WORLD ENERGY COUNCIL

World Energy Perspectives

Natural Gas Perspectives | 2017

ABOUT THE WORLD ENERGY COUNCIL

The World Energy Council is the principal impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.

Formed in 1923, the Council is the UN-accredited global energy body, representing the entire energy spectrum, with over 3,000 member organisations in over 90 countries, drawn from governments, private and state corporations, academia, NGOs and energy stakeholders. We inform global, regional and national energy strategies by hosting high-level events including the World Energy Congress and publishing authoritative studies, and work through our extensive member network to facilitate the world's energy policy dialogue.
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ABOUT THIS REPORT

The World Energy Perspectives report on Natural Gas is part of a series of reports based on expert insights from the World Energy Council's network of energy leaders and practitioners. This series provides a bottom-up assessment of the key issues.

This first Natural Gas report, produced in collaboration with the Global Gas Centre (GGC), looks at the long term future where there needs to be further investment and innovation.

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AN INITIAL FOCUS ON THE FUTURE OF GAS IN THE GRAND ENERGY TRANSITION DERIVED FROM THE 2016 WORLD ENERGY SCENARIOS

During the World Energy Congress in Istanbul in October 2016, the World Energy Council (the Council) presented three scenarios, developed in collaboration with Accenture Strategy and the Paul Scherrer Institute. In 2017, and with the support of the Global Gas Centre (GGC), the Council elected to analyse in greater detail, the place of gas in the three scenarios, identifying the central uncertainties affecting the role of gas and specifying the challenges facing the gas industry.

KEY FINDINGS

1 **Gas is expected to** provide a cleaner bridge to a renewable energy future: it is the only fossil energy source which is projected to grow to 2050 during The Grand Transition – a period when demand for either coal and oil will peak. However, the long-term future for gas is less secure: there needs to be further investment and innovation to ensure that natural gas holds an essential place in the global energy mix to 2060, but beware of stranded resources with the trend to carbon pricing.

2 **Over the coming decades,** the pattern of demand and pace of growth will reflect significant diversity in regional market dynamics with peak demand in some regions and continued growth in some others. The geographical centre of the global gas market will shift to Asia, where demand is expected to grow rapidly, providing new national policy frameworks and policy reforms are forthcoming and successfully implemented in key countries, such as China and India. Meanwhile, demand growth in Europe and North America is expected to stagnate or even decrease.

3 **In the near-medium term** the role of gas will be closely linked with developments in the power. Global electricity demand is expected to double by 2060 and the power sector offers the highest growth potential for natural gas. An increasing market share in power generation will be the main driver of gas demand growth in the medium term but gas faces tough competition from other energy sources, notable renewables, and the scope for growth will depend on key policy decisions by governments and regulators and presents highest uncertainty.

4 **There is significant downside** risk for gas if it doesn't succeed to innovate and develop new technologies making it "cleaner" and increasingly "renewable". All of the Council's scenarios fail to secure global warming below 2 degrees and further moves to reduce the use of fossil fuels in the energy mix would impact gas. The share of gas in power generation would especially be at risk in the absence of commercially viable Carbon Capture and Storage (CCS) and the economic viability of new technologies like biogas or Power to Gas is a challenge for gas evolving towards a renewable energy source.

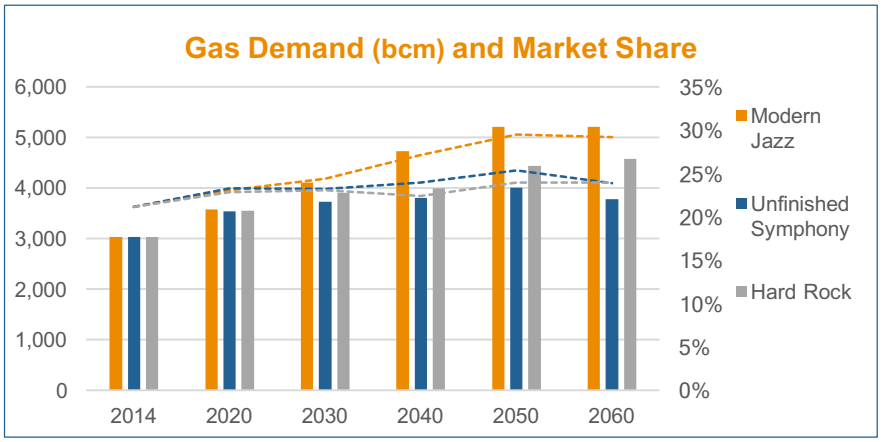
THE FUTURE OF GAS IN THE GRAND ENERGY TRANSITION

A BRIDGE TO A LOW-CARBON ECONOMY….

In the face of an anticipated peak of energy demand growth, a move towards renewable energies and the possible emergence of disruptive technologies, fossil fuels face a perfect storm over the next thirty years. Of the three main hydrocarbon fuels - oil, gas and coal, only gas faces a moderately secure future though there are clear risks on the horizon. All of the Council's scenarios see global gas demand growing while retaining a share between 25% and 30% of global energy mix.

Thanks to large reserves, gas supplies are likely to be plentiful in the medium to long term making the cleanest of hydrocarbons a good bridge to a low-carbon future. However, the pressure for continued de-carbonization of energy supplies means that this relatively clean fuel is likely to come under demand-side pressure.

Much will depend on the way the world evolves in terms of policy and societal change. The value of the Council's scenarios is that they show a range of possible outcomes.



In the market-driven world represented by Modern Jazz, gas is supported by strong economic growth in a globalised economy, increasing awareness of environmental issues and an active private sector. It is abundant and accessible and, as a result, by 2050 is the world's the main primary energy source. Gas demand grows by more than 70% between 2014 and 2050 and then reaches a plateau over the last decade of the period.

If, by contrast, the world becomes more focused on decarbonisation with the backing of appropriate government policies as represented by Unfinished Symphony, then gas has in the medium term a continued role as a major contributor to the decarbonisation of the electricity sector through coal substitution but, in the longer term, it is progressively replaced by renewables, starting with mature markets.

Mixed signals are given in a free-for-all world represented by Hard Rock: gas development is supported by weak environmental concerns but it is hampered by a fragmented market and a continued key role for coal, of which there are plentiful and cheap global supplies.

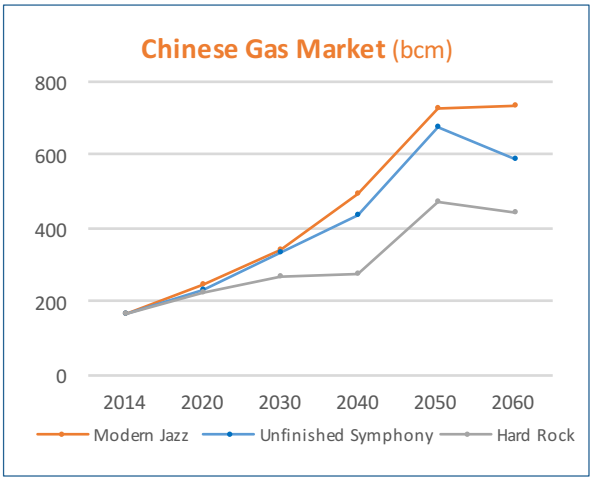
Modern Jazz **The first primary energy**	Unfinished Symphony **The bridging fuel**	Hard Rock **A major player**
• Market forces drive high economic growth in a competitive globalised world shaped by market mechanisms. • Awareness of environmental issues increases • Gas seen as low-cost cleaner fuel for power generation and transport. • Rapid deployment of RES	• Societal consensus on climate change leads to effective Govt policy on Energy • Moderate economic growth, rising energy efficiency, more stringent emissions standards and rapid deployment of renewables dampen growth for gas	• Promotion of national agendas result in low focus on climate change and a fragmented market • Energy shows high dependence on fossil fuels but gas growth is dampened by coal remaining in the mix
• **High growth** (+70%) to 2050 • 5,000 bcm in 2050 • Flat after 2050	• **Low growth** (+25%) to 2050 • 4,000 bcm in 2050 • Peak around 2050	• **Moderate growth** (+50%) to 2050 • 4,400 bcm in 2050 • Continues to grow

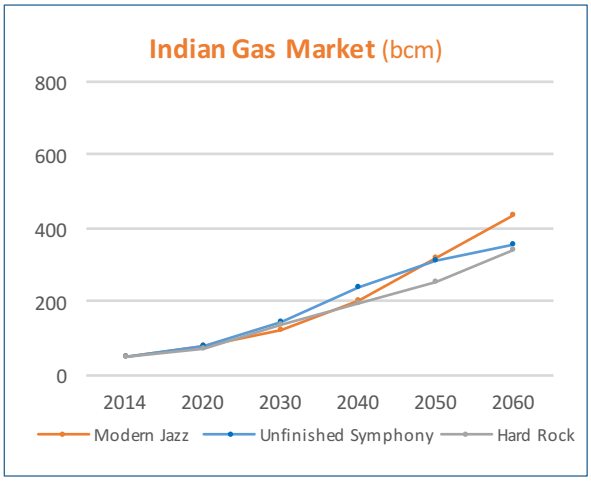
…..BOOSTED BY CONTINUED DEMAND FROM ASIA.

Gas is set to be an important and growing element of the energy mix in Asia but, again, varies according to the scenario. In Modern Jazz, from 2014 to 2030 Asia accounts for half of demand growth. This trend increases beyond 2030, with China and India accounting for more than 50% of growth in gas consumption. Their combined primary gas demand totals over 1,15O bcm in 2060.

In Unfinished Symphony, Asia represents 25% of demand growth in the years to 2030, with India and China providing particularly strong demand growth beyond 2030 when an anticipated decline in gas use in the United States and Europe is partially offset by these two Asian countries. Demand for gas in India grows as it seeks to displace coal in power generation.

Under Hard Rock natural gas faces contrasting pressures. The emphasis on security leads to a steep decline in energy trade, resulting in a substantial fall in liquidity and transparency in global markets. Thus, energy commodity prices become increasingly volatile and pricing at regional hubs sees widening differentials. Its growth averages 1.6% p.a. in the years to 2030, led by North America and Europe. Beyond 2030, gas growth slows substantially in Europe while North America sees a slight decline. However, China, India, Middle East and North Africa and Latin America continue to see significant growth in natural gas demand to 2060.





IT'S ALL ABOUT ELECTRICITY….

Global electricity demand could double by 2060 and the future of gas hinges on its ability to grab market share in this rapidly expanding sector. But gas demand in generation is very uncertain and dramatically varies across the scenarios. In 2014, 22% of the world's electricity was produced by natural gas. By 2060, this could decrease to 17% in Unfinished Symphony or increase to 26% in Hard Rock and 32% in Modern Jazz.

In a Modern Jazz world with improved quality of life, increasing technology, and rapid economic growth, lifestyles demand more electricity. Growth in demand for electricity averages 1.9% p.a. to 2030. New generation is dominated by natural gas and wind and solar. Beyond 2030, demand for electricity continues to climb but more slowly. By 2060, electricity generation will have doubled since 2014.

