sufficiently internalized
- Little consideration of life-cycle costs/much attention to investment costs (e.g. of building plans or refrigerators)
- Extremely short payback periods (mainly) in industry (two to three years)
- High transaction and search costs due to an enormous variety of products and suppliers
- Principal agent dilemma (e.g. split incentives in all rental buildings)

These and further technology, target-group and sector-specific barriers are widely recognized. If they are not removed systematically by an active efficiency policy, the enormous flow of capital into the inefficient expansion of energy supply will continue further. This would be an unnecessary burden on the environment and drive up overall costs for the provision of energy services.

The current instrument mix of German energy-efficiency policy is indeed partially targeted at removing some particular barriers. The policy still has large holes in respect of power-saving appliances and equipment, non-residential buildings, industry and transport. Even the German government admits that the current mix is not enough to achieve the annual energy savings of 1.5%, which are required by the EU Energy Efficiency Directive. This is despite the fact that the EU target is even lower than Germany's own Energiewende target. What is required to tap into the efficiency potentials and reach the targets?

Overcoming barriers with ambitious, targeted policy instruments

In order to remove the multitude of barriers, a well-designed mix of policy instruments is needed, including:

- Efficiency directives that protect consumers from wasteful buildings, appliances and equipment. Two examples are the EU Eco-Design Directive and the German Energy Savings Ordinance (for buildings).
- Support programmes that give incentives to switch to more efficient alternatives. An example is the programme of the German development bank KfW to support the energy-efficient construction and refurbishment of residential buildings.
- Energy consulting and information requirements. Examples are energy performance certificates for buildings, energy labels on appliances, but also professional education and on-the-job training for planners, craftspeople and sales people.

A combination of more and better regulation with a public fund for energy savings has the potential to close some of the holes in the current policy mix and finance the necessary support programmes (see Figure 12). The suggested national energy savings fund should be seen as a central independent institution for the coordination of energy efficiency. It can be financed from revenues of auctioning CO_2 emission allowances, from a surcharge on the price of final energy, or alternatively an adaptation of energy taxes and the phase-out of environmentally harmful subsidies.

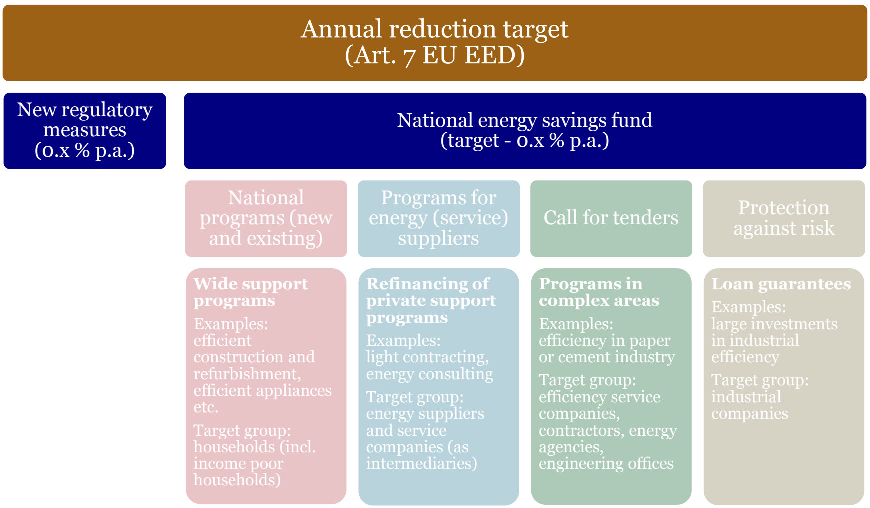

Figure 12:
Possible combination of regulation and a public energy fund to implement Art.7 of the EU Energy Efficiency Directive (based on Pehnt & Brischke, 2013)

6.2. Polycentric governance structures emerge and should be strengthened

The Energiewende is a complex process that cannot be designed and implemented by the national government in Berlin alone. There is a great opportunity in strengthening the role of German states, regions and municipalities in the Energiewende process and giving them the autonomy to act independently. In a multilevel political system the lower levels often have a catalyzing and pioneering function. In many areas of Germany they have already become the drivers of a highly dynamic development. The success of the "federal Energiewende" depends on a strong collaborative effort, which is characterized by "polycentric governance".

