The sustainable credentials of gas

A study of scenarios to 2050 by using PRIMES

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Introduction – Reassessing the future

"No one is less ready for tomorrow than the person who holds the most rigid beliefs about what tomorrow will contain."[1]

This study does not intend to prescribe what lies ahead. Nor ought it to create a fixed understanding of the future. It seeks better understanding of what might be possible in the years to come. From a number of possibilities explored, we are able to gain insight not only into what might be possible, but also what is worth aiming for, from a broad societal perspective; not only what to plan for in investment portfolios, but what to strive for in achieving a future energy system that perpetuates noble progress, and not bitter regret. The aims to reduce anthropogenic emissions that are harmful to our natural environment have been deemed worthy of all the human energy we can afford. Energy not to fight the old, but to create the new.[2]

Never has this been more apparent. The Paris Agreement reconfirms the urgency of deep decarbonisation to maximise the global temperature rise to 2 °C. At the same time, the European energy sector is undergoing one of the most transformative changes in its history. Accelerated technological change, shifting consumer preferences, the application of information and communication technology (ICT) to link generation, supply, distribution and demand provide unprecedented challenges and opportunities.

Moreover, Europe, with its many economically and industrially powerful nations, faces emissions reduction targets while at the same time struggling to recover from the economic crisis, with tightening constraints on increasingly required investments. Indeed, many assumptions for questioning possible future scenarios have changed since the *Eurogas Roadmap* was published in 2011. Within the energy landscape, three key lessons can be learned from the last five years:

1. **The perceived value** of gas has changed considerably for various reasons, while electrification of the energy system is often referred to as a solution.
2. **Technological innovation** is powerful, for example shown by the recent development of power-to-gas as a new technology to solve intermittency of renewable energy sources and electricity storage issues.
3. **Supply** of fossil fuels have gained a much longer time horizon than previously assumed, following new discoveries around the world, thus expanding the potential gas could offer in terms of volumes and enabling fuel. The longer horizon challenges competitiveness between fuels and other sources of energy. Continued globalisation of the gas market caused by liquefied natural gas (LNG) also opens new vistas.

A reassessment of the pathways towards a low-carbon future, and a determination of the new possibilities and opportunities and what it would imply for current policy considerations, is thus required. In addition, the last five years show that developments in each form of energy are not to be assessed in isolation, as everything is increasingly interconnected and thus interrelated.

[1] Watts Wacker, Jim Taylor and Howard Means, *The Visionary's Handbook*, 1999.
[2] Adaptation from Socrates.

These views and actions decided upon today do not need to be defined by the past, which informs us, but they do need to be forged by the future that we have collectively chosen to define.

This study envisions a future in which the EU's agreed climate targets are met. It demonstrates that considerable progress can be made early by tapping into the vast potential that gas (natural and renewable) offers in delivering a sustainable future.

Part 1
Questioning the future

KEY FINDINGS

This study finds that the **versatile role of gas enables a socially acceptable pathway to 2050 with even more ambitious emissions reductions by 2030, supporting higher shares of renewable energy, while limiting cost increases for consumers.** The lowest cost for decarbonisation until 2030 is met in the scenario with the highest gas demand, while until 2050 renewable gas offers system-wide opportunities. The lowest costs for decarbonisation are especially important as the economic outlook is the weakest in the short term while struggling to recover. Against this macro background, customers should not be faced with unnecessary costs.

This is based on the following four key findings:

Sectors difficult to decarbonise, such as residential, transport and industry, illustrate the versatile role of gas in reducing emissions. In the residential sector, more than three-quarters (76 %) of current buildings will still stand in 2050. This requires a tailor-made approach. Gas boilers are the selected preferable choice for consumers, leaving gas demand in the EU-28 stable until 2030, thanks to technological improvement and fuel switching. Another key driver for decarbonising this sector is a largely increased refurbishment rate of the existing housing stock, from less than the current 1 % to 2-3 %. In the transport sector, gas demand is set to pick up strongly before 2030, as it decarbonises heavy-duty road and maritime transport and contributes to clean air, while maintaining travel distance and load. In the industrial sector, the well-controlled high temperature heat by gas remains a key feature that is difficult to replace. However, despite a slight recovery of industrial demand, this sector is facing severe economic difficulty and Eurogas questions whether an outlook for Europe to a services-based economy recognises the value of industry and would be fully resilient.

A strong push for electrification would quickly result in system limitations and high overall costs. An often-presented view for the difficult-to-decarbonise sectors contains a very strong push towards electrification. However, the modelling shows that this would neglect the benefits of a mix of decarbonisation options in other sectors and require much stronger decarbonisation measures in the power sector, such as more carbon capture and storage (CCS) and/or nuclear in order to remain cost-effective. Despite electrification in the transport sector, gas demand is set to increase, confirming a need for gas fuel stations. Moreover, this study finds that electrification is limited and causes high upfront investments for electrical appliances for consumers.

Innovative gas solutions enable much higher shares of renewable energy, providing optionality to meet the 2050 targets. This study finds that decarbonisation does not mean a reduced gas demand. On the contrary, it finds that increasing the gas demand helps to meet emissions reduction targets, as we find that the scenario with a higher share of renewables (+7 %) goes hand in hand with a higher demand for gas (+9 %). Also, after 2030, the gas system remains crucial for decarbonisation pathways. Innovative technologies, like power-to-gas, enable the further growth of renewables. While still in its innovation stage, the power-to-gas solutions are equal to the costs of electrification, while innovation could very well result in even lower costs.

Delivering more ambitious emissions reductions in 2030 provides time for new options towards 2050. A switch to gas in power generation is not foreseen in the forecasts of the European Commission, while outlooks of the IEA for example see this potential. With such a switch, an additional 5 % of carbon dioxide (CO_2) reduction could be achieved by 2030. All scenarios require gas and gas imports in order to contribute to the lowest cost scenario. A market-driven security of supply remains important, and Europe should remain attractive to suppliers around the world.

Realistic pathways to our common future – scenarios and sensitivities

This study uses the PRIMES model to address the questions of future scenarios. It is the same model as that used by the European Commission for its Reference scenario. The consultant developed two scenarios to explore potential pathways to 2050. These scenarios meet the 2030 targets for greenhouse gas (GHG) emissions reductions, renewable energy and efficiency[3], and result in less emissions than was defined in the carbon budget of the *Low Carbon Economy Roadmap*[4] until 2050, which is compatible with a 2 °C global scenario. The scenario uses the available options according to their economic potential. Lastly, it assumes the implementation of the Third Energy Package creating a well-functioning internal market for electricity and gas. A sensitivity analysis was made for each of the two scenarios in order to address the consequences of different trends that affect the energy mix.

1. Scenario: Conventional Wisdom

- The aim of this scenario is to assess a future based on conventional wisdom.
- Economy to pick up towards 2020, but much lower compared with previous outlooks (EC, 2014).
- Renewable energy, especially wind power, is to increase to 47 % of all power generated in 2030 and 65 % in 2050.
- Nuclear power is limited by upcoming closures, but stable in the long term.
- CCS is to be developed at a slower pace than previously expected, but is still present.
- There is increased use of gas for shipping and truck transport, while other forms use hybrid technologies.

1.1 Sensitivity: Electrification

- The aim is to assess the consequences of an increasing push towards electrification and its consequences for the consumer, based on the Conventional Wisdom scenario.
- It addresses the first of the three key lessons mentioned in the introduction.
- Electrification is increased for heating and other stationary energy uses, and in transport.

2. Scenario: Innovative Gas

- The aim of this scenario is to assess the developments of recent years, addressing the second key lesson set out in the introduction.
- The macroeconomic outlook is the same as in the Conventional Wisdom scenario for comparability.
- It explores the potential of power-to-gas, with renewable gas being used in the full system.
- Less new nuclear sites are available, reflecting current societal concerns.
- Less CCS sites are available, and the technology develops at an even lower pace of.

2.1 Sensitivity: Fuel Switch

- The aim is to assess the consequences of a fuel switch in the power sector, based on the Innovative Gas scenario as it is found that this does not occur with the current model settings, and to address the third key lesson of the introduction.
- Gas has to be made competitive in the power sector, as indicated by the prices used by the International Energy Agency (IEA) in its World Energy Outlook (WEO) 2015 450

[3] EC (2014), Council Conclusions of 23-24 October 2014; being 40 % reduction of GHG emissions in the EU compared with 1990; 27 % renewables in gross final energy demand and 27 % energy efficiency measured as primary energy demand reduction compared to 2005 (PRIMES 2007 projection).

[4] EC (2011), COM/2011/0112 final.

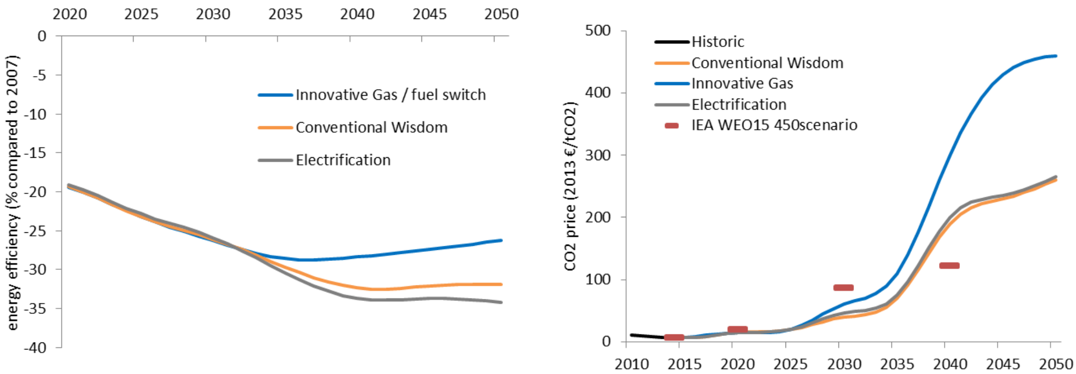
scenario.