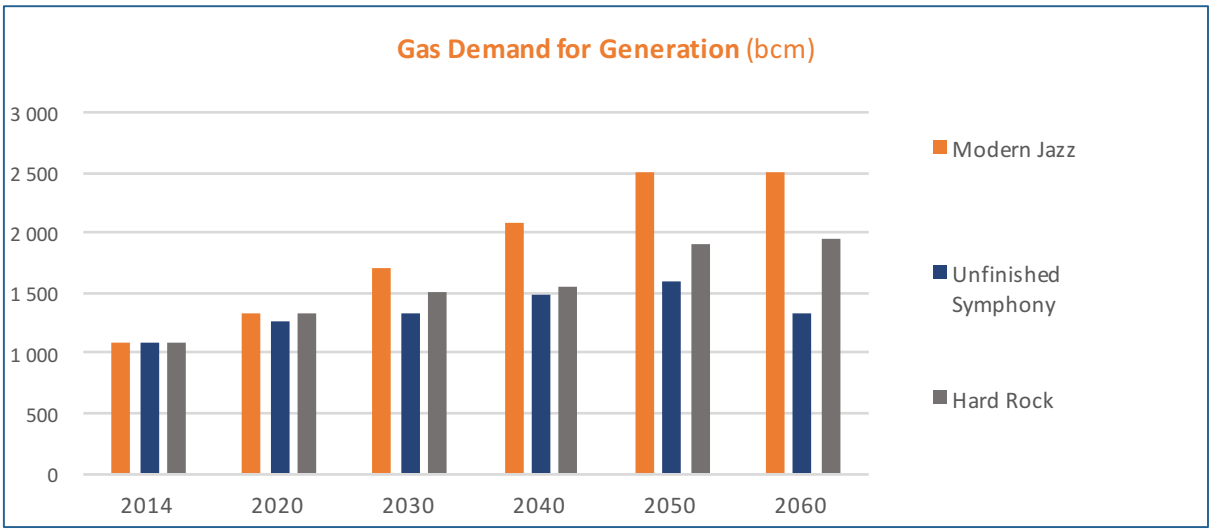
In this scenario, consumers increasingly see natural gas as a low-cost and cleaner source of power. In resource-rich regions, natural gas increasingly takes share from coal and fuel oil in power generation and as a feedstock for chemicals. Natural gas accounts for 50% of generation growth to 2050 by massively substituting coal. During the period, the production of electricity from gas triples but is very rapidly caught by wind and solar. The position of gas in electricity production, however, remains highly dependent on the deployment of Carbon Capture and Sequestration (CCS) beyond 2040. "Gas with CCS" represents nearly one third of the electricity production from gas in 2060.

In a more policy-driven economy represented by Unfinished Symphony, there is likely to be a much greater emphasis on energy efficiency and lower economic growth. Growth in electricity demand is fuelled largely by new wind and solar capacity, which encompass by 2030 53% of generation growth. Beyond 2030, demand for electricity slows to 1.2% p.a. and by 2060, electricity generation has grown 1.9 times since 2014. More than 39% of electricity generation comes from wind and solar power plants.

Between 2014 and 2050 natural gas benefits from the increase in electricity production and maintains its share of a little over 20%: electricity production from gas increases by more than 70% essentially through coal substitution. However, the longer-term picture is not so rosy; it begins a sharp decline at the end of the period to the benefit of renewables whose electricity production represents 2.3 times that of gas by 2060. At that time gas accounts for only 17% of electricity generation.

While coal has almost disappeared in electricity generation after 2050, the increasing use of CCS foster growth in gas-powered generation. The role of gas as a key fuel in the power sector is contingent on the ability of the electricity and gas sectors to develop and deploy massively high-performance and cost-effective CCS technologies.

Compared to Modern Jazz the future for gas is less promising in electricity generation if markets find themselves in a world that is fractured with inward-looking countries and geopolitical tension. The Council's Hard Rock scenario suggests that slower economic growth will limit electricity demand growth to a steady 1.6% p.a. to 2030 and 1.3% p.a. beyond. By then, the electrification of final energy consumption has reached 25%, with only 20% of electricity coming from wind and solar. Despite coal remains a major energy source in this scenario and dampens gas growth, gas demand for electricity almost doubles between 2014 and 2060.



…..BUT GAS FACES MAJOR UNCERTAINTIES: THERE ARE DOWNSIDE RISKS BUT ALSO OPPORTUNITIES.

The Council's three scenarios show that globally gas is bound to grow at least until the middle of this century but in no scenario does the world manage to limit global warming to below 2°C from pre-industrial times. A global concerted effort to reduce carbon emissions poses a risk for the future of gas. Even though it has lower emissions that oil or coal, gas could be the most vulnerable as it is easier to substitute than oil and lacks the political backing enjoyed by coal in key markets. Some gas producers – in particular, those exposed to high cost resources, - could find that their resources are stranded.

The future uptake – or not - of CCS is also a major risk. It is a key enabling technology in two of the Council's scenarios (Modern Jazz and Unfinished Symphony) but in reality is so far failing to take off. Energy leaders surveyed in the Council's annual World Issues Survey, place an increasingly lower emphasis on the technology. Yet, in Unfinished Symphony, power generated by CCGT with CCS represents 89% of total power generated by gas.

Even though it has lower emissions that oil and coal, natural gas is still a fossil fuel that emits greenhouse gases. However, emerging innovative technologies could give the possibility to position itself as a renewable energy and dramatically change the role of gas in the energy transition. The potential of biogas remains significant but there are technical and economic hurdles. Nevertheless, the experience of Germany with nearly 2,000 projects and 6 TWh production shows that biogas cannot be written off.

The role of gas in the transport sector is also questionable. Decarbonisation of the transport sector is one of the most challenging elements of energy transition. The contribution of gas to this process is limited to heavy-duty freight and marine transport, with a potential market share of around 7%-8% of transport fuels by 2060, but at most 300 bcm. CCNG for light vehicles could also have an important role to play in decarbonisation of transport provided the economic and regulatory environment is favourable. In the European Union's the "Clean Power for Transport" package, which established natural gas and bio methane as part of the European Union mix of alternative fuels, lays the foundation for a significant development of CNG and LNG in road and maritime transport, which could give gas a market share substantially above the one predicted in the three scenarios.

THE COUNCIL'S THREE SCENARIOS

For its 2016 report, the Council developed three scenarios as a tool to provide an insight into possible alternative futures in the years to 2060: Modern Jazz, Unfinished Symphony, and Hard Rock. Modern Jazz represents a 'digitally disrupted', innovative, and market-driven world while Unfinished Symphony is a world in which more 'intelligent' and sustainable economic growth models emerge as the world drives to a low carbon future. The Council has also introduced an emerging and more fragmented scenario called Hard Rock, which explores the consequences of weaker and unsustainable economic growth with inward-looking policies.

Many lessons can be learned from the Modern Jazz, Unfinished Symphony and Hard Rock scenarios. Each of these scenarios contributes to the debate on how environmental goals, energy security, and energy equity can best be achieved considering a broad range of industry and policy structures. All three scenarios are based on some pre-determined elements. The global population will grow substantially more slowly in the next 45 years - rising by around 40% - leading to slower growth in the labour force. Technology will continue to evolve at a rapid pace and will reshape economic and social options. The world will become increasingly multi-polar as Asia increases its weight in the global economy and world politics and a large urbanised middle class will continue to grow in all regions. Global and national agendas will continue to focus on environmental danger zones such as climate change, pollution, biodiversity, deforestation and the availability of water.

THE GRAND ENERGY TRANSITION

The Council's 2016 World Energy Scenarios report highlights that a major transformation in the global energy system is underway that will radically change the global energy mix in the years to 2060. It predicts per capita energy demand will peak before 2030, in stark contrast to historic growth levels, which have seen global demand for energy more than double since 1970. Technological innovation, government policies and lower growth expectations will have a significant impact on the sector in the coming decades. The report goes on to highlight that there will be a shift in final energy consumption with demand for electricity doubling by 2060. Solar and wind, which currently account for approximately four percent of power generation, will see the largest increase so that by 2060 they will represent between 20 percent and 39 percent of power generation.

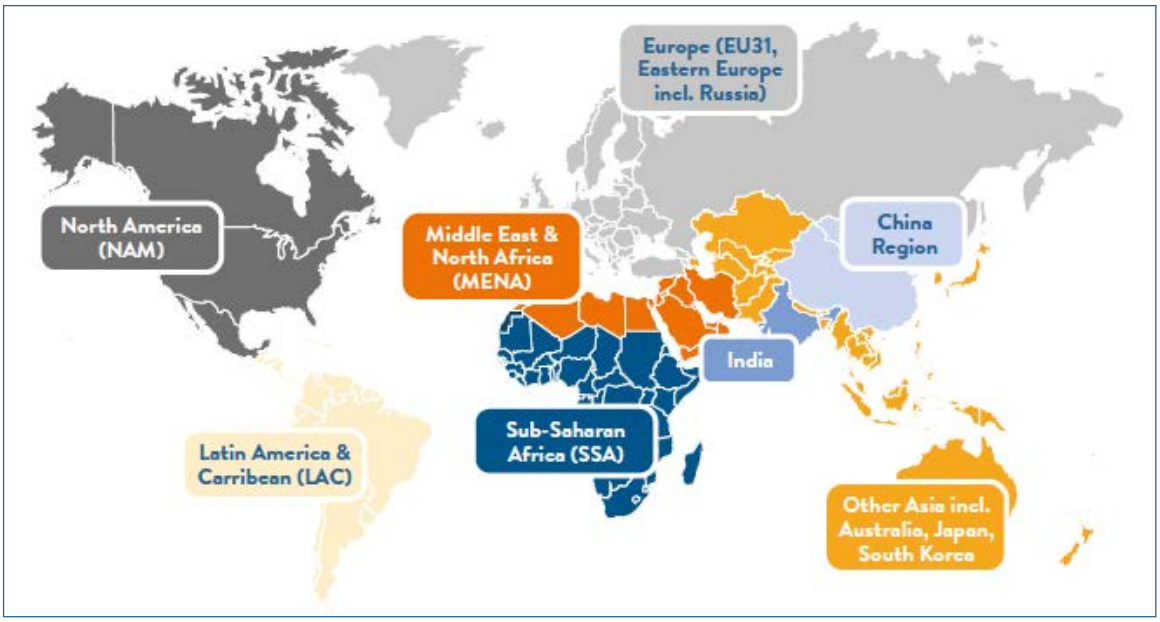
Fossil fuel usage could fall to as little as 50 percent of the primary energy mix in one of the scenarios, with very differing futures for coal, oil and natural gas. However, in all three scenarios the carbon budget is also likely to be broken within the next 30 to 40 years. Oil will continue to play a significant role in the transportation sector representing over 60 percent of the mix in all three scenarios to 2060 and natural gas will continue to increase at a steady rate.

INTRODUCTION

During the World Energy Congress in Istanbul in October 2016, the World Energy Council (the Council) presented three scenarios, developed in collaboration with Accenture Strategy and the Paul Scherrer Institute. In 2017, and with the support of the Global Gas Centre (GGC), the Council elected to analyse in greater detail, the place of gas in the three scenarios, identifying the central uncertainties affecting the role of gas and specifying the challenges facing the gas industry.

NB:

- The figures given in the Scenario report are mainly expressed in MTOE. In this analysis, figures related specifically to gas volumes are expressed in bcm with the following conversion: 1 MTOE = 1.047 bcm.
- The primary source used for the data related to fuel production and consumption is the IEA's Energy Balances (IEA 2015a).
- The 8 world regions mentioned in the document are described in the following map.