Polycentric governance is understood as being the delegation of responsibility to many centres of decision-making that formally are independent of each other but in practice often interrelated. The concept was coined by economist and Nobel laureate Elinor Ostrom. One of her key ideas was that it is difficult, if not impossible, to find a single governance model that can deal with the multitude of specific local challenges. Principles for the efficient design of local institutions are more successful if they are based on polycentric governance theory. Delegating decisions to the local level helps to engage citizens and authorities more in governing important social and environmental challenges. In other words, self-organization is key, even although it does not appear in standard economic theory. Ten years of experience with the Energiewende show that many projects that are implemented on the ground go far beyond what is supported by the state and "rational" on the market.

Polycentric governance acknowledges the creative and constructive potential of NGOs, voluntary work initiatives and other non-market organizations. It supports their work as a necessary and conducive part of the overall Energiewende process.

There are numerous examples of the importance of polycentric dynamics in the area of energy. Regional energy networks, bio-energy villages, 100% renewable municipalities, newly founded energy cooperatives, citizens' financing of renewable power plants and the like all illustrate that spatially limited development can act as transformative nucleus and push forward the ideas of the Energiewende.

Polycentric governance still means that the federal government retains responsibility for the Energiewende process, including ambitious target-setting, suitable framework conditions, and the balancing of conflicting interests regarding energy policy (between industry, civil society, academia, between federal states and municipalities).

Re-socialization: prosumers, energy cooperatives, 100% renewable municipalities, regional networks

The formation of the first "transformative nuclei" started in Germany as far back as 40 years ago. Throughout the whole country local and regional groups were founded in the vicinity of planned NPPs. Very early on, these groups discussed alternatives to an energy supply system that is based mainly on coal, nuclear power and oil.

Alongside this social development, the technology for decentral power generation was also further developed. Substantial improvements were achieved in respect of wind power, photovoltaics and biogas, but also small-scale CHP and energy savings in applications. Increasing production of these systems triggered economies of scale and improved their economic performance. Starting in the early 90s the first feed-in law and later the EEG were the major drivers of this process. The laws were enacted against massive resistance by the well-organized energy industry in Germany. The share of power from renewable sources in overall electricity generation increased from 7% in 2000 to about 30% today (AG Energiebilanzen, 2015).

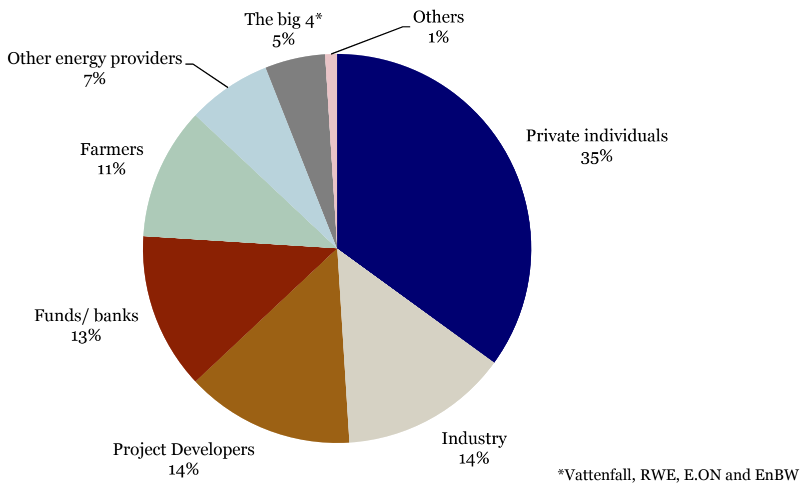

Figure 13:
Diversity of actors in the ownership of renewable power generation capacity 2012 (source: Renewable Energies Agency 2012)

This dynamic development was not driven by large energy corporations but by a wide variety of actors (see Figure 13). Many small-scale investors were irritated by the global financial crisis of 2008/09 and stock market crashes and started looking for new investment opportunities, which they found in renewable energy projects or other ethical investments. Privately owned wind farms and solar parks became sought-after investments and more and more citizens grouped in energy cooperatives to finance and implement power plants running on renewable energy.