- The emissions reductions of this sensitivity come in addition to the climate targets.

THE PRIMES MODEL

The PRIMES model is a model that explores 'what-if' questions by changing input parameters and showing the consequential effects on the results. The PRIMES model is a modelling system that simulates a market equilibrium solution[5] for each form of energy supply and demand. The market equilibrium is achieved for each 5-year interval and is dynamic over time. It reflects considerations about market economics, industry structure, energy/environmental policies and regulations, which are conceived so as to influence the market behaviour of energy system agents. A more detailed description of the PRIMES model is included in Appendix 1: The PRIMES model.

Figure 1: Energy intensity (left) and CO_2 price development (right)



The PRIMES model foresees strong improvements in energy efficiency for all scenarios and sensitivities, but after 2035 the required efficiency improvement for decarbonisation is less for the innovative gas scenario and deepest for the electrification sensitivity.

The modelling of the Emissions Trading Scheme (ETS) interacts with the emitting energy sectors. The ETS prices derived endogenously depend on the surplus, the discount rate and the issuing rate of allowances. All scenarios include the Market Stability Reserve (MSR), which implies that the price trajectory is likely to be concave (prices rising earlier) towards 2050. However, until 2030, the carbon dioxide (CO_2) price increases only slightly – to EUR 40/tonne in the Conventional Wisdom scenario and to EUR 60/tonne in the Innovative Gas scenario – then increases significantly due to stronger measures for emissions reductions: in 2050 it is up to EUR 260 and EUR 450/tonne respectively. The CO_2 price in the low carbon scenarios reach high levels in the long term, but the payments for acquiring allowances are stable or even decrease in the long term, as the ETS sectors attain very low carbon intensity.

The scenarios and sensitivities in this study meet the 2030 targets for greenhouse gas emissions reductions, renewable energy and efficiency.[6] It does not exceed the carbon budget of the *Low Carbon Economy Roadmap*[7] defined until 2050 as cumulative emissions for 2010-2050, which is compatible with a 2 °C global scenario.

[5] Market equilibrium solution means a scenario where demand and supply are equalised, taking into account consumer choice.
[6] EC (2014) Council Conclusions of 23-24 October 2014; being 40 % reduction of GHG emissions in the EU compared to 1990; 27 % renewables in gross final energy demand and 27 % energy efficiency measured as primary energy demand reduction compared to 2005.
[7] EC (2011) COM/2011/0112 final.

Part 2 Results:
The versatility of gas: decarbonising each sector

This section lays out, sector by sector, the principle results of the modelling for both the Conventional Wisdom and the Innovative Gas scenarios. Attention is also paid to the possibilities and effects in each sector, and should deliberate efforts for electrification (Electrification sensitivity). Attention is also paid to the results of the accompanying analysis of a coal-to-gas switch up to 2030 (Fuel Switch sensitivity).

The Conventional Wisdom scenario demonstrates a stable gas demand to 2030, and a realisation of the 2030 and 2050 targets. However, it basically depends on - not necessarily socially desirable - CCS and nuclear. Electrification falls short of deep penetration rates, due to higher costs and burdens on the consumers. The Innovative Gas scenario provides for a path that achieves all the targets and the highest renewable energy penetration, in a cost-saving way with a high economic upside.

DOWNSTREAM SECTORS – THE UPSIDE POTENTIAL

Market liberalisation and market functioning present more choices for consumers, and lead to more active and vocal consumers. Clearly there is a shift in attention to downstream developments, logically following a strong focus on the wholesale markets over the past years. The consumers in the residential sector are becoming more involved as actors in the energy sector by being able to switch to different suppliers and technologies, having access to better information on consumption (and responding accordingly) and being able to become a producer of energy themselves. These developments are, on the one hand, driven by changing social values and behaviour that seek to uphold aims to preserve our planet's well-being, and on the other hand by economic considerations (subsidies and savings).

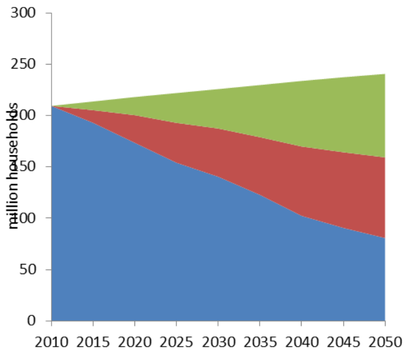
Heating and cooling makes up a large sector of Europe's energy demand. In 2015 it represented 36 % of the EU's final energy consumption, of which gas covered 44 % across Europe, albeit with a considerable variation across Member States. Providing for customer choice and driving down cost without hampering emissions reductions are key advantages for a future scenario supported by gas utilisation in an increasingly intelligent way. Up until 2030, the Innovative Gas scenario achieves all of this: lower cost, ambitious emissions reductions and consumer choice. Furthermore, the pathway is laid for greater cost reductions toward 2050, and even more ambitious emissions reductions.

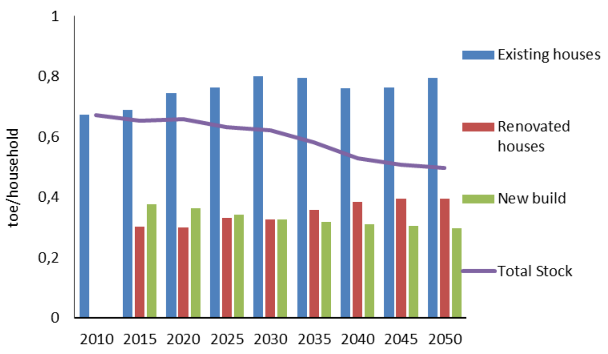
Conventional Wisdom: stable gas demand to 2030

Residential sector

A key parameter for the changes in the residential sector is the expected development of the housing stock. The model shows that more than three-quarters (76 %) of the currently existing buildings will still stand in 2050. This implies that while the Near Zero Energy Buildings (NZEBs), a key policy objective, is for newly built houses, the majority of the change is expected from the refurbishment of existing houses. It is assumed in the model that the refurbishment rates would need to be pushed upwards from the historic 1 % to a value between 2 and 3 % per year, and to change the average energy demand per house from 145 kWh/m^2 in 2015 to 68 kWh/m^2 in 2050.

Figure 2: Development of housing stock in all scenarios and sensitivities (left), and average energy consumption for heating (right)

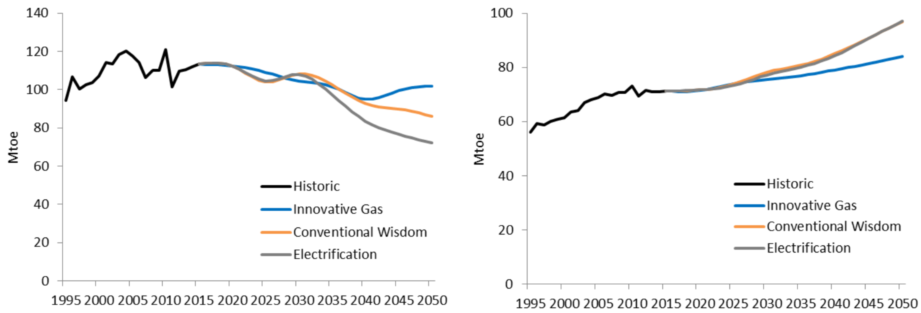




In this context of lower energy demand in the residential sector, the energy mix itself will also change over time. A key driver is the increasing shift away from oil and coal use for heating, to be replaced by efficient and cheap natural gas boilers, especially until 2030. The contribution from the natural gas sector to energy savings in the residential sector takes place by technological progress in heating appliances and the low cost of new equipment. Switching from traditional gas boilers to modern condensing gas boilers would easily save more than 20 % of energy use. In this scenario, gas demand is expected to remain stable until the 2030 climate targets are met.

Thereafter, the continuously reduced demand for energy due to the changes in the building stock will limit heating demand for natural gas as well.

Figure 3: Gas demand (left) and electricity demand (right) in the residential sector



Services and agriculture

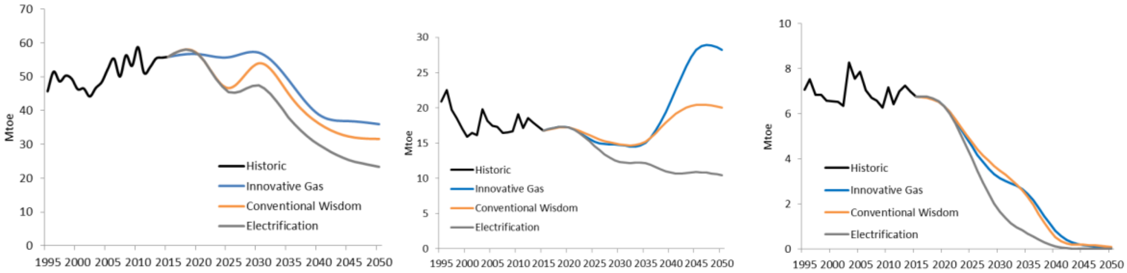
Likewise in the service and agriculture sector, energy efficiency is the key driver for all scenarios. Measured against 1995 levels, it is assumed that this sector is already 20 % more efficient in terms of value added, which is assumed to be 45 % in 2030 and 67 % in 2050, or similar to the residential sector. This is due to the improved thermal integrity of buildings for services, the wider use of heat pumps and the use of more efficient appliances overall. The energy requirements for heating and cooling are assumed to be reduced by a factor of three in 2050 compared with 2010.