1. OUTLINE OF THE REPORT: 'WORLD ENERGY SCENARIOS 2016: THE GRAND TRANSITION'

DISRUPTIVE TRENDS WILL FUNDAMENTALLY CREATE A NEW WORLD OF ENERGY

Since 1970, the world has seen rapid growth in energy demand, mainly satisfied by fossil fuels. The future will be different. Disruptive trends are emerging that will create a new world for the energy industry, characterised by lower population growth, radical new technologies, greater environmental challenges, and a shift in economic and geopolitical power. These underlying drivers will re-shape the economics of energy. This uncertain journey into the new world of energy can be called "**The Grand Transition"**.

THREE SCENARIOS

Three new exploratory and metaphorically named scenarios looking to 2060: **Modern Jazz, Unfinished Symphony,** and **Hard Rock** have been built. These scenarios provide an open, transparent, and inclusive framework in which to think about a very uncertain future.

Pre-determined Elements

- **Population** has doubled since 1970, but **will grow significantly more slowly** in the next 45 years - rising by around 40% - **leading to slower growth in the labour force.**
- **New technologies,** which include the full diffusion of information technology, automation, more productive resource technologies, and health technologies will reshape economic and social options.
- The shift to a **multipolar world as Asia increases its weight in the global economy and world politics** and the emergence of a large urbanised middle class.
- Global and national agendas will be shaped by the need to avoid crossing planetary boundaries, with a focus on the **danger zones: climate change, biodiversity, deforestation…**

Critical uncertainties

- Pace of **innovation and productivity.**
- **Development** of international **governance and geopolitical change.**
- **Priority** given to **sustainability and climate change.**
- **Selected** 'tools for action': the **balance between the use of markets and state directed policy.**

Main characteristics of the three scenarios

- **Modern Jazz** represents a 'digitally disrupted', innovative, and market-driven world while **Unfinished Symphony** is a world in which more 'intelligent' and sustainable economic growth models emerge as innovation drives towards a low carbon future.
- The Council has also introduced an emerging and more fragmented scenario called **Hard Rock**, which explores the consequences of weaker and unsustainable economic growth with inward-looking policies.
- Many lessons can be learned from the Modern Jazz, Unfinished Symphony and Hard Rock scenarios. Each of these scenarios contributes to the debate on how environmental goals, energy security and energy equity can best be achieved considering a broad range of industry and policy structures.

Economic indicators

Indicators	2014	2030			2060		
		Modern Jazz	Unfinished Symphony	Hard Rock	**Modern Jazz**	Unfinished Symphony	Hard Rock
Population (million)	7,266	**8,501**			**10,184**		
CAGR (2014-20xx)		**1.0%**			**0.7%**		
GDP (Trillion USD2010 MER)	70	**122**	114	93	**312**	256	150
CAGR (2014-20xx)		**3.5%**	3.1%	1.8%	**3.3%**	2.9%	1.7%
GDP per capita (USD2010 MER)	9,686	**14,322**	13,396	10,901	**30,627**	25,172	14,684
CAGR (2014-20xx)		**2.5%**	2.0%	0.7%	**2.5%**	2.1%	0.9%
Light-duty vehicle fleet (bn)	1.1	**1.6**	1.5	1.5	**3.0**	2.8	2.9
Car ownership (cars/1000 people)	153	**173**	167	169	**278**	258	268
CAGR (2014-20xx)		**0.8%**	0.5%	0.6%	**1.3%**	1.1%	1.2%
Primary Energy Intensity (MTOE/USD2010 MER)	194	**132**	134	174	**55**	59	122
CAGR (2014-20xx)		**-2.4%**	-2.3%	-0.7%	**-2.7%**	-2.6%	-1.0%
Final Energy Intensity (MTOE/USD2010 MER)	133	**96**	98	125	**42**	45	92
CAGR (2014-20xx)		**-2.0%**	-1.9%	-0.4%	**-2.5%**	-2.3%	-0.8%

2. MODERN JAZZ

KEY POINTS: A MARKET-DRIVEN GLOBALISATION THAT WORKS

- Modern Jazz is a **competitive world** shaped by market mechanisms and open economies.
- Globalisation boosts efficiency and productivity and technology transfer. The result **is strong economic growth** and **increasing energy demand.**
- Despite the **absence** of an **international climate framework,** policymakers, supported by the values of civil society, **support an energy transition** through **light-touch policy intervention.**
- Emerging technologies are **exceptionally disruptive.**
- Rapid improvements are possible in the **economics of renewable energy** and **storage technologies** leading to drastic shift without substantial economic disruption.
- From 2014 to 2030 total primary energy supply (TPES) grows at a rate of 1.0% p.a. Energy supplies grow more slowly from 2030 to 2060. The **diversification of the primary energy mix accelerates and fossil fuel share of primary energy has fallen to 63% in 2060.**
- **Gas demand grows by more than 70%** between 2014 and 2050 and then reaches a plateau over the last decade of the period.
- The period begins with a **growing diversity** of natural gas suppliers and consumers. **Markets are liquid** and **short-term trade** continues to grow.
- Consumers increasingly see **natural gas** as a **low-cost** and **cleaner source** of power and transportation. Growing **investments in natural gas power generation** and rapid deployment of both utility-scale and decentralised renewables lead to **substantial de-carbonisation of energy systems.**
- The 2°C target is not reached as the world exceeds the 1000 Gt CO_2 Intergovernmental Panel on Climate Change (IPCC) carbon budget for 2°C between 2040 and 2060 and in 2060, the world is on track for 3°C of global warming in 2100.

TOOLS FOR ACTION

With market forces dominating, private industry is the strongest actor. Technology choices and developments are driven by competitiveness, cost, and reliability. Markets give a stronger voice to consumers whose values drive a behavioural shift to products and services that meet a high level of environmental and social compliance. Many are willing to opt for ‘green energy’ through their utility company. Thus, **demand for clean energy solutions grows throughout the period**.

Policymakers respond with enabling policies to account for externalities using a pro-technology, light-touch approach and take measures such as liberalisation of gas and electricity markets, emissions-reduction requirements that adjust along with technology deployment, light-touch tax schemes for emissions and subsidy schemes for renewables, reductions in fossil fuel subsidies, open borders, liberalised trade, and high global economic cooperation…

Open economies make global competition and growth possible in new geographies; **globalisation boosts efficiency and productivity** and **technology transfer enables developing economies to catch up more quickly**. The result is strong economic growth that averages 3.3% p.a. from 2014 to 2060 and increasing energy demand.

REGIONAL TRANSITIONS

By 2035, Asia has become the dominant economic region. China is the number-one economy in the world, the largest global manufacturer and is in transition to consumption and services-led growth. India rises as the world's most populous country and the third-largest economy.

By 2040, rising labour costs in China and other Asian countries encourage investors to increasingly look to Africa. As the population of Sub-Saharan Africa (SSA) surpasses the population of India, investor support helps move the region from less technologically intensive production to capital-intensive, manufacturing production as industrial activity spreads to meet growing consumer demand.

Meanwhile, the economies of Europe, Japan, and Russia continue their slow relative declines.

Russia, the Middle East and Latin America continue to play an important role as global suppliers of energy throughout the period, with the Middle East and North Africa (MENA) leading the way. New competition emerges from North America (NAM) but supplies hit their peaks in 2030.

TECHNOLOGY ADOPTION

Support for lower-carbon technologies varies broadly across regions; however, on a global level, there is **consensus on the importance of making renewable energy sources more reliable and economically competitive.** Industry-led Research, Development and Demonstration (RD&D) drives down the cost of technologies.

Changes in consumer preferences for technology affect both the energy intensity of GDP and the carbon intensity of primary energy. The biggest impacts are in power and transport systems. Growing investments in natural gas power generation and rapid deployment of both utility-scale and decentralised renewables lead to substantial de-carbonisation of energy systems.

Light-touch policy support is the underlying driver for the shifts in technology adoption. Many of the OECD countries and industrialised nations continue current levels of national subsidy and taxation schemes for renewables and implement planned policies. By 2030, high energy consumption regions start to see a growing number of carbon trading schemes with meaningful carbon prices based on national and local initiatives. These prices are passed on to customers who are increasingly aware of the carbon footprint of goods and services.

CLIMATE CHALLENGE

Carbon intensity of GDP falls at an historically unprecedented rate of 2.8% p.a. from 2014 to 2030 and accelerates to a decline of 4.5% p.a. from 2030 to 2060, but it is not enough to counteract the upward pressure on emissions from sustained high economic growth. GDP growth drives carbon emissions to increase at a pace of 0.7% p.a. before peaking in 2030. Beyond 2030, accelerated carbon intensity reductions drive emissions to decline at 1.4% p.a. to 2060.

The world exceeds the 1000 Gt CO_2 IPCC carbon budget for 2°C between 2040 and 2060 and in 2060, the world is on track for 3°C of global warming in 2100.

FINAL ENERGY CONSUMPTION

Total Final Energy Consumption grows 25% from 2014 to 2030 and begins to slow-down drastically beyond 2030.

Industry

Industrial demand for energy grows at a rate of 2.0% p.a. from 2014 to 2030. Beyond 2030, demand slows drastically to 0.3% p.a. as industrialised economies shift to service-led growth. Industrial activity also becomes increasingly efficient through a transition to gas and renewables for power, and through the electrification of processes and heating.

Transport

Rapid economic growth, open economies and freedom of mobility translate into high volumes of air traffic, freight and car-ownership.

Demand for petroleum-based transport fuels grows at a rate of 1.0% p.a. to 2030, but demand declines at 0.7% p.a. beyond 2030 as transport fuels diversification accelerates.

Electric Vehicles (EVs) deployment is supported by technology breakthroughs in battery technology. By 2030, there are more than 63m EVs and hybrid EVs globally. By 2060, this number rises to more than 800m, which reflects 26% of the light-duty vehicle fleet.

In heavy-duty freight and marine transport, concerns about the volatility of crude prices, an abundance of cheap and flexible natural gas supplies, and regional emissions standards lead to demand for CNG and LNG technology penetration.

ELECTRICITY

With improvements in quality of life, increasing technology, and rapid economic growth, lifestyles demand more electricity.

Growth in demand for electricity averages 1.9% p.a. to 2030. New generation is dominated by natural gas and wind and solar which encompass 36% of new generation.

Beyond 2030, demand for electricity continues to climb at a rate of 1.4% p.a. to 2060. By then, electricity generation has grown twice since 2014. By 2060 wind and solar generation reflect 30% of total electricity generation.

PRIMARY ENERGY

Modern Jazz		2014	2020	2030	2040	2050	2060	CAGR (2014-30)	CAGR (2014-60)
Total		13 652	14 793	16 085	16 649	16 847	17 013	1.0%	0.5%
Coal		3 902	3 831	3 636	3 102	2 303	1 832	-0.4%	-1.6%
Oil		4 276	4 683	5 123	4 941	4 545	3 962	1.1%	-0.2%
Gas[1]	**MTOE**	**2 891**	**3 417**	**3 927**	**4 515**	**4 974**	**4 968**	**1.9%**	**1.2%**
	Share	**21%**	**23%**	**24%**	**27%**	**30%**	**29%**		
Nuclear		659	815	856	947	1 085	1 262	1.6%	1.4%
RES		1 923	2 048	2 544	3 145	3 941	4 988	1.8%	2.1%
- Biomass		1 408	1 415	1 580	1 768	2 106	2 671	0.7%	1.4%
- Hydro		334	375	413	461	515	562	1.3%	1.1%
- Others		181	258	551	916	1 320	1 755	7.2%	5.1%

[1] Expressed in bcm with the conversion factor of 1 MTOE=1.047 bcm, 2014 Gas demand is 3,026 bcm. The difference between this figure and those produced by other entities is mainly due to differences in conversion factor (e.g. in BP Statistical Review, 1 MTOE= 1.11 bcm)

From 2014 to 2030 total primary energy supply (TPES) grows at a rate of 1.0% p.a.