The nuclear catastrophe in Fukushima in 2011 gave additional momentum to such projects and initiatives. Within two years, more than 130 rural districts, municipalities, regional networks and cities grouped together to meet their energy demands to 100% with renewable sources. The number of energy cooperatives has increased to nearly 1 000 as of today (Müller & Holstenkamp, 2015).

The term "prosumer" is characteristic of this social trend towards re-socialization of energy production and use based on modern technology. Prosumers are today's modern energy users who produce the electricity they consume themselves, e.g. with a rooftop PV system, a small-scale CHP or a share in a wind farm.

CO_2 free cities are more liveable cities

There are 13 cities in Germany with more than half a million inhabitants and about 80 cities with more than one hundred thousand inhabitants. Together with several hundred cities with between 20 000 and 100 000 inhabitants they are the centres for development and application of the transformation challenge posed by the Energiewende. The physical manifestation of the Energiewende occurs in municipalities. Thus, municipalities should engage pro-actively in local implementation and with as much power as possible. The national government and the states have the task of demanding this engagement and supporting it.

Germany's urban areas are where a majority of Germans work, live and spend their leisure time. These are all functions of liveable cities for which people consume various energy and mobility services. In order to provide these services in a positive, smoothly running, sustainable and climate-friendly way, deep structural change is required. Cities only have few decades to go through this challenging transformation process, which entails the decarbonization of virtually all activities in cities. The principle to follow is similar to the strategy for the whole Energiewende: Tap into the energy-saving potentials in respect of electricity and space heating first, and cover the remaining energy demand in the least environmentally harmful way.

Liveable cities will have to abolish today's dominating separation of areas for living, working and leisure. This is a major strategy to avoid congestion due to large streams of commuters, transport related energy consumption, as well as CO_2 emissions and not least air pollution. If city planning is oriented towards sustainable lifestyles, cities will become more liveable, as dwellings and workplaces are redesigned, additional parks and green areas are created and the amount of air pollution and noise emissions can be reduced.

As the potential to utilize renewable energy sources in cities is limited, they should start cooperation with the urban hinterland. This kind of urban-rural link is particularly beneficial in respect of the utilization of bio energy and wind power. Utility companies or municipalities themselves can take shares in wind parks or bio gas plants, which will be built in surrounding rural areas with the respective potentials. Moreover, there might be the potential to produce wood pellets which can be used as a heat source for small district heating grids or large municipal buildings such as schools or administrations. Someday the “Kurort” (spa town) sign as you enter cities might be retrofitted or replaced with a label “CO_2 neutral”.

Re-municipalization: creating added value for citizens instead of privatizing profits

The majority of about 14 000 concessions in the electricity sector have expired in the last five years. Until the end of 2010 there were about 200 municipal acquisitions of transmission grids and more than 70 new foundations of municipal utility companies. Most newly founded utilities strive to become active along the whole value chain, including eco-efficient services (see Figure 14). The rapid development of decentral power generation technology based on renewable energy sources has created the opportunity to organize power supply in small decentral units, guarantee a high degree of security of supplies, and at the same time achieve further targets such as climate change mitigation, economic sustainability and social responsibility (Berlo & Wagner, 2013a, 2013b).

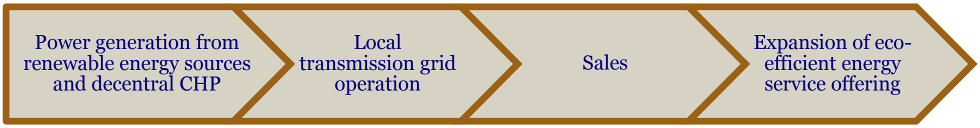

Figure 14:
By expanding their value chains, municipal utility companies improve their economic standing (Berlo & Wagner, 2013b)

Another argument for the re-municipalization of local energy supplies is the electricity price hike in recent years, which has triggered an increasing demand for customer and sector-specific energy-saving services. This an interesting field for utility companies that have – due to their well-developed local ties and local knowledge – a competitive advantage. Moreover, highly developed ICT offers new ways of bi-directional steering and regulation of power generation, distribution and consumption, which further supports the trend towards decentralization and re-municipalization.