The share of gas is maintained in the Innovative Gas scenario, in a context of gas replacing coal and oil, slightly decreased district heating and an increased share of renewables. As a result, gas consumption remains stable in this scenario until 2030, after which lower demand and renewable energies set the scene. The electrification sensitivity analysis shows a significant downward potential for gas through stronger electrification, even prior to 2030. In the services sector, the use of combined heat and power (CHP) enables the increasing uptake of renewables, while at the same time meeting the high energy demand of building for heating.

District heating

Demand for distributed heat will decline until 2035, following stronger energy-efficiency measures in the residential and services sectors. Production from boilers for district heating depends on the main source chosen to supply heat and on the demand for distributed heat. As a result, the share of gas in boilers for district heating is projected to decline steadily between 2020 and 2035. The electrification sensitivity shows that demand for district heating is much lower on such a pathway. This creates investment challenges for district heating, reaffirming the direct role of gas in each sector.

Figure 4: Gas demand for the services and agriculture sector (left), total energy demand (centre) and gas demand for the district-heating sector (right).



Electrification: limited in the cost-optimising model

Box 1: Is electrification a silver bullet?

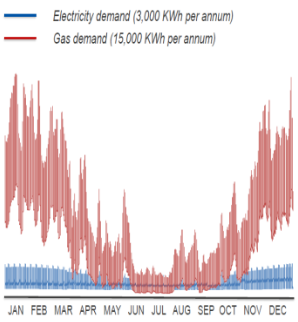
The electrification of heating has gained in consideration by consumers. New electrical appliances are increasing in market share and accommodate electricity produced from renewable sources. The intermittency of renewable energy production, however, poses a challenge for achieving a reliable energy system.

The PRIMES model assumes that smart grids develop well, albeit only for electricity, for two main purposes: to manage the recharging of battery-based cars to avoid load spikes, and to manage power generation from widely distributed renewables. The modelling based on PRIMES finds little scope for the development of fuel cells using hydrogen, and for micro-CHP and fuel cells powered by gas. However, the projections of future market shares of modern gas appliances (micro-CHP, fuel cells) could be higher if the learning-curve assumptions were more optimistic for these technologies (such as the Japanese experience in cost-effective micro-CHP development[8]). Gas-based smart systems, in which state-of-the-art gas appliances support decentralised renewable energy production by locally balancing demand and supply, have not been included in the modelling.[9]

This sensitivity represents the strongest push for electrification in stationary energy uses, considering economic and behavioural constraints, as modelled in PRIMES. It was found that electrification of the heating sector is limited by the very high upfront costs of electric heating appliances. From a cost optimisation perspective, the economics do not justify full 'all-electric' heating. In addition, spatial planning should include both gas and electricity infrastructure, as all-electric would limit the choice for consumers and impose a high investment.

Moreover, an often-overlooked limitation of switching to all-electric systems is the capacity needed for heating, especially in winter. The gas grids are capable of efficiently carrying vast amounts of high-density energy, without even being noticeable, as the pipes are underground. Replacing natural gas with electricity would have significant consequences on the grid requirements, particularly for peak requirements. Moreover, not only are there demand fluctuations within a year, but also strong differences between years, which influence total energy and gas demand.

Figure 5: Electricity and gas demand in Germany in a typical year. Source: Thuga, 2014



[8] International Gas Union (IGU) (2015).
[9] Joint Fuel Cell and Hydrogen Undertaking (2015).

This sensitivity on electrification finds a maximum share of electricity in energy used for heating of 17 % in 2030 and 27 % in 2050, after currently being some 12 %. Behaviour change in using these appliances is a key uncertainty, and has the potential to limit the increasing demand for electricity. Consequently, the share of renewable electricity penetration is limited and increasing up to a peak of 19 % just before 2040. The sensitivity shows the large role gas could still play while gradually greening gas supplies and effectively utilising the existing infrastructure. Full electrification of the sector is thus not a realistic pathway to reduce emissions in this sector.

Innovative Gas: maintaining convenience

The robustness of the low carbon strategy illustrated by the Conventional Wisdom scenario is weak from two perspectives:

- Firstly, the achievement of deep emission cuts in the long term greatly depends on the availability of deep decarbonisation options in the electricity sector, such as CCS and nuclear, which are surrounded by significant uncertainty.
- Secondly, the scenario needs to depress several of the currently efficient and convenient ways of using energy, mainly those using gas (heating and cooling, cooking, water heating, district heating and cogeneration).

The Innovative Gas scenario provides an alternative carbon-free solution for buildings: it allows consumers to continue using gas and maintains technology robustness, simplicity and convenience, while drastically reducing emissions. The power-to-gas technology, which is central in this scenario, needs high amounts of electricity generation, but the amount of electricity distributed remains at reasonable levels, as the low-carbon gas is a decarbonising energy carrier in all sectors, including residential. This implies the importance of gas grids being available to accommodate an increasing gas demand after two decades of decline. Maintaining the current distribution infrastructure thus provides optionality for deeper decarbonisation to the benefit of the consumer.

Conclusions

- The scenarios show a gas demand that remains stable until 2030, contributing to emissions reductions due to fuel switching and technological improvement.
- A key driver to decarbonise the residential sector is the refurbishment of existing buildings, as more than three quarters (76 %) of all current houses will still stand in 2050 through higher renovation rates and the replacement of heating equipment, e.g. replacing traditional gas boilers with condensing boilers.
- The future of district heating is found to be uncertain due to a broad range of outcomes. Moreover, a push for electrification would limit the economic potential of district heating, affirming the benefits of a balanced energy mix and technology-neutral policy.
- The expansion of the electricity sector is often regarded as the key to success in decarbonising our energy system. Although electrification will make sense in some instances and locations, it is not a silver bullet. As this study shows, its potential is limited, largely due to cost barriers. A broader diversification of the energy mix is more cost-efficient while decarbonisation continues.
- Moreover, even when pushing electrification to its limits in the model, natural gas remains essential in the residential sector. Maintaining the gas distribution grid is therefore key in order to maintain the benefits of the full gas system and its increasingly renewable content,

i.e. synthetic gas generated through power-to-gas technology, bio-methane and bio substitute natural gas, as well as hydrogen.

- The gas grids are capable of efficiently carrying vast amounts of high-density energy, without even being noticeable as the pipes are underground. Replacing natural gas with electricity would have significant consequences for the grid requirements, such as during peak requirements. In addition to demand fluctuations within a year, there are strong differences between years, which influence total energy and gas demand. Moreover, there is public resistance to the expansion of high-voltage power cables.
- In addition to the model results, there is further innovation potential in developing micro-CHP, fuel cells and gas heat pumps, among other technologies. Moreover, natural gas is an essential part of a smart energy system – especially as an all-electric system is not possible – gradually becoming renewable and maintaining convenience for the consumer.

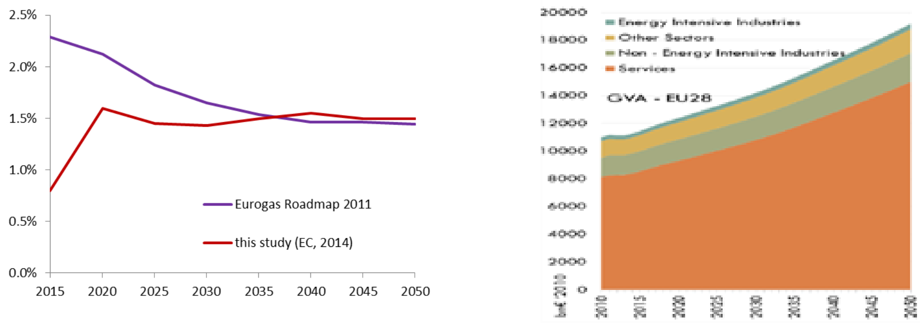
INDUSTRIAL SECTOR – BALANCING EUROPEAN TARGETS IN A GLOBAL CONTEXT

The European industrial sector represents roughly 20 % of total natural gas demand. The economic crisis and its aftermath over the last years had a significant impact on industrial activity. While the economy is set to grow, Europe’s industrial sector is facing numerous challenges, often related to their active role in the global market. Globally operating industries are able to economically optimise their assets through a shift to countries where operating costs are lower. There is evidence that innovation and industrial integration increasingly play a role and in this respect the EU has possibilities to maintain the industrial composition, provided that the low-carbon transition is also innovation-intensive. While European energy prices have remained quite competitive, industry is facing threats mainly due to increased taxes on energy.

Box 2: Economic expectations have profound consequences for forecasted energy demand

Europe is still struggling to shift to economic growth after the economic crisis. In the EU, the annual average gross domestic product (GDP) growth rate is projected to remain quite stable over the long term, albeit much lower than in previous decades. After an average potential growth of 1.1 % until 2020, a slight increase to 1.4-1.5 % is projected for the remainder of the projection horizon. Over the whole period 2013-2060, average output growth rates in the EU-28 is projected to be 1.4 %.

Figure 6: Current economic outlook (left) and structure of the economy (right) according to the European Commission as included in this study.