Decrease in demand for fossil fuels in some sectors and the penetration of renewable energy sources in power drive down the share of fossil fuels to 79% of primary energy in the period.

Energy supplies grow more slowly from 2030 to 2060. The diversification of the primary energy mix accelerates and fossil fuel share of primary energy has fallen to 63%. By **2060, renewable energy sources (RES) exceed gas and become the first source of primary energy**.

Globalisation and technology transfer lead to a tight convergence of energy intensities across regions. Global energy intensity declines by 72% from 2014 to 2060 (averaging 2.7% p.a.) and the he world makes **significant strides in reducing primary energy intensity of GDP**.

Coal

Although the demand for energy is growing, the role of coal in primary energy declines from 2014 to 2030. This decline is seen all over the world except for India. Coal peaks in 2020 in China and declines at a rate of 2.4% from 2020 to 2060. Globally, coal declines at a rate of 2.3% p.a. from 2030 to 2060.

Wind, Solar, Geothermal

Solar, wind and geothermal generation grow more rapidly than any other fuel source in primary energy up to 2060, averaging 5.1% p.a. in the period, driven by solar.

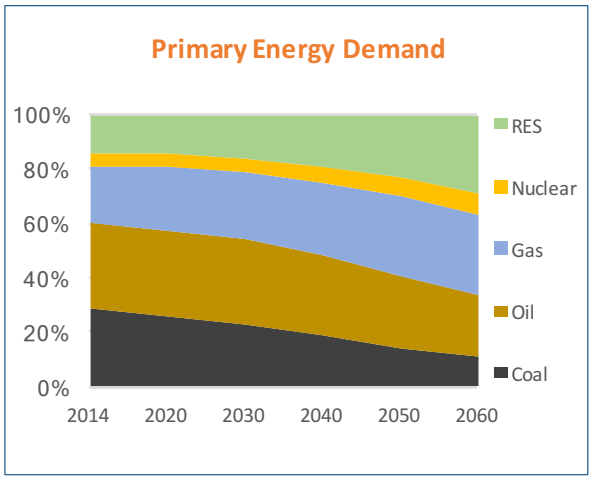
Continued technology advances lead capital costs for Photovoltaics (PV) and concentrated solar to decline by more than 75% in the period to 2060.

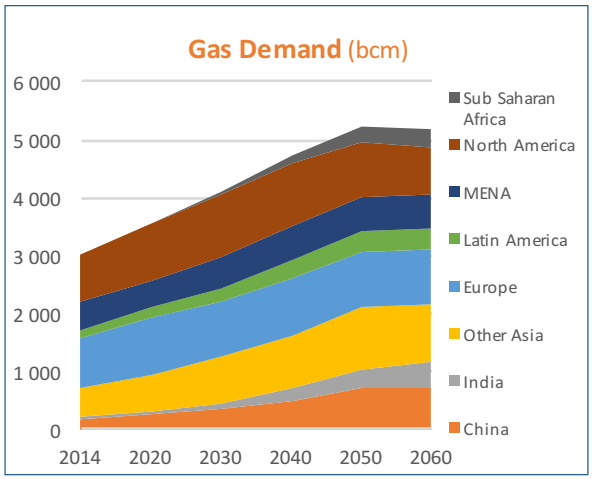
Thus, solar electricity generation grows from 200 TWh in 2014 to 1,400 TWh in 2030, and around 5,700 TWh in 2060. China accounts for the largest share of capacity additions.

Wind generation also rises from 717 TWh in 2014 to more than 2,500 TWh in 2030 and 8,800 TWh in 2060. The largest additions are seen in China, India, Europe, NAM and Asia Pacific (APAC).

IMPLICATIONS FOR NATURAL GAS

Rise of gas as Primary Energy





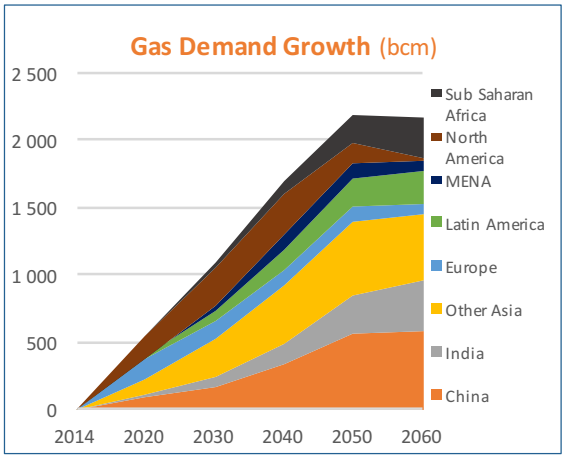
From 2014 to 2030 gas demand grows at a rate of 1.9% p.a. Consumers increasingly see natural gas as a low-cost and cleaner source of power and transportation. In resource-rich regions, natural gas increasingly

takes share from coal and fuel oil in power generation and as a feedstock for chemicals. Despite the decline of global energy intensity, gas demand grows by more than 70% between 2014 and 2050 and then reaches a plateau over the last decade of the period.

Market development

The period begins with a growing diversity of fossil fuel suppliers and consumers. Growing exports of Australian and US LNG create competition across regional gas markets, facilitating the emergence of new pricing mechanisms for gas and diffusing the power of OPEC and Russia. Markets are liquid and short-term trade continues to grow.

A move towards Asia



From 2014 to 2030 Asia accounts for 49% of demand growth.

In China, demand grows in industrial power use and transportation. Asia Pacific and India also see growth in power, commercial, residential and non-energy use.

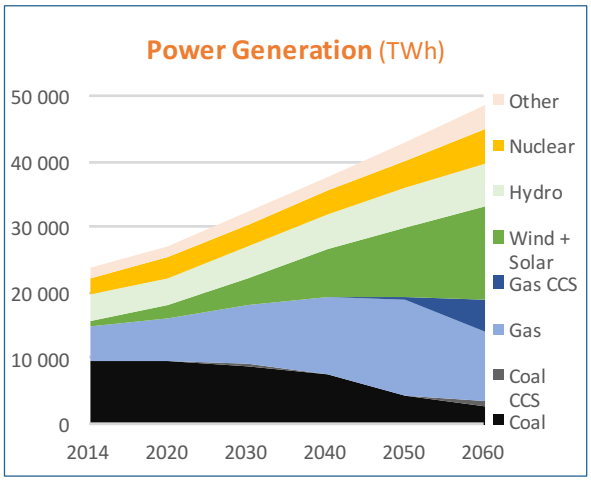
Outside of Asia, NAM and Latin America and the Caribbean (LAC) drive growth, reflecting 25% and 8%, respectively, of global growth of gas in TPES to 2030.

Beyond 2030, China and India account for more than 65% of growth in gas consumption. Their combined primary gas demand totalises over 1,15O bcm in 2060.

Natural gas in TPES grows at 5.7% p.a. in SSA in the second half of the period, reaching 330 bcm and driving 24% of global gas growth from 2030 to 2060.

RD&D and gas exploration lead to continued rapid growth of unconventional gas supplies driven by the US, Canada, Australia, Argentina, and China. Unconventional gas production continues to grow to 2040 peaking at 1,250 bcm and reaching 26% of total natural gas supplies in the same year. Beyond 2040, unconventional gas production declines rapidly, settling at 340 bcm in 2060.

Up to 2030, MENA gas supplies grow fastest to meet demand, followed by the US and Asia Pacific. Beyond 2030, MENA dominates supply additions, reflecting 37% of growth from 2030 to 2060 and reaching 1,350 bcm of gas production. Asia Pacific and China follow, reflecting 17% and 16% of growth respectively. SSA reflects 11% of supply growth, which is mostly used to meet domestic demand.



Massive switch from Coal to Gas in power generation

Up to 2050 new generation is dominated by natural gas which accounts for 50% of generation growth before declining to 10% in the last decade.

Natural gas increases its market share by 10% between 2014 and 2060 by massively substituting coal. During the period, the production of electricity from gas is multiplied by 3.

The position of gas in electricity production, however, remains highly dependent on the deployment of Carbon Capture and Storage (CCS) beyond 2040. "Gas with CCS" represents more than 30% of the electricity production from gas in 2060.

Transport

In heavy-duty freight and marine transport, concerns about the volatility of crude prices, an abundance of cheap and flexible natural gas supplies, and regional emissions standards lead to demand for CNG and LNG technology penetration.

This drives natural gas shares to reach 6.5% of transport fuels by 2060. Nevertheless, gas demand in transport remains limited to 290 bcm, or 4.5% of total gas demand.

3. UNFINISHED SYMPHONY

KEY POINTS: A WORLD OF GLOBAL COOPERATION DRIVEN BY GOVERNMENTS

- A **societal consensus** builds on the world's need to **act fast on climate change.**
- National governments unite and take **effective policy action** on climate change.
- By 2030, a **global CC(U)S mandate** and political pressure to reduce CO_2 emissions dissuade utilities from investing in any new coal projects. Thus, **coal's decline** in TPES accelerates.
- A strong governance system provides clear signals about how markets should develop and policies facilitate **more efficient technology transfer.**
- More stringent carbon pricing schemes incentivise energy companies and energy-intensive industries to deploy cleaner technologies.
- **Efficiency** is a **primary focus** for governments. Strong gains are made through local and national policy support, and through RD&D in demand-side technologies and digital tools that help shift Through **strategic planning,** and the build-out of smart infrastructure, the **electrification of transport** continues to build momentum.
- Moderate economic growth, rising energy efficiency, and increasingly stringent emissions standards **dampen growth for natural gas.**
- Nevertheless, in 2060, the **world is off-track for meeting the COP21 commitments**

TOOLS FOR ACTION

The world has concluded that for many issues, the cost of action later will be much higher than taking preventative action. Thus, a **societal consensus builds on the world's need to act fast on climate change**. Many households seek out opportunities to reduce their energy consumption and opt in to purchase 'clean power' from their local utility.

Strong Global Governance

With renewed commitment on climate after the COP21 agreement, the United Nations Framework Convention on Climate Change (UNFCCC) is increasingly effective in building a global carbon mitigation strategy with clear targets and milestones for countries.

Integrated Planning

With a strong governance system providing clear signals about how markets should develop, national governments rise to the occasion to avoid the impacts of big systemic issues like climate change. **Key to transformation is integrated planning** that ties national agendas to global sustainable development targets.

With clear long-term objectives in place, national governments are better equipped to establish adequate regulatory frameworks and to facilitate regional integration, which becomes a critical driver of increasing energy access and resilient climate strategies.

Enabling Business Models

The public pushes governments to hold companies accountable for adopting more sustainable practices. Over time, this leads to new business models for profitability and longevity.

More stringent carbon pricing schemes incentivise energy companies and energy-intensive industries to deploy cleaner technologies. The private sector plays a critical role in bringing this technology to energy markets.

PRODUCTIVITY AND ECONOMIC GROWTH

Policymakers start to look beyond GDP growth to measure the effectiveness of policy actions. Policy direction that attempts to balance growth with security, environmental and social outcomes shapes a more sustainable model for economic growth.

A key to the transition to more sustainable economic growth is intelligent infrastructure and circular economies. This approach boosts societal wellbeing, avoids potential costs, and leads economies to grow at 2.9% p.a. from 2014 to 2060.