Disentanglement of power: interplay of social and technological innovation

The development of photovoltaic technology departed from a niche application in space research and is now a commodity that can be used by everybody. The Renewable Energy Sources Act triggered demand which in turn enabled substantial investment into product and process innovation. As a result, the power generation costs of photovoltaics fell below the purchase price, the so-called “grid parity”. As of today, more than one million photovoltaic systems not only generate about 7% of the German electricity demand but also contribute to the restructuring of the overall energy system. Power no longer comes exclusively from large thermal power plants owned by oligopolists, but also from the roof of one’s own house, of the school, of the apartment block, of the farmer’s shed etc.

When the sun does not shine or the wind does not blow the power grids are still needed to secure supplies. Hence, existing regulation needs to be further developed so that decentral users of the power grids participate adequately in the costs of the grids and security of supply.

The technological revolution in renewable energy technology, which besides photovoltaics also includes wind power and bio gas, was not without opposition. The transformation towards a climate-responsible society is a challenge that does not only require a shift in technology but also major overthrows in power structures and decision making structures. It is easy to understand that those who lose power and economic influence during the change process oppose the transformation. In return it is crucial to win a broad majority for the Energiewende and to achieve the integration of various involved actors, in order to accomplish a climate-neutral society in a democratic country.

7. The German Energiewende in an international context

- The trend of global energy economy indicators remains alarming for most world regions.
- The steep cost-digression of renewable-energy technology, a favourable investment climate and numerous co-benefits of transforming energy systems are strong drivers of a global Energiewende.
- Despite the specific setting of the Energiewende in Germany, there are some lessons to be learnt from it, including the importance of a sound science base and ambitious quantitative targets, the key role of energy savings, the potential for large macroeconomic benefits, and not least the crucial role of a decentral bottom-up movement.

The Energiewende in Germany is still in its infancy. The dynamic development that has taken place in the power generation sector needs to be maintained and spread to the other important areas of heat, transport and, not least, efficiency. The Energiewende has to accelerate to meet its ambitious target.

While many countries in Europe and beyond have started to act on climate-change mitigation and on transitioning their energy systems, overall global trends remain alarming. Driven by income growth (and to a lesser extent population growth) global CO_2 emissions continue to rise even further, and other key drivers of emissions, namely the energy intensity of the economy and the carbon intensity of the energy mix, have worsened in several regions of the world (Mundaca T., Markandya, & Nørgaard, 2013).

Despite these trends, there are various factors that favour a global Energiewende, including the price-drop in low-carbon technology, the favourable conditions for financing investments into these technologies, and not least the enormous co-benefits besides climate-change mitigation. These factors, together with the ever more visible impacts of climate change, have started to change the perception that mitigation is a burden. The shift from burden-sharing to benefit-sharing is crucial for the prospects of an effective global climate regime. While a comprehensive Energiewende does entail drastic changes to the energy-economy, it is the only way to go, a way that is beneficial not least from an economic perspective.

6.3. Steep cost digression in the cost of low-carbon technology

In power generation, global capacity additions of clean energy technology overtook those of conventional sources for the first time in 2013, and further dynamic development is forecasted. This means that the transformation of the power system is taking place not only in Germany, but in many world regions. Countries like Germany or Denmark already face some of the challenges related to the transition, and these will have to be tackled by many other countries in the medium-term.