The economic structure is also expected to change. The European Commission foresees a decreasing role for industry in Europe and economic growth in the services sector. The share of services in GDP increases from 75 % in 2015 to 78 % in 2050. This raises concerns about the position of Europe in the global economy and could have strong consequences for our society. At the least it shows Europe in need of an open economy because then it would rely on industrial activity on other continents and should benefit from the global market.

This economic outlook is published in the European Commission’s Ageing Report 2014 and directly input to the PRIMES model. The results of this new study are thus illustrating a services-based economy, while a stronger economy and/or increasing industrial base would raise energy demand.

Scenarios: following the economic downturn, energy intensity will drop around 2030

The economic downturn and the related price environment have resulted in a sharp fall in investments[10], slowing down the rate of energy-efficiency improvements. On average, the energy intensity of the total industrial activity, measured against the value added, has dropped by 35 % since 1995, indicating a highly successful improvement achieved by the industry itself. In all scenarios it is expected to have decreased by 45 % in 2030 and 60 % in 2050 compared with the intensity of 1995. Compared with 2015 this means a drop of 20 % in energy intensity to 2030 and of 38 % to 2050. The decrease of energy intensity is based on the gradual shift of the industrial structure towards higher value-adding activities that are less energy and material-intensive, while the main energy-intensive and traditional industrial processes are projected to not change much.

The slowdown of industrial activity in Europe in the recent past has left considerable unused industrial production capacity. The economy is assumed to regain some strength in the short term, thus enabling the industry to recover slightly to the mid-2020s by using the currently underutilised capacity, which would lead to a small increase in energy demand. Later, the energy intensity is assumed to reduce energy demand. The model includes more than 40 types of industry, ranging from chemical, cement and paper to non-ferrous steel, and assesses 250 industrial processes. In industry, demand for fuels, first and foremost, is generated by the need for process heat. Consequently, primary energy demand is dictated more by the heat load than by the relative fuel prices. Heat based on coal and oil can be gradually replaced by lower carbon natural gas while maintaining the production of high-temperature heat, maintaining the share of gas roughly until 2030. The benefit of gas is its physical characteristic for delivering well-controllable, high-temperature heat. The use of on-site CHP remains stable until the mid-2020s. Despite a decline in large-scale CHP, the medium and small-scale plants are of special interest. Natural gas remains a key fuel due to its well-controllable steam and heat flow, and as such benefits the quality of the end product.

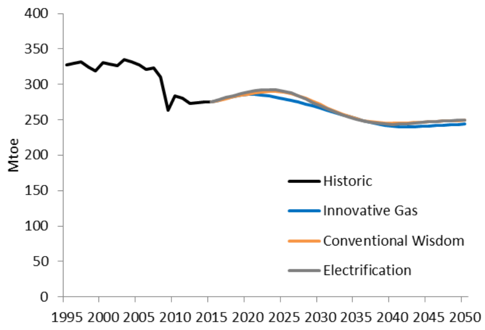
Electrification: only for low-temperature heat

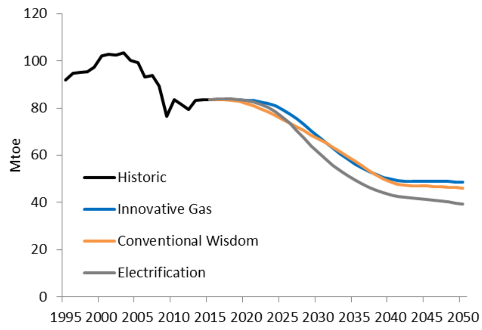
The sensitivity towards electrification indicates that this is difficult for industrial processes as they require high-temperature heat and electrification lends itself mostly to low-temperature heat. Natural gas thus remains an important fuel in this sector. Natural gas is also used by industry for non-energy purposes, mainly as feedstock for the manufacture of fertilisers and petrochemical products.

System integration of industrial clusters helps to keep Europe's energy industry competitive and helps to keep high-tech employment in Europe. It also creates a critical mass for joint industrial efforts to capture their CO_2, and induce the development of a market justifying the high costs of the investments required for the construction of CCS.

Figure 7: Total energy demand in industry (left) and its gas demand (right)

[10] IEA Medium Term Gas Market Report 2015.





Conclusions

- All scenarios expect energy intensity to decrease due to a gradual shift towards less energy-intensive activities. Note that PRIMES assumes a services-based economy with increasing unemployment.
- If the role of energy-intensive industry in the EU is to be maintained, this could influence total energy demand.
- Heat demand in industry takes place at different levels. High temperature heat is difficult to achieve with electricity, and fuel switching to natural gas is thus a key option for further emissions reductions.
- Energy-efficiency improvements are largely commercially driven. If legally imposed together with taxes and levies, they can reduce the industry's global competitiveness.

TRANSPORT SECTOR – REDUCING EMISSIONS WITHOUT COMPROMISING TRAVEL DISTANCE

The transport sector is difficult to decarbonise due to its large and diverse stakeholders and high infrastructure requirements. The different ranges of transport (domestic, international and intercontinental) raise challenges of cleaning up the sector. Air-quality regulation is a key driver toward lower emissions in this sector. Gaseous energy as a transport fuel allows cleaning up and decarbonising the transport sector without compromising travel distance, and without exempting heavy goods transport from emission improvements.

Conventional Wisdom: clean air and maintaining load

This study confirms what many studies show: gas will play an exponentially increasing role in transport for decades to come. Until 2030, natural gas will provide a quick decarbonising solution, and, the enabling step is the availability of gas fuelling stations.

Energy consumption peaked in 2007 across all modes of transport and started to decline thereafter, suggesting a decoupling from GDP growth. This trend is expected to continue. In fact, the energy intensity of transport indicated a 17 % decrease relative to 1995, and is expected to be further reduced by 39 % by 2030 and 63 % by 2050. The reduced energy intensity in the scenarios is due to improved energy-efficiency standards in passenger transport, such as CO_2 car standards, and to a much lesser extent in freight transport. In the scenarios, beyond 2025, new-generation biofuels based on lignocellulose feedstock will make significant progress in transport modes where electrification is not possible, such as aviation.

Key trends in fuel consumption are expected in road and maritime transport. Road transport has been considered to be a sector that would be decarbonised primarily through biofuels and electrification. But concerns about the sustainability of biofuels have limited their increase. On the other hand, natural gas as a transport fuel is a proven technology and easy to use in conventional combustion engines. For cars, as they are generally used for low-to-medium travel distances and have relatively low energy requirements due to their size, compressed natural gas (CNG), hybrid and electric engines seem to have a strong potential. But heavy goods vehicles and trucks require high-energy density to transport their loads. Electricity, and its related challenges for high capacity transmission and storage, is not well suited. Natural gas, on the contrary, is able to deliver a solution for heavy goods transport, in the form of CNG and LNG.

The same applies to maritime transport. The high-energy density, in combination with the availability of many LNG terminals along Europe's shores, creates great opportunities to decarbonise the shipping sector. Moreover, other emissions would also be drastically reduced. For example, an LNG-powered crude oil tanker would use 25 % less energy and emit 34 % less CO_2, more than 80 % less nitrogen oxide (NO_x), and 95 % less sulphur oxide (SO_x) and particulate matter than a conventionally fuelled vessel.[11] The compatibility of LNG with ship engines has already been demonstrated, as shown by ships sailing in the Baltic Sea, but also by ships travelling outside Europe, such as Qatar's LNG tankers.

Electrification: gas still set to increase

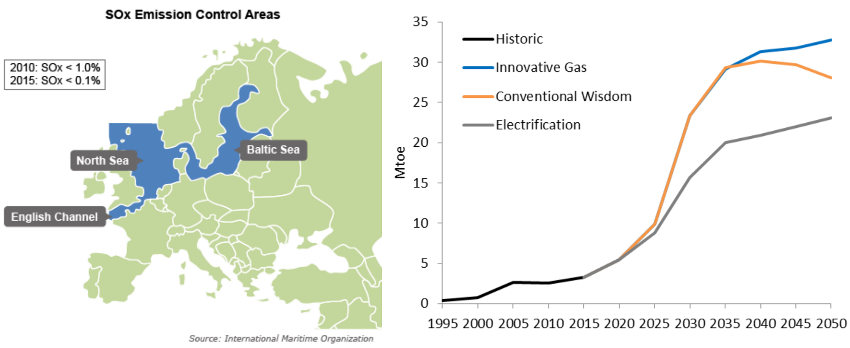
[11] Det Norske Veritas (DNV).

Even with electrification sensitivity, in which all-electric mobility is preferred over hybrids, gas in transport continues to increase, due to the fact that hybrid vehicles running on electricity and gas are envisioned to be favoured over those using electricity and diesel or petrol. The increase in gas is further driven by its competitive advantage for heavy goods transport and maritime shipping. Solely focusing on electric transport would hamper the decarbonisation of this sector, and natural gas fuelling stations would still be required. This would provide an opportunity to explore the role of gas beyond 2030.

Innovative Gas: decarbonisation beyond 2030

In the Innovative Gas scenario, volumes continue to rise until 2050 when they are projected to be about 32 million tonnes of oil equivalent (Mtoe). The penetration of bio-methane and power-to-gas enable an immediate decrease in the net emission factor of gas-fuelled vehicles without any technology constraints, using the existing infrastructure.