Intelligent infrastructure is supported by policies that facilitate more efficient technology transfer. More and more pressure builds to develop circular business models and create circular economies. Companies concentrate on rethinking products and services from the bottom up to prepare for inevitable constraints on resource consumption.

INTERNATIONAL GOVERNANCE

Unfinished Symphony is shaped by a strong global governance structure and an emphasis on diplomacy, leading to a world of increasing regional and global cooperation.

Strong Global Cooperation

By 2020, the US, China and Europe have agreed on appropriate regional frameworks for carbon pricing. By 2030, the UNFCCC successfully negotiates an agreement between the US, China, India and Europe that establishes a framework for India's transition and supports technology transfer and funding for sustainable development.

Regional Integration

In many regions, global trade developments focus on building regional partnerships and funding for infrastructure projects.

The most important economic shift created through regional integration occurs in Africa. Industrial sectors benefit the most, thereby positively influencing Africa's industrial development and fostering the build-out of infrastructure in the region.

Similarly, Latin America and the Caribbean (LAC) is also engaged in the same process, with integration of energy infrastructure delivering a sizable contribution to the development of resilient energy systems.

CLIMATE CHALLENGE

All regions make great progress in carbon abatement. This is due largely to local support creating an impetus for national action and global cooperation. Global reductions in carbon intensity of GDP average 4.7% p.a. from 2014 to 2060. **Nevertheless, in 2060, the world is off-track for meeting the COP21 commitments, but has the possibility to recover through technologies and policies that drive towards negative carbon emissions beyond 2060**.

Local Support

Energy Efficiency is a **primary focus** for governments. Strong gains are made through local and national policy support, and through RD&D in demand-side technologies and digital tools that help shift consumer behaviour. Governments provide substantial support to RD&D investments directed to nuclear, hydro and Carbon Capture Utilisation & Storage CC(U)S technologies, and make progress in longer-term bets such as power-to-gas and hydrogen.

Unified Action

As 2020 approaches, many of the commitments made at COP21 are off-track. There is consensus that the global framework for managing emissions requires more financing and binding targets that align directly to the IPCC emissions budget for 2°C.

The United Nations Framework Convention on Climate Change (UNFCCC) pushes to instil caps and penalties in order to improve compliance with emissions-reductions requirements. Agreements increase the funding for a transition in both developed and developing economies. Funding is partially obtained through the implementation of an interregional trading scheme that links emissions markets in Europe, Asia and the Americas. By 2030, local taxation and support schemes are directly linked to long-term emissions targets.

Technology Transition

Strong government mandates and rising carbon prices force a rapid transition in energy technologies. On the demand side, top-down mandates and technology support for intelligent infrastructure and smarter buildings enable consumers to use energy more efficiently. Technology support also is instrumental in deploying large-scale low-carbon energy generation.

FINAL ENERGY CONSUMPTION

Total final energy consumption (TFEC) grows by 19% to 2030, and plateaus to 2060. Growth is largely driven by increased energy delivered for industry and transport.

Industry

Demand for energy grows at a rate of 1.5% p.a. from 2014 to 2030. Beyond 2030, demand flattens as increasingly stringent policies impose changes in energy-intensive industrial activity and economies shift to service-led growth. Industrial activity also becomes increasingly efficient, through a transition to gas and renewables for power, and through the electrification of processes and heating.

Transport

Significant breakthroughs in storage technologies open the door to a **revolution**. Through strategic planning, emissions standards, and the build-out of smart infrastructure, the electrification of transport continues to build momentum. By 2030, more than 86mn EV and hybrid EV are on the road. By 2060, this number has grown to 900m representing **32% of the global vehicle fleet**.

ELECTRICITY

An emphasis on energy efficiency, moderated economic growth and higher electricity prices dampen electricity demand early in the period. Growth in demand for electricity is 1.6% p.a. by 2030, fuelled largely by new wind and solar capacity, which encompass 53% of generation growth. Natural gas accounts for 28% of growth in generation.

Beyond 2030, demand for electricity slows to 1.2% p.a. and by 2060, electricity generation has grown 1.9 times since 2014, and the electrification of final energy consumption has reached 29%.

Solar installed capacity dramatically increases and generation rises from 200 TWh in 2014 to 1,700 TWh in 2030 and almost 8,000 TWh in 2060. China accounts for the largest share of capacity additions. Installed capacity of wind also grows rapidly and generation grows 13 times in the period, reaching 9,300 TWh in 2060.

Intermittent renewables reach 15% of electricity generation in 2030 and **38% in 2060**.

PRIMARY ENERGY

Substantial shifts in Primary Energy supplies

Electrification of energy use and the deployment of renewables lead to substantial shifts in primary energy supplies. **By 2030 fossil fuels fall to 74% of primary energy**. Slowing population growth and high carbon prices mean supply growth is flat in the second half of the period. By 2060, Total Primary Energy Supply (TPES) is just 10% higher than in 2014, and the **share of fossil fuels has fallen to 50%.**

Unfinished Symphony		2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total		13 652	14 499	15 291	15 178	15 095	15 085	0.2%
Coal		3 902	3 509	3 062	2 058	1 063	724	-3.6%
Oil		4 276	4 589	4 671	4 378	3 862	3 261	-0.6%
Gas	**MTOE**	**2 891**	**3 375**	**3 554**	**3 637**	**3 822**	**3 604**	0.5%
	Share	**21%**	**23%**	**23%**	**24%**	**25%**	**24%**	
Nuclear		659	848	1 123	1 413	1 683	1 959	2.4%
RES		1 923	2 178	2 882	3 692	4 666	5 538	2,2%
- Biomass		1 408	1 532	1 835	2 145	2 564	2 949	1.6%
- Hydro		334	381	438	488	553	609	1.3%
- Others		181	265	609	1 059	1 549	1 980	5.3%

Coal

With the world's largest energy consumers agreeing to take unified action on climate change, coal declines at a rate of 1.5% p.a. from 2014 to 2030. Coal in China peaks before 2020.

By 2030, a global CC(U)S mandate and political pressure to reduce emissions of carbon and other pollutants dissuade utilities from investing in any new coal projects. Thus, coal's decline in TPES accelerates, averaging -4.7% p.a. from 2030 to 2060.

Wind and Solar

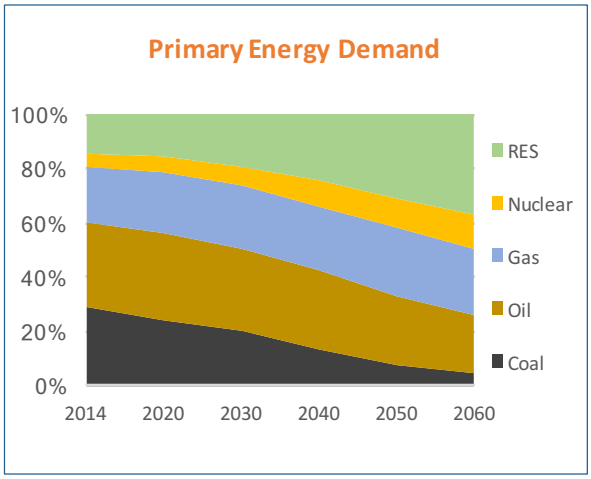
Solar and wind generation grow more rapidly than any other fuel source to 2060, averaging 5.3% p.a. in the period. Continued technology advances reduce capital costs for PV by more than 75% to 2060.

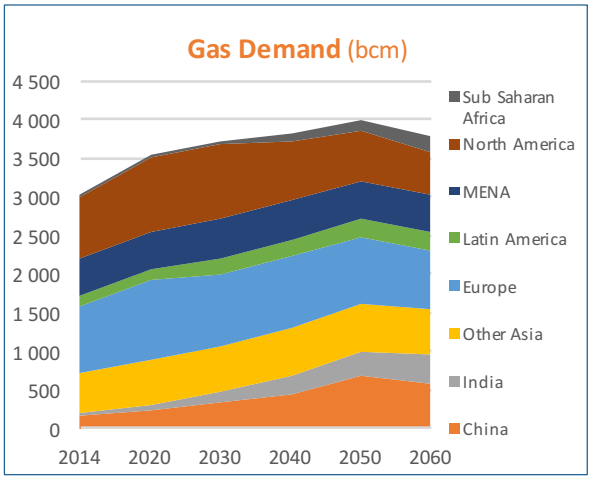
CARBON CAPTURE AND STORAGE (CCS)

The US, EU31 and China enact the world's first-ever national carbon emissions standards that impose carbon capture and storage (CCS) on coal-powered generation. Early retirement, retrofits and conversions cause significant shifts in coal and natural gas-fired power generation. All remaining coal plants are retrofitted with CC(U)S technology post 2030, and natural gas plants post 2050. By 2060, CC(U)S technology captures 4.8 GtCO2/yr and finding commercial uses for captured CO_2 becomes a higher priority for industry and governments.

IMPLICATIONS FOR NATURAL GAS

Natural gas: A transition fuel





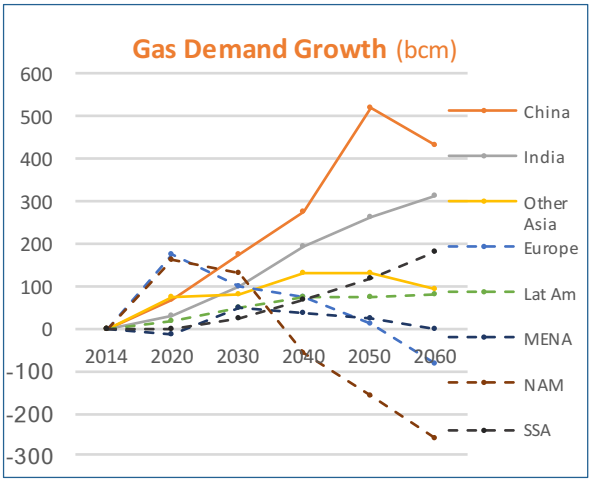
Gas is gradually disregarded in favour of renewables. By 2040 the share of renewables exceeds that of gas.

Moderate economic growth, rising energy efficiency, and increasingly severe emissions standards dampen growth for natural gas, which averages 1.3% p.a. from 2014 to 2030, reaching 3,721 bcm of consumption, and peaks at 4,002 bcm in 2050.

By displacing coal, which accounts for only 7% of primary energy demand in 2050, natural gas contributes massively to the de-carbonisation of electricity generation.

Beyond 2050, global gas demand declines, reaching 3,773 bcm in 2060.

Gas markets move to Asia



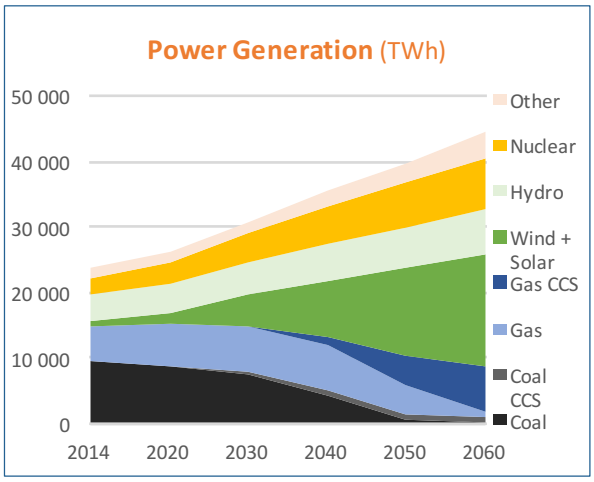
From 2014 to 2030 China represents 25% of demand growth, followed by NAM which reflects 19% of consumption growth.