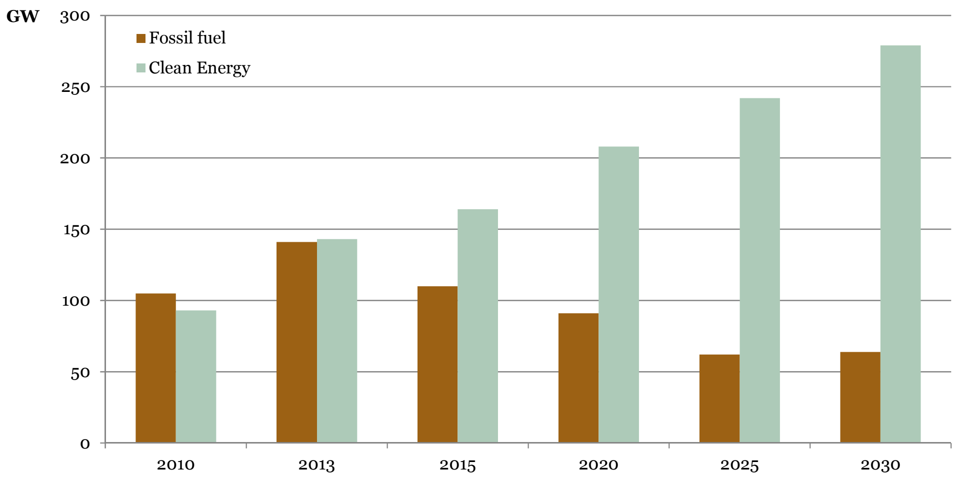

Figure 15:
Power generation capacity additions and forecast 2015-2030 (source: Bloomberg NEF)

The largest driver of the rapid increase in capacity additions is the steep (and to some extent unexpected) cost digression of renewable-energy technology. In Germany the feed-in tariff for power from photovoltaics dropped about 80% from 43 ct/kWh in 2005 to 8.7 ct/kWh in 2015. The cost of photovoltaic power generation is expected to decrease further to 4-6 ct/kWh in Europe in 2025, reaching 2-4 ct/kWh in 2050 (Fraunhofer ISE & Agora Energiewende, 2015). Similar but less drastic developments could be observed for the cost of wind power. In particular on-shore wind power in good locations is already cost-competitive with conventional power plants. The competitiveness of renewable energy will further improve when national and international carbon-pricing regimes are tightened and start to send significant price signals. Furthermore, it is important to remember that there are many low-cost energy-efficiency options, which are even cheaper than generating power – be it from renewable energy sources or fossil fuels (see Figure 16).

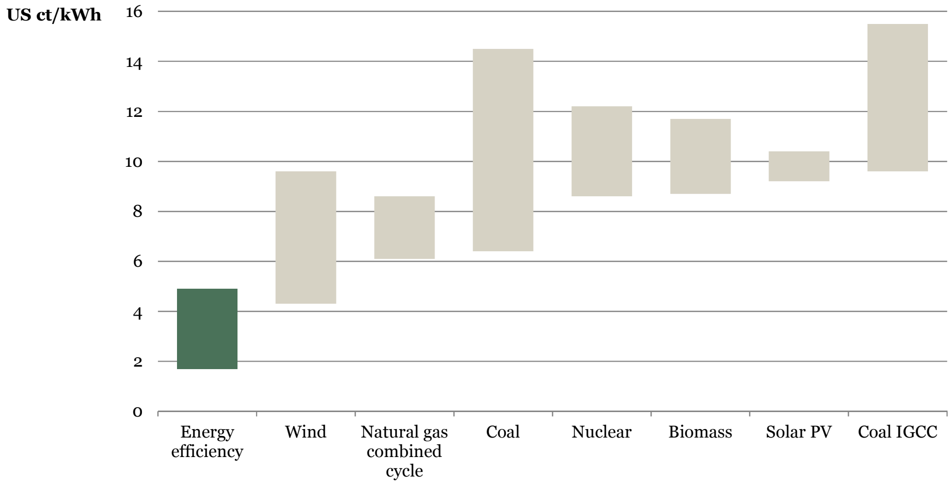

Figure 16:
Levelized cost ranges of electricity generation and achieved energy savings in the US (Molina, 2014)

6.4. Favourable conditions for investment in the Energiewende

Global investment in renewable energy and energy-efficiency technology have risen enormously over the last decade and due to falling technology costs these investments lead to more and more renewable energy and energy savings on a per-unit basis. Currently there are at least three large drivers that favour further investment into the transition of energy systems around the world.

Firstly, oil and gas prices are very low. This means the incentives to invest in new and more risky exploration projects are also low. At the same time, low-carbon technology investment becomes less and less risky from an economic perspective.

Secondly, financial markets are in an prolonged period of low interest rates. This makes it comparably more attractive to invest in real capital such as renewable energy, energy efficiency and the infrastructure involved, rather than in financial products.

Thirdly, in many countries investment rates are low and increased investment in low-carbon technology and infrastructure has the potential to improve growth prospects, in this case green growth. Early movers in specific renewable-energy technology, energy efficiency, sustainable mobility and so forth have the opportunity to take larger shares of growing markets of the future.