Figure 8: SO_x emission control areas in Europe, driving gas demand for maritime transport (left) and gas demand in transport (right)



Conclusions

- Driven by stricter air quality regulation, the challenge is to clean up and decarbonise the transport sector while maintaining travel distance and load. Natural gas provides a quick win for decarbonising the transport sector, as it can be used in conventional combustion engines. The energy density of gas makes it a key option to initiate decarbonisation of heavy-duty road transport and shipping. This is shown in both scenarios, in which the use of gas increases up to 2030. Natural gas with an increasing share of renewable gas provides an alternative for yet-to-be-developed biofuels.
- Also after 2030, gas demand continues to increase in the transport sector. The Innovative Gas scenario shows that increasing volumes of renewable gas continues to strengthen the role of gas as a transport fuel beyond 2040. It highlights that while natural gas contributes to emissions reductions in the short term, it also provides potential for renewable energy by increasing the shares of hydrogen and renewable gas, thus preventing a lock-in effect with respect to natural gas.
- For car and light-duty transport, the model assumes mainly electrification. It therefore does not show the further potential of CNG. However, even with stronger electrification of transport, gas demand in this sector is set to increase for heavy goods transport, requiring an increased number of fuelling stations.
- Fuel stations are an enabling condition to decarbonise the transport sector. Ensuring the availability of gas at fuel stations enables trucking companies to change their fleet and

significantly contribute towards carbon reduction. A coordinated approach, such as through the Blue Corridor, drastically increases the certainty required to make the fleet investments.

- Health and environmental concerns are pointing in the direction of further reductions of sulphur dioxide (SO_2), NO_X and particulate matter emissions.
- Gas bunkering is not included in Eurostat data collection, while it can significantly contribute to European maritime decarbonisation. This contribution should therefore not be neglected in assessing total gas demand.

POWER SECTOR – INNOVATING THE ENERGY MIX OF THE FUTURE

Whether in a scenario where a trend toward electrification is politically chosen, or in a scenario where gas and its associated innovative role in greening the system are fully employed, a robust role for gas is foreseen in power generation. This is necessary to enable more renewables in the system, and to achieve the 2050 emissions reductions target.

Yet this contrasts with the general trend that has been observed in Europe. The power sector has been drastically transformed over the last decade. The low electricity demand, the increase of renewables and the oversupplied global coal market have put pressure on gas-fired power generation. Moreover, the combined effect has led to a paradox, with the gas-to-coal switch offsetting the contribution of the increasing amount of renewable energy to emissions reductions. Adding to the complexity is uncertainty about nuclear energy. Closures are announced, while new plants face social resistance. The investments needed require a thorough assessment of future necessities for continued robust and sustainable power generation.

The future demand for electricity in all sectors depends on behavioural change and the progress in energy efficiency. While traditionally strongly linked to GDP, the decoupling started with the beginning of the economic crisis in 2008. Demand for electricity is set to rise in all scenarios, albeit limited by efficiency improvements. Therefore power demand is set to increase until 2030 by 0.6 % per year, while economic growth is on average 1.3 % per year.
The decoupling in this period mainly results from the energy-efficiency measures. Demand for electricity grows faster after 2030 (1.3 % per year) and closer to GDP growth, due to transport electrification. Driven by Emissions Trading Scheme (ETS) prices, which markedly rise in the low-carbon scenarios, power generation needs to reduce emissions significantly well before 2030 and become a near-zero emitter shortly after 2030. To this end, the model shows increasing shares of renewables suppressing the role of other fuels, except that of gas, which maintains an important balancing role in the system. Power generated from coal and nuclear may see over-capacity, when operating is out of the money, but closing is more expensive. Moreover, cycling requirements for lignite, coal and nuclear power plants are too high. After 2030, electrification is projected to increase further in the transport sector for cars, in addition to gradually increasing electrification in the other sectors. This increasing demand is projected to be met by renewables, requiring them to grow at a faster pace than prior to 2030.

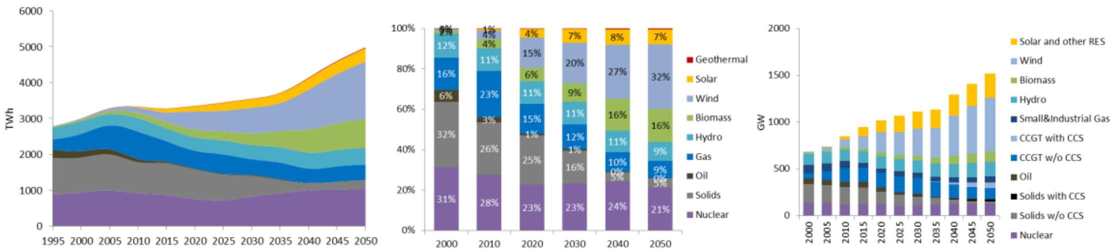
Conventional Wisdom: wind and nuclear?
Compared with current trends, the Conventional Wisdom scenario already demonstrates a significant increase in the share of renewables in total power production, with an increase from 27 % in 2020 to 47 % in 2030 and 65 % in 2050. Among renewables, hydropower is expected to increase slightly until 2030 and somewhat more strongly up to 2050 in both scenarios. Geothermal energy increases mainly after 2035, but its absolute volume remains low. Solar is expected to increase gradually in both scenarios in absolute terms, or to 8 % of the electricity demand, but its capacity is limited due to a lack of viable and socially acceptable space, such as rooftops. This scenario anticipates the most significant increase in wind generation, rising from 4 % in 2010 to 20 % in 2030 and to 32 % in 2050. Up to 2030 this increase is mainly onshore, but after 2035 mostly offshore, where the necessary scale will be achievable.

National regulatory measures are also a key driver. The total installed capacity of coal plants will continue to drop over the forecast period, driven by economic and regulatory plant retirements. A drop in nuclear capacity reflects political decisions taken in the aftermath of the Fukushima nuclear accident, such as in Germany, but also as recently announced in France and assumed for Belgium. This scenario shows an increase in installed capacity to 2040, but still well below the pre-Fukushima levels. The increase is particularly pronounced in Eastern Europe and is driven by the replacement of plants that have reached the end of their often already much extended lifetime.

These assumptions involve important investments in system adequacy and balancing, including back-up capacity for which natural gas is the most relevant fuel. Following the substantial mothballing of gas-fired power plants over past years, this declining trend is expected to slow down towards 2050. Nevertheless, this still requires an increase in investment in gas plants, peaking in the decade from 2030 to 2040.

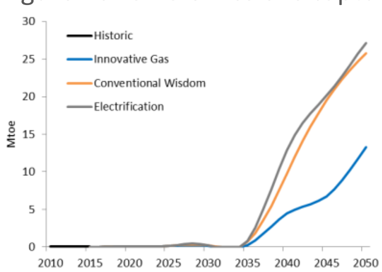
CCS is developed later and to a lesser extent than previously assumed by the PRIMES model, and only in the long term after 2035. Driven by the strongly increasing CO_2 prices – which reach EUR 40/tonne in 2030 and EUR 260/tonne in 2050 – the model selects CCS for the reduction of emissions from coal and gas plants.

Figure 9: Power mix, absolute numbers (left), shares (centre), and installed capacities



Electrification sensitivity: tougher decarbonisation of the power sector after 2030
The effects of a stronger promotion of electrification in stationary energy uses will create a higher demand for electricity, particularly after 2030. The power demand will rise considerably, especially in the period to 2030, which will result in a higher demand for gas, but also for renewables.
As the challenge to decarbonise the expanding power sector increases, so does the dependency on decarbonisation options. This sensitivity shows a higher dependency on nuclear and CCS. The cumulatively captured CO_2 emissions are 10 %[12] higher in the electrification sensitivity compared with the conventional wisdom scenario on which it is based.

Figure 10: GHG emissions captured and stored in the scenarios



[12] 4.8 % of all cumulative CO_2 emissions are captured in the Conventional Wisdom scenario, while this number is 5.3 % in the electrification sensitivity.

Innovative Gas scenario

Two fundamental challenges that must be overcome in order to integrate high levels of renewable electricity into the electricity system are:

1. the utilisation of excess electricity that is produced when renewable generation exceeds electricity demand;
2. having an adequate source of dispatchable generation available when renewable generation production is low.

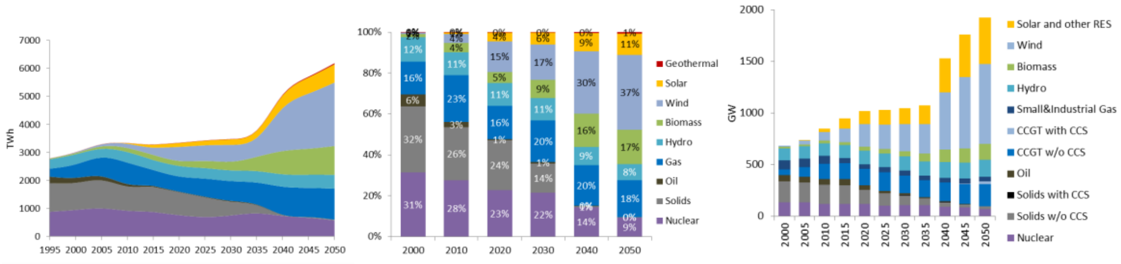
This is addressed in the Innovative Gas scenario analysing the current effects of power-to-gas – a newly developed feature in the PRIMES model. This scenario shows that the conversion of electricity to hydrogen and further to methane for use outside the power sector has the potential to utilise nearly all excess renewable electricity that would otherwise be curtailed[13], while also creating energy storage opportunities. The gas grid allows this energy to be used in all sectors, while it also maintains and utilises the existence of gas-fired power plants and infrastructure. Gas-fired power plants are to retain their share as seen in the first decade of this century.