Europe and India each reflect 14% of consumption growth to 2030 and Asia Pacific reflects 12%.

Beyond 2030, declines in consumption in the US and Europe are offset to an extent by India and China, as India looks to displace coal in power and China seeks to displace oil in transport.

SSA also sees strong additions, as the region skips over coal generation in power.

Power Generation



Gas maintains its share over 20% until 2050 and benefits from the increase in electricity production: by 2050 electricity production from gas increases by more than 70% essentially through coal substitution.

It begins a sharp decline at the end of the period to the benefit of renewables whose electricity production represents 2.3 times that of gas in 2060.

Mandates for CCS diminish the role of coal and foster growth in gas-powered generation with CCS.

The ability of the electricity and gas sectors to develop and deploy massively high-performance and cost-effective CCS technologies is therefore crucial to maintaining the position of natural gas in generation.

Transport

Natural gas benefits from the development of transport-related technologies (heavy freight and marine). This drives natural gas shares to reach 5.7% of transport fuels by 2060. Nevertheless, gas consumption in transport remains limited to 230 bcm, or 4.9% of global gas demand.

4. HARD ROCK

KEY POINTS: INWARD LOOKING COUNTRIES AND GEOPOLITICAL TENSIONS

- Geopolitical tensions diminish **international governance** systems.
- Governmental policies based on local context and without due consideration for global impacts **cannot adequately address the issue of climate change.** Reduced funding capacity leads to **lower investment in clean energy technologies**. Many countries find they can no longer support renewable energy subsidies beyond 2020.
- Population growth and **slow progress on energy intensity** translate into TPES growth of 34% from 2014 to 2060.
- **national agendas**, increasingly investing in regional resource development.
- Thus, the primary energy mix remains heavily dependent on fossil fuels and **coal demand remains resilient** throughout the period, mainly in Asian countries.
- Low economic growth and a decline in global trade lead **to moderated demand growth for natural gas** which must compete with more affordable coal.
- In most regions, countries do not meet the Intended Nationally Determined Contributions (INDC) commitments set out at COP21. Emissions concentrations translate to about **3°C of global temperature rise**.

Hard Rock explores a world where the geopolitical tensions weaken international governance systems. Governments establish policies that balance security, social welfare and environmental concerns based on the local context and without much consideration for global impacts, resulting over time in a disagreement on how markets and political systems develop across the world.

Rising nationalist policies in US and Europe weaken international trade agreements. Export-oriented growth becomes less important as an economic growth strategy, leading to stagnating global GDP growth.

Although in many regions environmental concerns remain a priority on national agendas, weak economic performance and low international cooperation make it more challenging to tackle global issues.

TOOLS FOR ACTION

Market structures and policy systems increasingly splinter and focus on local and national needs. Diversifying and adapting local economies to a new world with high geopolitical tensions become the primary focal point. **Strong national governments**, **societal values** and **state-owned enterprises** therefore become the predominant tools for action.

Developing regions are increasingly looking to the Chinese archetype of state-controlled economic growth. Shifting political systems provide benefits on a national level but lead to a lack of global cooperation which, in turn, limits global competitiveness. Dampened economic growth limits funding capacity for renewables' support schemes and in some regions, wage stagnation and other socio-economic challenges make low-income citizens less willing to pay more to subsidise cleaner energy generation.

STATE-OWNED ENTERPRISES

The period begins with governments already owning the worlds' largest oil companies and controlling three-quarters of the world's energy reserves.

From 2015 to 2030, as Asian economies rise in the global economic landscape, the importance of state-owned enterprises in the global economic and energy context continues to grow. However, state-owned enterprises also struggle with growing levels of corruption, too much political interference, and lower profitability. These trends reshape the global economy by increasingly transferring economic power and influence to the central authority of the state.

While this results in a lower economic growth trajectory, state capitalist economies tend to weather the effects of recession and market volatility more robustly than the liberal market economies.

PRODUCTIVITY AND ECONOMIC GROWTH

A divergence in political systems and market structures across regions leads to a slowdown in global economic growth.

The drag created by a decline in global cooperation is, to a certain extent, countered by an emphasis on developing diversified national economies, building domestic expertise, and maturing local policies. This ensures continued economic growth, albeit at a moderate pace of 1.7% p.a. from 2014 to 2060.

In industrialised nations, weakened trade relationships necessitate governments to come to terms with the reality that export-led growth is no longer a sustainable model. Many governments invest in stimulating domestic growth and diversifying local economies.

In developing nations, employment becomes a significant driver. Just after 2030, China surpasses the US to become the number-one.

Broadly varying challenges across regions spawn a variety of business models. Large, integrated utilities work best in some regions, such as China and Europe, while in others, such as India and SSA, distributed energy solutions deliver energy to rural communities. No one business model dominates.

INTERNATIONAL GOVERNANCE

Nationalist and protectionist policies create a climate of **low global cooperation**, as well as concerns about security, and pose a challenge for international governance systems.

Within this context, national governments choose lowest cost and/or most attractive resources to promote their national agendas, increasingly investing in regional resource development and utilising selective bi-lateral relationships with a few strategic partners to ensure access to energy resources.

CLIMATE CHALLENGE

With low economic cooperation, reduced capacity for investment and an emphasis on resolving national economic and security concerns first, the **climate change challenge slides down** the list of priorities for national governments. The reduction in carbon intensity averages just 1.5% p.a. from 2014 to 2060, and the world surpasses its 1000 Gt budget for CO_2 between 2040 and 2060.

Lower economic growth results in less energy—and carbon-intensive economic activity in the US and Europe but reductions in these regions are offset by continued growth in carbon emissions in China and India, where economic transition into heavy industry increases emissions throughout the period.

Thus, in most regions, countries do not meet the Intended Nationally Determined Contributions (INDCs) commitments set at COP21. Emissions concentrations translate to about 3°C of global temperature rise.

In 2060, physical and economic destruction caused by the impacts of climate change make adaptation the primary focus.

FINAL ENERGY CONSUMPTION

TFEC grows by 46% from 2014 to 2060. Growth is most rapid to 2030, averaging 1.3% p.a. in the period. Beyond 2030, consumption growth moderates, averaging 0.6% p.a.

A global slowdown in economic growth dampens the outlook for industrial sector delivered energy.

ELECTRICITY

Slower economic growth reduces electricity demand early in the period. Still, the strong momentum of economic development and growing focus on domestic energy sources and efficiency boost electricity demand to a steady 1.6% p.a. to 2030.

Beyond 2030, demand for electricity slows to 1.3% p.a. to 2060. By then, the electrification of final energy consumption has reached 25%, with 20% of electricity coming from wind and solar.

PRIMARY ENERGY

High energy demand

Population growth, and slow progress on energy intensity translate into TPES growth of 34% from 2014 to 2060.

Low mobilisation on climate issues and the priority given by many states to energy security based on local resources helps to **preserve the position of coal and oil in the global energy mix**.

Reduced funding capacity leads to **lower investment in clean energy technologies**, especially in transport. Many countries can no longer support EV incentives and renewable energy subsidies beyond 2020, leading to higher prices and lower consumer demand for new, cleaner sources of electricity and transport. Thus, the primary energy mix remains heavily dependent on fossil fuels.

From 2014 to 2030, the share of fossil fuels falls just from 81% to 79%. By 2060, fossil fuels remain the dominant source of energy, accounting for 70% of primary energy.

Hard Rock		2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total		13 652	14 865	16 154	17 012	17 654	18 272	0.6%
Coal		3 902	3 932	3 923	4 044	3 524	3 194	-0.4%
Oil		4 276	4 578	5 044	5 180	5 176	5 139	0.4%
Gas	**MTOE**	**2 891**	**3 392**	**3 727**	**3 811**	**4 231**	**4 370**	0.9%
	Share	**21%**	**23%**	**23%**	**22%**	**24%**	**24%**	
Nuclear		659	840	994	1 160	1 391	1 713	2.1%
RES		1 923	2 123	2 467	2 816	3 330	3 856	1.5%
- Biomass		1 408	1 498	1 631	1 742	1 960	2 098	0.9%
- Hydro		334	377	414	459	511	563	1.1%
- Others		181	248	422	615	859	1 195	4.2%

Coal

Energy security and affordability concerns spur growth in domestic production of coal in India and other parts of Asia. Coal demand remains resilient in India throughout the period. Chinese demand for coal peaks in 2020, at more than 2,100 MTOE. Declines in Europe and NAM are not enough to offset this consumption growth in Asia. Thus, coal in TPES does not peak until 2040, at 4,000 MTOE.

Oil

Demand for domestic energy leads to a rise in upstream exploration in resource-rich regions. The Middle East remains the number-one producer and exporter of oil.

Unconventional resource development continues to grow rapidly in NAM. Once US production peaks in 2030, Canada drives most supply growth through 2060, followed by Argentina and later Russia. Production peaks in 2040 at 16 mb/d, accounting for nearly 16% of global oil production.

Nuclear

With increasing national government support for domestic energy sources, nuclear in TPES grows at 2.1% p.a., reaching 9% share of TPES in 2060. Nuclear also accounts for a 15% share of electricity generation. Most of nuclear additions throughout the period are in China and India. NAM and Europe keep nuclear installations relatively flat.

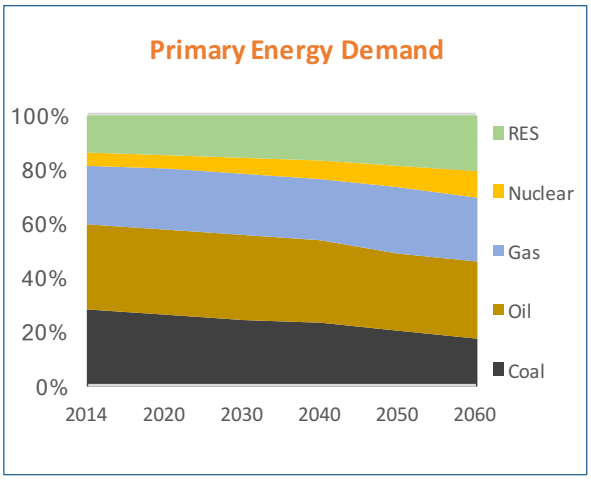
Solar and wind

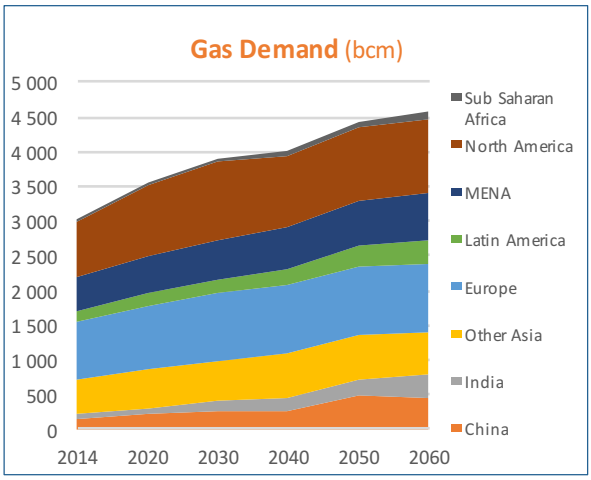
Solar and wind generation grow rapidly, averaging 4.2% p.a. in the period. Continued technology advances reduce capital costs for PV and concentrated solar by 40% to 50% across regions to 2060.