6.5. The co-benefits of a global Energiewende

Without co-benefits neither the German nor any Energiewende can be successful (see section 4.7). For various contexts it is even debatable whether decarbonization is the main benefit. It is, however, the most salient and overarching social challenge, so it is fair to focus the discussion on it.

International co-benefits from climate change mitigation have recently been studied by various actors and from many different perspectives. The Global Commission on the Energy and Climate (GCEC) has tweaked the well-known marginal abatement cost curve (see for example Figure 11) in their report "Better Growth Better Climate: The New Climate Economy Report" and presented a marginal abatement benefits curve instead (New Climate Economy, 2014). This curve includes the monetarized benefits from less local air pollution, rural development benefits related to land use and forestry, benefits from reduced fossil fuel price volatility and benefits from a modal shift in transport.

The International Monetary Fund (IMF) took another approach in their study on global energy subsidies (Coady, Parry, Sears, & Shang, 2015). In their definition of subsidies the non-internalization of external costs was included. In other words, if carbon-energy taxes do not reflect true social costs (including the cost of climate change, air pollution and other environmental damage), the difference between the tax level and the true costs is considered a subsidy. With this definition the IMF came to the impressive finding that a phase-out of all subsidies would result in additional government revenues of USD 2.9 trillion in 2015.

While bundling and monetizing co-benefits of climate-change mitigation is a tricky exercise that rests on many simplifications and assumptions, which is acknowledged both by the GCEC and the IMF, there is also the option to look at impacts one by one without translating everything into the language of money. In recent research on the impacts of the carbon reduction pledges that countries submitted in advance of the climate conference COP21 in Paris this year, the potential for co-benefits in the EU, the US and China was mapped. The results illustrate impressively that the co-benefits of decarbonization are not only about money (e.g. savings from reduced fossil fuel imports), but also about providing hundreds of thousands of jobs in an meaningful sector as well as preventing hundreds of thousands of premature deaths (see Table 3).

Table 3:
Selected co-benefits of a 100% renewable energy trajectory, compatible with the 2 degrees target, as compared to the current policies trajectory (source: Höhne et al., 2015)

Co-benefit	EU	US	China	Total
Cost savings from reduced fossil fuel imports (billion per year)	USD 170	USD 160	USD 190	USD 520
Premature deaths from excessive ambient exposure to fine particulate matter prevented	46 000	27 000	1 200 000	1 300 000
Creation of additional green jobs in wind, solar and hydro energy	430 000	650 000	1 900 000	3 000 000

6.6. Knowledge gained from the German Energiewende

"What can we learn from them [Germany]? We can't transplant their desire to reject nuclear power. We can't appropriate their experience of two great nation-changing projects—rebuilding their country when it seemed impossible, 70 years ago, and reunifying their country when it seemed forever divided, 25 years ago. But we can be inspired to think that the Energiewende might be possible for other countries too." (Kunzig, 2015)

The German Energiewende cannot be and should not be the blueprint for energy transition in other countries. Firstly, the Energiewende is not yet advanced enough to serve as a reliable role model. Secondly, the socio-economic, political and geographic conditions are different from country to country. Thirdly, the ambition should not be to copy Germany, but to avoid its mistakes and perform better.

Despite these disclaimers, there are certainly many specific insights from the Energiewende that can inform and inspire engagement in energy transition elsewhere:

- Sound science about the necessity and technical feasibility of the Energiewende helped to form both political and social consensus about its desirability.
- An explicit and ambitious target system serves as the reference base for the evaluation of progress and the continuous adjustment of policy interventions.
- Despite the doubtless need for electrification of the energy system, the heat and transport sectors are crucial areas for comprehensive energy transition, which is often forgotten in the German case.
- The Energiewende is simply not feasible without realizing substantial energy savings, for which there are three main drivers, namely energy-efficient technology, structural change of the economy, and sufficiency in the consumption of energy services.
- The Energiewende is beneficial from a macroeconomic perspective. Current expenses are easily outweighed by future returns, and the co-benefits today are

in many cases also the main driving force behind the engagement in the Energiewende.

- The successful management of the Energiewende depends on many actors at various levels and cannot be mastered by national politicians alone. Actions taken by citizens, municipalities, regions, various types of networks, cooperatives and clusters are key for the actual implementation of grand plans.

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