Power-to-gas is regarded as a chemical storage in the model. It converts excess electricity into gaseous energy, which is injected into the gas grid. The first step is conversion to hydrogen, that can be injected into the gas grid albeit to a limited extent.[14] The second step is converting the hydrogen into methane. This innovative technology to convert power to gas competes with other forms of energy storage and demand-side response, but these are limited by the potential (for hydropower), costs, sites available (compressed air energy storage) and location of use (batteries can only be used at low voltage/distribution levels). Beyond the uptake of hydrogen, it is converted into methane and injected into the gas grid, in which all of this renewable gas can be used in every sector as a non-carbon fuel utilising the full extent of the gas network and gas applications. The assumed learning curves for power-to-gas are conservative for the conversion process of electricity to hydrogen, the capture of CO_2 from air and the conversion to syngas (methane). The conservative assumptions about learning imply high costs of the power-to-gas output. There is, however, significant potential for cost reductions, in which case the prospects of low-carbon gas will be higher than those projected in the context of the Innovative Gas scenario.

Figure 11: The power mix (left) and change in capacities compared with 2015 (centre), and the power mix in the Innovative Gas scenario

[13] Joint Fuel-Cell and Hydrogen Undertaking, 2015.

[14] A blending rate of 15 % hydrogen in a natural gas flow is technically possible, taking into account its effects on end-user appliances. This is slightly optimistic, as this level might not always be met due to gas flow fluctuations following gas demand. Converting the hydrogen into methane does not have such a limitation.



This scenario demonstrates that there is another option to a reliable and clean energy system besides nuclear and CCS. If cost curves do not significantly improve and/or social acceptance does not ultimately allow nuclear and CCS on a large scale in the long run, the costs of even mild electrification (as shown in the sensitivity) would become exceedingly high. But if nuclear and CCS are absent, energy conversion and storage in the gas grid are a very viable opportunity to realise an energy system consistent with the EU's aims. Renewable gas also has the merit of remaining sustainable over a long time period beyond 2050.

Innovative Gas scenario with a fuel switch

The scenarios in the PRIMES model assumed no fuel switch to gas in the power sector before 2030, due to the assumed prices of gas, coal and CO_2. Eurogas has therefore added a fuel switch to assess the effects of such a switch. The fuel switch is modelled by increasing the load factor of gas plants in the PRIMES model to increase gradually to 60 % by 2020, and decrease after 2030 driven by a diminishing power supply from conventional power plants. As such, the switch takes place within the system boundaries of the model, implying that using the IEA's price forecast would not result in higher costs caused by new investments and thus could be potentially lower. Therefore, the results are comparable with the Innovative Gas scenario.

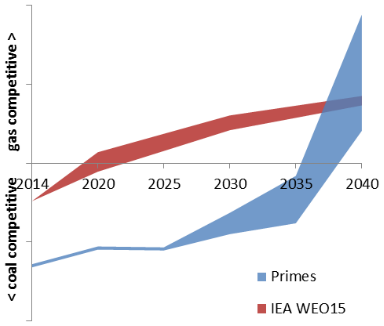
Box 3: The IEA's WEO 2015 sees a different future for the power sector before 2030

The supply of fossil fuels has gained a much longer time horizon than previously assumed, following new discoveries around the world, expanding the potential that gas could offer in terms of volumes and as an enabling fuel. The longer horizon challenges competitiveness between fuels and other sources of energy. Continued globalisation of the gas market due to LNG also opens new vistas. The recent developments in commodity prices have already started to make gas competitive in power generation.

This is reflected in the IEA's World Energy Outlook 2015, as shown in s for a fuel switch as of 2020.

Figure 12. To address this further effect on emissions, additional sensitivity analysis is provided by Eurogas, based on a changed load factor of the power plants in the model. This difference has significant consequences for the outlook and justifies the sensitivity analysis for a fuel switch as of 2020.

Figure 12: Competitiveness of gas in power generation according to PRIMES and the IEA's WEO 2015[15]

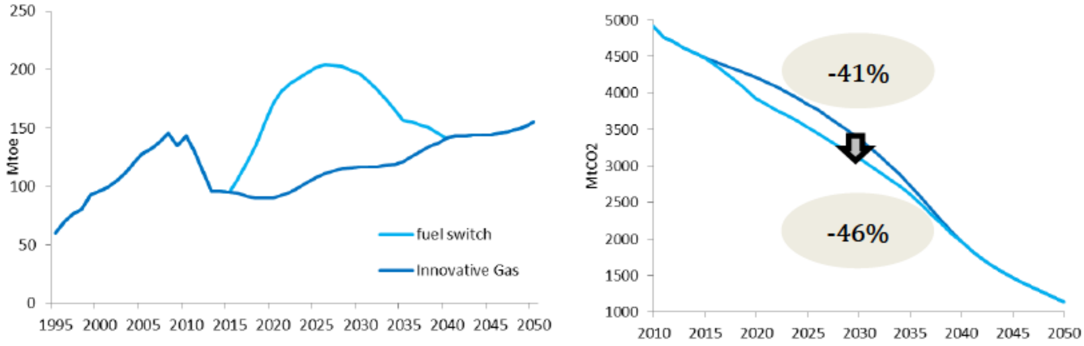


The analysis shows that such a fuel switch drives up gas demand considerably, peaking at just over 200 Mtoe, while emissions are reduced by some 5 000 Mt CO_2, or an additional 5 %

[15] Comparing costs of electricity production by using gas, coal and CO_2 prices as published by PRIMES and in the IEA WEO 2015 for the 450 scenario and low oil prices. It assumes a gas plant efficiency of 50 %, with gas emitting 0.402 tCO_2/MWh, and a coal plant efficiency of 35 % corresponding to 0.960 tCO_2/MWh.

emissions reduction in 2030 in addition to the 41 %, as reached in the Innovative Gas scenario on which this sensitivity is based.

Figure 13: Gas demand in power generation in the fuel switch sensitivity in blue (left), and its stronger emissions reduction path (right)



Conclusions

- As the PRIMES model did not provide for a fuel switch to gas in power generation, Eurogas has added such a scenario for the period to 2030, encouraged by the IEA's World Energy Outlook 2015 and based on increasing the load factors in the PRIMES model.
- A switch to gas in the power sector (Figure 11) creates significant additional CO_2 emissions reductions, considerably exceeding the 2030 target and thus providing more time for the use of tougher decarbonisation choices after 2030.
- The comparison of the Conventional Wisdom scenario and the Innovative Gas scenario shows that a higher share of renewables (+7 %) goes hand in hand with the higher demand for gas (+9 %).
- Strong electrification in the consumption sectors increases the decarbonisation challenge in the power sector, leading to a stronger dependency on technologies such as nuclear power and CCS.
- Renewable energy is recognised as an important contribution to achieving a low-carbon society. To obtain the highest share of renewable energy, power-to-gas is essential in the period to 2050, as the Innovative Gas scenario shows. This long-term use of the gas system also provides an additional reason to maintain the use of gas in power generation, in addition to gas plants generating electricity flexibly to back-up variable renewable energy, such as wind and solar.
- Electricity generated from gas-fired power plants varies significantly among the scenarios. The related current (risk of) divestment of these power plants jeopardises a cost-efficient achievement of the EU's climate targets.
- Recognising the uncertainty in estimating costs over the next 20 to 30 years, combined-cycle gas plants have both lower capital expenditures and lower total levelised costs. Gas plants are also quicker to build, taking 20 to 40 months as opposed to the 55 to 65 months required for a coal power plant and 60 to 80 months for a nuclear plant. In addition, the permitting process is shorter and more straightforward compared with other energy sources.[16]

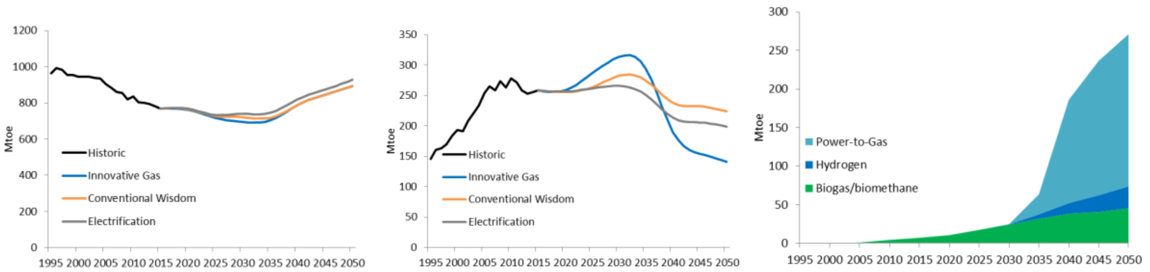
SUPPLY – SUPPLYING THE TRANSITION

[16] European Gas Forum (2013).

Currently, gas is supplied to over 275 million citizens across the EU-28 (Eurogas, 2014, Eurostat 2014). Nevertheless, the security of this supply has been a key topic in recent years.

All scenarios: import dependency to remain while meeting decarbonisation targets
In all scenarios, primary energy production is set to decline until 2030 due to the decreased production of fossil fuels, and then it will reverse into an increase caused by the increased production from renewable energy. To meet the total energy demand of Europe's citizens and businesses, imports of energy, including gas, are still required. While the scenarios show a significant role for gas up to 2050, its production in the EU-28 is set to decline due to the depletion of gas fields. Moreover, the sensitivities show a variable degree of the required imports. As imports remain necessary to a varying degree, the key objective is therefore to deal with imports in such a way that necessary supplies of energy are secured.