Thus, solar electricity generation grows from 200 TWh in 2014 to 800 TWh in 2030, and 3,270 TWh in 2060. China accounts for the largest share of capacity additions, followed by India, NAM and Europe. Wind electricity generation grows from 720 TWh in 2014 to nearly 2,000 TWh in 2030, and 5,600 TWh in 2060. The largest additions are in China, India, Europe and NAM.

IMPLICATIONS FOR NATURAL GAS

A moderate growth of Gas

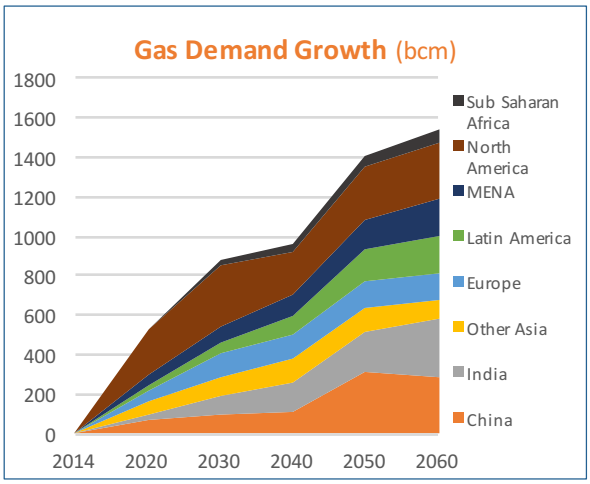




Low economic growth and a decline in global trade lead to moderated demand growth for natural gas. Still the share of primary energy rises to 24% in 2060.

Gas supply struggles to meet demand due to trade restrictions and must compete with more affordable coal.

Markets



Natural gas growth averages 1,6% p.a. to 2030, led by NAM and Europe. China and India see moderated growth, adding below 200 bcm to TPES.

Beyond 2030, gas growth slows substantially in Europe; NAM sees a slight decline; however, China, India, MENA and Latin America continue to see significant growth in natural gas demand to 2060.

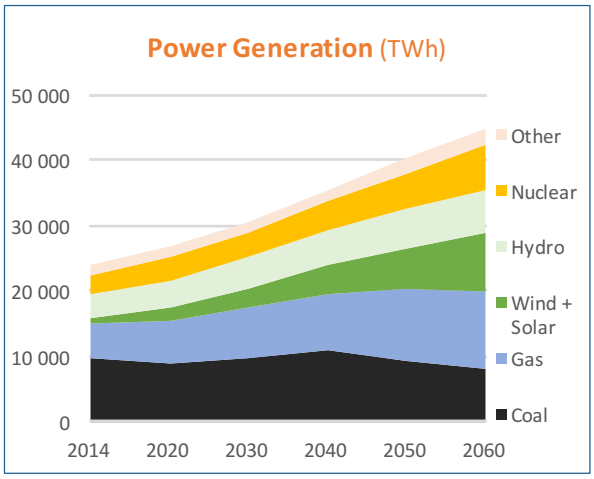
The emphasis on security leads to a steep decline in energy trade, resulting in a substantial fall in liquidity and transparency in global markets. Thus, energy commodity prices become increasingly volatile and pricing at regional hubs sees widening differentials.

Production

Natural gas production growth is seen in NAM, China and MENA to 2030. NAM supply additions reflect 40% of added supplies from 2014 to 2030. Russia struggles to boost supplies in a low-trade climate, while China and NAM invest in RD&D to ensure steady domestic supplies through 2060. China and MENA lead the way from 2030 to 2060, with MENA surpassing the US as the number one producing region in 2050.

Unconventional gas production grows rapidly before peaking in 2030 at 966 bcm, reflecting 26% of global gas production in the same year. Growth is led by production in NAM, China, Australia and Argentina. As energy demand begins to slow in the second half of the period, unconventional gas production declines rapidly, settling at just 79 bcm in 2060.

Power generation



Growth in natural gas account for 38% of added generation by 2030.

Although coal remains a major energy source in this scenario, gas production benefits from increasing demand for electricity and more than doubles between 2014 and 2060.

The lack of consideration of climate issues does not require the implementation of CCS technologies and slows the development of wind and solar

Transport

By 2060, natural gas increases its share in heavy-duty transport, to 7,2% of transport fuels. Nevertheless, the use of gas in transport remains limited to around 300 bcm, or 6.4% of total gas demand.

5. REGIONAL ANALYSIS

KEY POINTS

- In **mature markets,** demand for gas progresses in the first phase mainly by substitution of coal in power generation and declines dramatically in the second phase in Unfinished Symphony and moderately in Modern Jazz. The low mobilisation on climate issue in Hard Rock slows the deployment of renewables and prevents any decline during the period.
- In **emerging markets,** economic growth and potential of substitution of other energies lead to international trade and more limited consideration of environmental issues.
- In any case, by the end of the period the gas market landscape has dramatically changed. Whatever the scenarios, Asia will drive gas consumption growth while the market has entered a decline phase in mature economies.

MATURE MARKETS

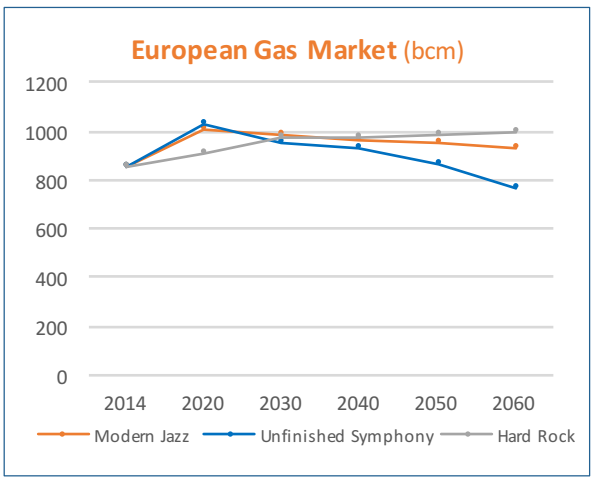
In two scenarios, **Modern Jazz** and **Unfinished Symphony**, demand for gas progresses in the first phase and then begins to decline at a pace depending on the region and the scenarios.

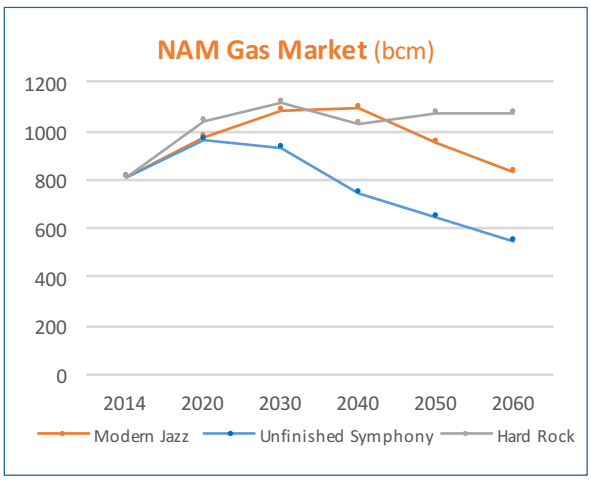
This trend is particularly marked in **Unfinished Symphony**, where there is a sharp and rapid decline due to the importance of environmental issues. After having benefited from an incentive policy for the substitution of coal for gas in electricity production, gas is in turn gradually replaced by renewable energies in the production of electricity.

The trend is similar but appears later in **Modern Jazz**

In **Europe,** peak demand occurs quickly in both scenarios, around 2020, while in **North America** peak demand occurs somewhat later in Modern Jazz, around 2040.

In **Hard Rock**, however, there is no phase of decline during the scenario period just a stagnation in demand from 2030 onwards, in Europe as well as in North America. These two markets remain the most important gas markets with around 1,000 bcm each. The least environmental pressure in these areas mainly explains these differences.

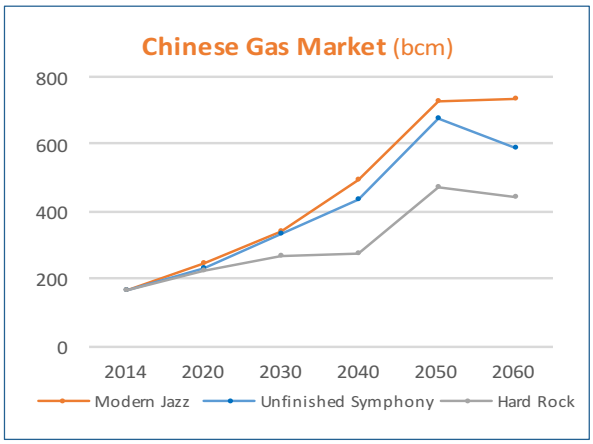


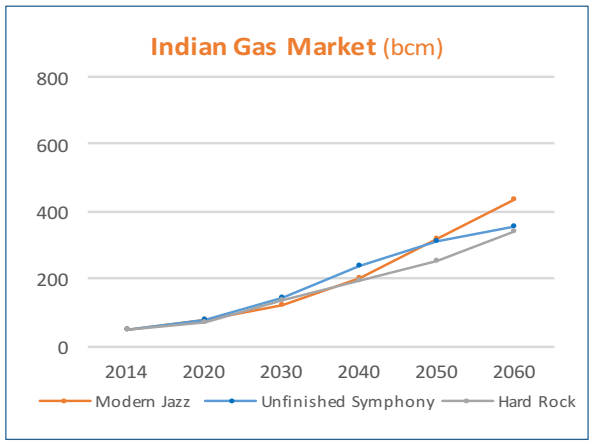


EMERGING MARKETS

Asia

In all scenarios, the Chinese and Indian markets are experiencing extremely strong growth.





Between 2014 and 2050 the Chinese market is multiplied by 2.9 in the worst-case scenario (Hard Rock) and by 4.5 in the most favourable (Modern Jazz). In India, the growth is even stronger, as **over the same** period the Indian market is multiplied by 5.7 in Hard Rock and by 7.1 in Modern Jazz. In 2050, the Chinese and Indian markets added are close to 1,000 bcm in Modern Jazz, a little higher than Europe and North America.

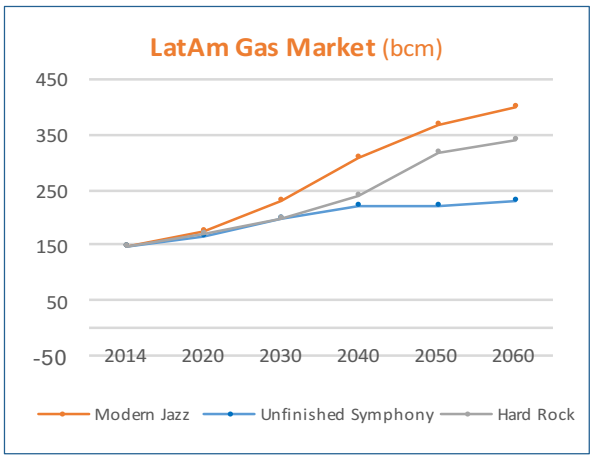
By the end of the period, there appears a significant change: Chinese market stabilizes (Modern Jazz) or even enters a phase of decline (especially in Unfinished Symphony). This development reflects a greater maturity of the gas market, which is approaching that of Europe and North America, with a lag of about twenty years.