Figure 14: Primary energy production (left), net imports of natural gas (centre) and renewable gas production in the Innovative Gas scenario (right)



The electrification sensitivity also shows continued gas import dependency. More electrification would imply higher reliance on the electricity grid. In 2014, electricity supply interruptions stood at an average of 16.2 mins/a (medium voltage). In comparison, gas network outages stood at an average of 3.52 mins/a.

Innovative Gas – gaseous energy beyond natural gas
What has so far lacked recognition is the potential for increased domestic indigenous supply in the technical advances of renewable gas production, such as in gasification, anaerobic digestion, electrolysis and methanisation.

Besides natural gas, biogases are becoming increasingly important, produced by gasification and anaerobic digestion, and upgraded to natural gas quality in order to be used in the full natural gas system. In 2013, 15 billion cubic meters (bcm) of biogas were produced. This amount of gas could heat the equivalent of approximately 4.5 million households. These gases are set to increase to 45 Mtoe in 2050 in both scenarios.

The conversion of electricity to gas is key for making a more fully renewable energy system reliable and complete. This is due to the current void of long-term energy storage in the midst of rapidly increasing shares of intermittent production of renewable electricity. The Innovative Gas scenario shows the effect of power-to-gas on the production of synthetic methane and the significantly larger production of renewable electricity that is enabled by gas. In this scenario, gas itself is increasingly becoming renewable, with some 250 bcm of renewable gas projected by 2050. This means that renewable gas itself would be domestically produced on a scale equivalent to well over the total of natural gas produced in Europe today. Gas as a renewable fuel in and of itself is not merely something to be relegated to the future.

Imports are part of all scenarios

Making import dependency a specific policy target would limit the options for a low-carbon future. After the 2009 gas crisis, which mainly hit countries in Southeast Europe where supplies are not very diverse, Europe has seen significant investments in infrastructure and security of supply provisions. The existing annual capacity of LNG terminals in Europe is almost 200 bcm (almost half of Europe's needs). Current use of LNG is about 20 % of the existing capacity, so Europe is well equipped for diversification. Moreover, the expanding LNG market, where massive new supplies are about to come on-stream for the global market – from the USA to Australia – adds to the diversification options. Next to LNG, there is 93 bcm (Gas Infrastructure Europe, 2016) of gas storage capacity across the EU-28. Diversification is also increasing for pipeline gas. The new development of the Southern Corridor will bring new gas supplies from the Caspian region (Azerbaijan) via Turkey and Greece to countries in Southeast Europe. In the larger part of the EU, Member States have gained access to various sources of supply in recent decades by increasingly integrating their markets. These countries no longer depend on a single source.

Conclusions

- The scenarios and sensitivities of this study show that natural gas continues to play a significant role in the European energy mix, pointing in the direction of continued indigenous production and imports, a fully interconnected EU gas system and a true internal energy market in order to maintain cost-effective decarbonisation options.
- Renewable gases of biological origin or from power-to-gas are becoming increasingly important as an additional source of gas and as a decarbonisation option for all demand sectors.
- The Innovative Gas scenario illustrates the win-win effect of enabling more renewable energy production through gas, while at the same time adding significant renewable gas to the system.

Part 3 Costs are lower with higher gas demand

An affordable transition is essential for all European citizens. To meet the decarbonisation targets, the PRIMES model shows the additional costs compared with the recently published Reference Scenario of the European Commission, based on current policies and market trends.

Figure 15: Total gas consumption, in both scenarios and both sensitivities

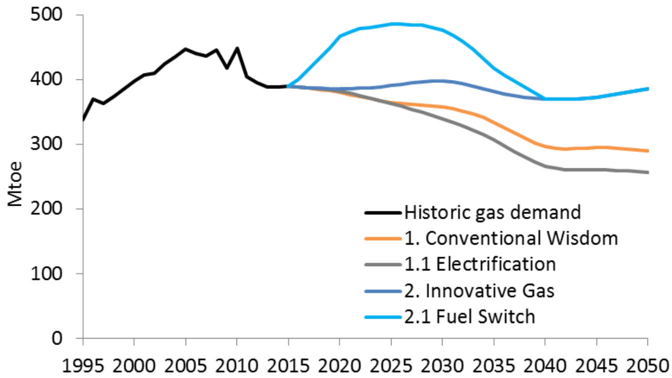
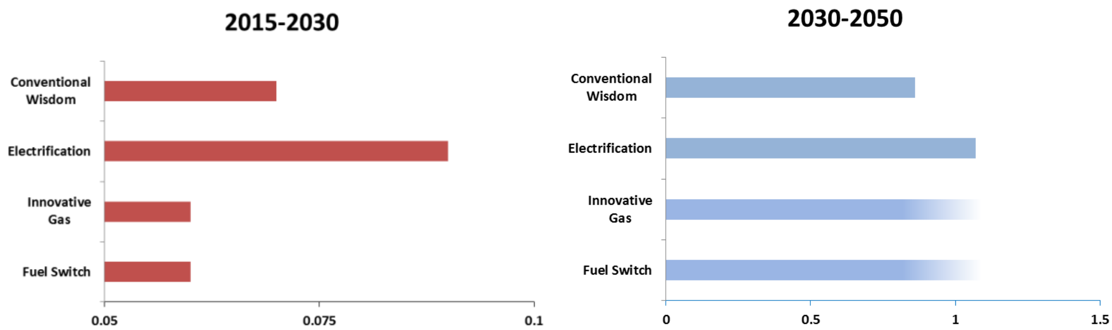


Figure 16: Total additional system costs for decarbonisation, expressed as a percentage of cumulative GDP, for the period 2015-2030 (left) and the period 2030-2050 (right).



The Conventional Wisdom scenario is more cost-effective than the Electrification scenario, up to 2030 and from 2030 to 2050. While the economy is struggling to pick up, high costs before 2030 can be regarded as a critical additional burden for society. In contrast, the Innovative Gas scenario shows the lowest cost up to 2030, while having the highest shares of natural gas. This also demonstrates that if nuclear and/or CCS are less available, renewable-based gaseous energy transported by the gas grids provides a very cost-competitive alternative. Moreover, the fuel switch shows the additional emissions reduction that can be achieved when gas becomes competitive for power generation (thanks to CO_2 price reforms and/or different global price developments) within the system boundaries of the model. As such, this sensitivity can be regarded as having the same total cost as the Innovative Gas scenario. Up to 2050, the full development and deployment of power-to-gas (2015-2050) do not exceed the costs of stronger electrification, even though power-to-gas learning curves are modelled conservatively. Higher longer-term costs also have the innate potential of being brought down as technology improves in efficiency. This innovative technology is thus already competitive, while a fuel switch would provide for more time to develop tough decarbonisation options to a mature level, thanks to its more ambitious emissions reductions by 2030.

Investments in gas infrastructure do not increase to meet decarbonisation targets as the scenarios and sensitivities do. Investments in electricity infrastructure, however, do differs among the scenarios. In the forecast period of 2015-2050 the innovative gas scenario requires € 335 billion less investments in electricity grid expansion compared to the Electrification sensitivity.

Comparison with other outlooks

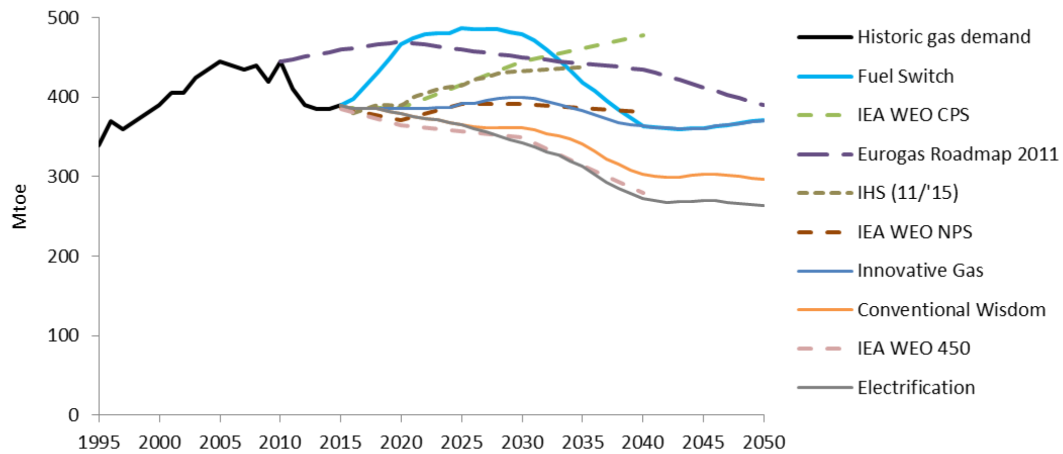
In the last few years gas demand has declined due to less industrial activity resulting from the economic crisis and global commodity price developments making gas less competitive for power generation, while the increasing share of renewable energy further reduced supplies for power generation. The starting point of this study is thus much lower than that of the Eurogas Roadmap of 2011. However, this study finds that a return to those levels is still realistically possible, as shown by the Fuel Switch sensitivity.

Compared with other outlooks, the Conventional Wisdom and Innovative Gas scenarios, as well as the electricity sensitivity, do not reflect the highest possible gas demand. The total gas demand is comparable with the IEA World Energy Outlook 2015 New Policies Scenario (NPS), which meets the 2030 climate objectives, although the IEA sees a higher gas demand after 2030.

Forecasts of consultants such as IHS, Wood Mackenzie and Pira support a stronger role for gas due to more optimism in the industrial outlook (e.g. Pira), power generation (e.g. IHS) and transport.

While 2050 might seem far into the future, for the energy industry and its often long-term investments it seems much sooner. Therefore, the role of gas should be recognised for its contribution to emissions reductions and for enabling higher shares of renewables in the energy system, as this study and others demonstrate.

Figure 17: Comparison of outlooks for total European gas demand



Conclusion of the study

The common objective is to achieve the EU's climate targets for 2030 and 2050, as well as the agreed objective of COP21, the 21st Conference of Parties. Exploring pathways to these goals is thus essential to achieve them in a pragmatic and cost-effective way.

As regards 2030, this study finds that an ambitious 5 % greater emissions reduction can be achieved, thus providing essential time for intensive decarbonisation options towards 2050. This can be achieved by a fuel switch to gas in the power sector.

Sectors that are difficult to decarbonise due to their variety of demands, such as residential, transport and industry, illustrate the versatile role of gas in reducing emissions. In the residential sector, gas demand remains stable until 2030, whereas the key driver is the development of the housing stock with regard to energy efficiency. Heating all these different types of houses cost-efficiently whilst reducing emissions requires a tailor-made approach. Gas boilers are the preferable choice for consumers due to their high performance and low costs. At the same time, it is essential to increase the refurbishment rate of the existing housing stock. In addition, gas and the gas system are essential to back up electricity from variable renewables, to address the challenge of electricity storage and to enhance the share of renewable energy in a smart energy system, which is not the case in the model used.

Electrification is often seen as a silver bullet, but all scenarios show that this would quickly be hampered by system limitations and result in high upfront investments for electrical appliances, as well as high overall costs for the consumer. The modelling shows that a strong push for electrification would neglect the benefits of a mix of decarbonisation options and therefore require much stronger decarbonisation measures in the power sector, such as a 10 % higher reliance on CCS and nuclear power. Despite the model showing electrification of the transport sector for cars, gas demand is set to increase before 2030, as it decarbonises heavy-duty road and maritime transport and contributes to clean air, while maintaining travel distance and load.

After 2030 and towards 2050, innovative gas solutions enable much higher shares of renewable energy, providing options for intensive decarbonisation. This study finds that decarbonisation does not mean less gas demand. On the contrary, it finds that increasing gas demand helps to meet emission reduction targets, as a higher share of renewables (+7 %) goes hand in hand with a higher demand for gas (+9 %). Also after 2030, the gas system remains crucial for decarbonisation pathways. Innovative technologies, like power-to-gas, enable the further growth of renewables. Gas will thus configure an energy system that can continue beyond 2050 as a sustainable zero-carbon system, while maintaining convenient ways of using energy. Of course, intensive decarbonisation, in light of a 1.5 °C temperature increase, and a combination of CCS and renewable gas could offer a negative carbon system.

The lowest cost for decarbonisation until 2030 is met in the scenario with the highest gas demand, while renewable gas offers system-wide opportunities until 2050. Achieving decarbonisation at the lowest cost is especially important because the economic outlook is weakest in the short term while the economy is struggling to pick up.

All scenarios require gas and gas imports to reduce the costs of decarbonisation, confirming an approach of indigenous production and diverse imports, as well as a fully interconnected, open internal market. Continued investment in gaseous energy and its associated infrastructure is justified by long-term renewable energy deployment and deep decarbonisation.

To conclude, this study finds that the versatile role of gas enables a socially acceptable pathway until 2050 with even more ambitious emissions reductions by 2030, supporting higher shares of renewable energy, while gas is becoming more renewable itself by 2050 and limiting the cost increase to consumers.

Appendix 1: The PRIMES model

The model

The PRIMES model is a so-called 'what-if' model. This type of model addresses what-if questions by changing input parameters and showing the consequential effects on the results. This helps decision-makers, for example by questioning the effects of policy measures, in this case for the energy sector.

The PRIMES model is in fact a detailed model within a set of other models. PRIMES focuses specifically on Europe, and consists of multiple sub-models (Emissions Trading System, emissions projections, biomass, land use). It also draws from the inputs of macro and global modelling built up by E3M. Inputs are derived from many studies, including the IEA's Technology Perspectives, the Ageing report of the European Commission and, on a global level, by the IMF. The PRIMES model contains projections for each of the EU-28 Member States, simulating the energy balances and greenhouse gas emission trends for future years. The projections are made at 5-yearly intervals. The model is calibrated every 5 years and this latest version is calibrated on the year 2015.

The PRIMES model is a modelling system that simulates a market equilibrium solution for each form of energy supply and demand by finding the prices of each energy form, such that the quantity producers find the best supply matches the quantity consumers wish to use, including the effects of regulation, oligopolies, distortions, cross-subsidies and taxes. The market equilibrium is achieved for each time period and the simulation is dynamic over time. Prices produced from this cocktail are linked by feedback loops with behaviour. It also represents in an explicit and detailed way the available energy demand, supply technologies and pollution abatement technologies. The system reflects considerations about market economics, industry structure, energy/environmental policies and regulation, which are conceived so as to influence market behaviour of energy system agents.

The updated version includes the developments of 'prosumers' and decentralised production activity (such as roof-top solar panels). The remaining demand at a decentralised level is supplied through the networks. The basis of the model is on the possibilities available to consumers and the way they make their decisions, including their perception and their access to technologies, through the addition of risk-premiums in the economic choices. For transport, factors such as refuelling stations are included, interlinked with the distance travelled. It also includes details on heat demand in industry, in addition to a comprehensive coverage of all industrial sectors. The power sector is modelled with a higher granularity in the 2015 version of the model, optimising hourly demand and supply balances.

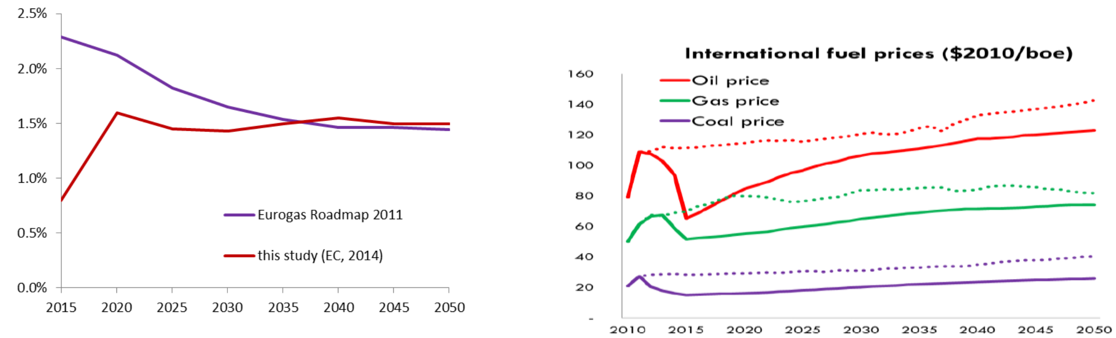
Variability is modelled by 120 typical days of high/low wind and/or sunlight, affecting the operation of the power plants in the model for which fast ramp rates for flexible operation are included. Curtailment of renewable energy production is captured in the updated model. With further deployment of wind and solar power, flexibility is delivered by gas and hydro. With the inclusion of these technical characteristics in the model, system stability can be analysed better.

Macroeconomic background[17]

Demographic development interrelates with housing requirements and economic activity. Following the dynamics of fertility, life expectancy and migration rates, the overall size of the population is projected to be almost 4 % larger by 2050, and to be much older than it is now. As a result, the labour supply is set to stabilise in 2023 and thereafter to decrease, leading to a small increase in the expected unemployment rates.

Europe is still struggling to shift to economic growth after the financial crisis. In the EU, the annual average GDP growth rate is projected to remain quite stable over the long term, albeit much lower than in previous decades. After an average potential growth of 1.1 % up to 2020, a slight increase to 1.4-1.5 % is projected for the remainder of the projection horizon. Over the whole period 2013-2060, average output growth rates in the EU-28 are projected to be 1.4 %. The economic structure is also expected to change, with a very slow recovery of activity in industry after the recent crisis for energy-intensive industries, construction, agriculture and the energy sector itself, but slightly more so in the non-energy intensive industries and equipment goods.

Figure 18: GDP growth rates compared with the previous Eurogas Roadmap (left) and fuel prices (right) in which the dotted lines represent the PRIMES EU Reference Scenario of 2013



Notes: boe is barrels of oil equivalent.

Global context and prices according to PRIMES

Eurogas may not, cannot and will not forecast prices. Therefore the projections of the Reference scenario as acknowledged by the European Commission are taken as a given. E3Mlab's world model shows global coal demand to decelerate until 2020 due to the introduction of climate pledges, but remains strong in the rest of the outlook in non-Organisation for Economic Cooperation and Development (OECD) countries, while its supply will decrease after 2020 by a restructuring of the mining industry. Coal prices are therefore expected to stay low in the short term. Global oil demand will grow more slowly than coal and stabilise after 2040 due to efficiency improvements in the transport sector and the saturation of demand in OECD countries, while particularly non-Organisation of the Petroleum Exporting Countries (OPEC) oil production keeps prices low in the short term and then increases later as a result of demand growth in developing regions. Shale gas emergence in the USA and potential LNG exports drive a reduction of global gas prices, which sees further downward pressure following a nuclear revival in Japan. After 2020, the average EU import price of gas will increase and by 2050 stand higher than recent peaks following a steadily increasing global demand.

[17] Based on the European Commission's Ageing Report, which is input to the PRIMES model. EC (2014), The 2015 Ageing Report – Underlying assumptions and projection methodologies.