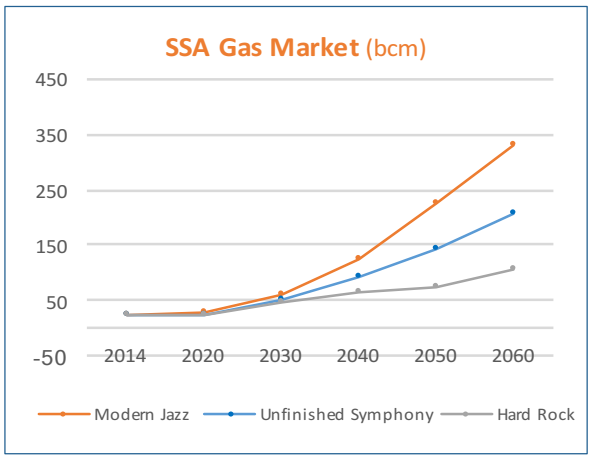
Latin America & Carribean

By 2060 market is also growing in all scenarios but more moderately than in Asia (multiplied by 1.5 in Unfinished Symphony and 2.7 in Modern Jazz).

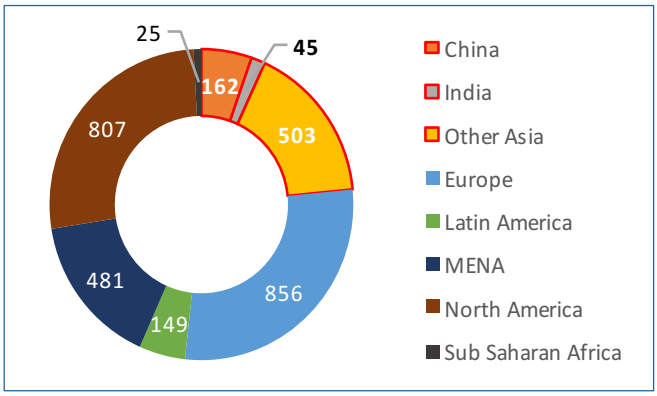
Sub-Saharan Africa

Almost negligible in 2014, SSA market is experiencing a real explosion in Modern Jazz, where it is multiplied by 9 in 2050 and 13 in 2060, benefiting from the development of the LNG market, which allows the exploitation of its resources. On the other hand, in the Hard Rock scenario, where security of supply concern incentivises countries to favour local resources and slows down the growth of the international market, the market reaches only about 76 bcm by 2050 and 106 in 2060.



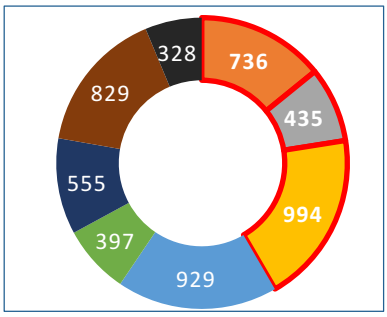


A GENERAL MOVE TOWARDS ASIA

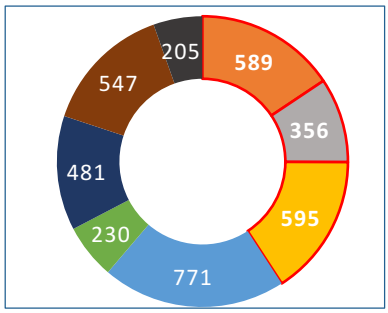


In 2014, the Asian gas market (710 bcm) accounted for 23% of global gas market.
By 2060 it would be
x 3 in Modern Jazz (2,165 bcm)
x 2.2 in Unfinished Symphony (1,540 bcm)
x 1.9 in Hard Rock (1,384 bcm)

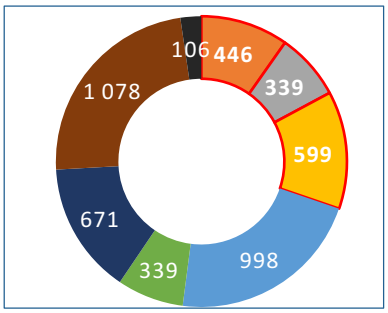
2060 - Modern Jazz
Asia 42%



2060 - Unfinished Symphony
Asia 41%



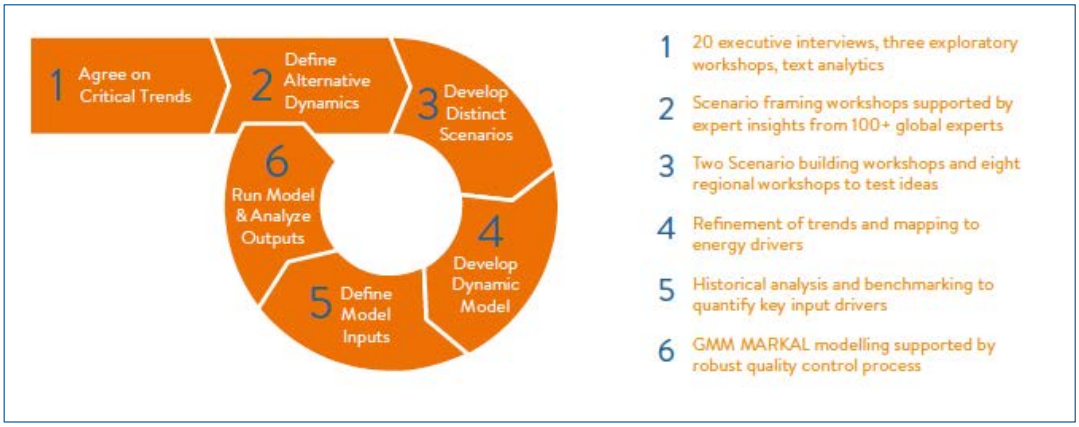
2060 - Hard Rock
Asia 30%



In any case, whatever the scenarios, Asia will drive gas consumption growth

METHODOLOGY

PROCESS



THE GLOBAL MULTI-REGIONAL MARKAL MODEL – AN OVERVIEW

The scenarios were quantified using the Global Multi-Regional MARKAL Model (GMM). GMM is a tool used to quantify and enrich the scenario storylines developed by the World Energy Council. GMM's detailed technology representation enables the model to provide a consistent and integrated representation of the global energy system, accounting for technical and economic factors in the quantification of long-term energy transitions. The model is driven by input assumptions reflecting the scenario storylines and applies an optimization algorithm to determine the least-cost long-term configuration of the global energy system from a social planner's perspective with perfect foresight.

GMM belongs to the family of MARKAL (MARKet ALlocation) type of models, where the emphasis is on a detailed representation of energy supply, conversion and energy end-use technologies (i.e. a so-called "bottom-up" model). GMM is a technologically detailed cost-optimization model that has been developed by the Energy Economics Group at the Paul Scherrer Institute (PSI) over a number of years (Rafaj, 2005; Gül et al., 2009; Densing et al., 2012; Turton et al, 2013; Panos et al. 2015; Panos et al. 2016). The Council joined as a model partner to support continued development and dissemination of the model with the goal of improving transparency, accessibility and credibility of global energy scenario modelling. In this regard, the Council and PSI have developed GMM into a fully open source model available to all Council members (subject to licensing). Such tools do not seek to directly model the economy outside of the energy sector, which is represented as a set of exogenous inputs to the model based on a coherent scenario storyline.

GMM is applied to identify the least-cost combination of technology and fuel options to supply energy services using a market-clearing optimization algorithm. This algorithm simultaneously determines equipment investment and operating decisions, and primary energy supply decisions for each region represented in the model to establish equilibrium between the cost of each energy carrier, the quantity supplied by producers, and the quantity demanded by consumers. Additional information about the model and its methodology can be found at the PSI's website **https://www.psi.ch**

GEOGRAPHIES

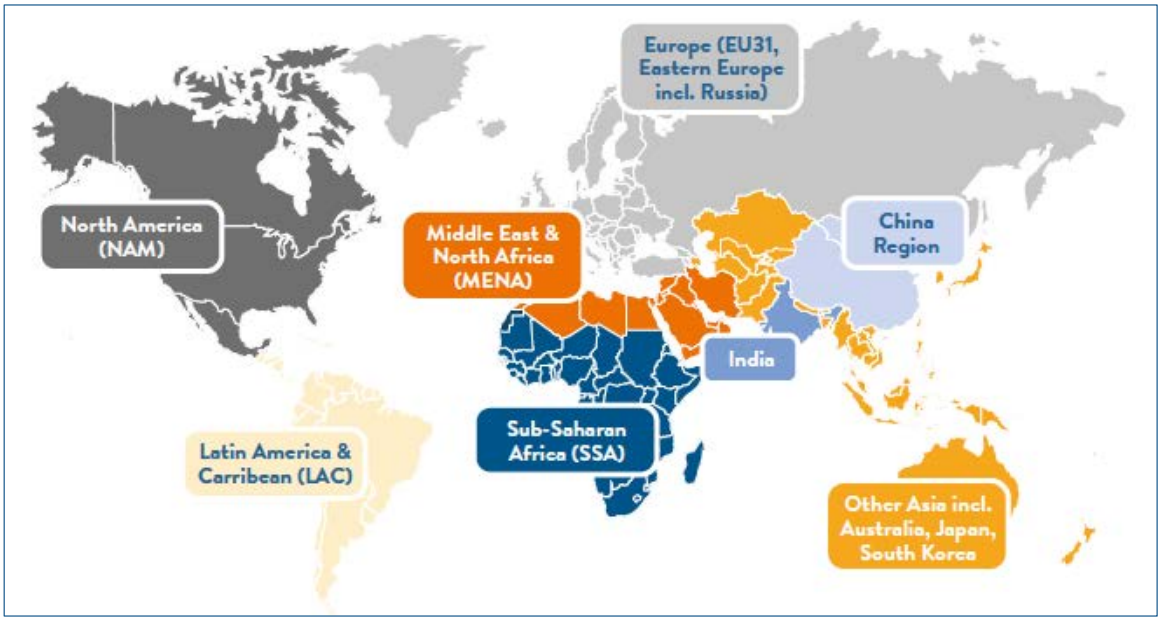
PSI's model contains 15 world regions. For this report, the Council highlights eight world regions, which have the biggest impact on the energy sector shown in figure below.

Major countries are modelled as separate regions: Brazil, China, the European Union (including Croatia (which joined in year 2013), together with Iceland, Norway and Switzerland), India, Russia, and the USA.

Aggregated regions include: Eastern Europe (Albania, Armenia, Belarus, Bosnia and Herzegovina, Georgia, Macedonia, Moldavia, Serbia, Turkey, Ukraine) and Russia; South and Central Asia (excluding India); the developed far East (Japan, Korea and Taiwan); Australia together with New Zealand; other Latin America together with the Caribbean (excluding Brazil and Mexico); the Middle East together with North Africa; Canada together with Mexico; and Southeast Asia and the Pacific.

For each region, scenario assumptions influence the dynamics of demand and supply technologies (cost, efficiencies, availability). The regional and technology differentiation leads to a large-scale optimization model with approximately over 200,000 equations.

THE 8 WORLD REGIONS FOR THE GRAND TRANSITION NARRATIVE



CALIBRATION OF ENERGY DEMANDS, TECHNOLOGIES AND ENERGY RESOURCE POTENTIALS

The GMM model is calibrated to recently published statistics for the year 2010. This calibration covers current demands for each energy subsector, the technology and fuel shares, and estimates on current costs and efficiencies of technologies. A primary source used for much of the calibration of fuel production and consumption is the IEA's Energy Balances (IEA 2015a). To ensure a better representation of developments since 2010 (up to the year 2013), the model uses additional statistics for recent years for which reliable data are available (EIA, 2015; BGR, 2016; IEA, 2015b; see Turton et al., 2013 for further references).

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