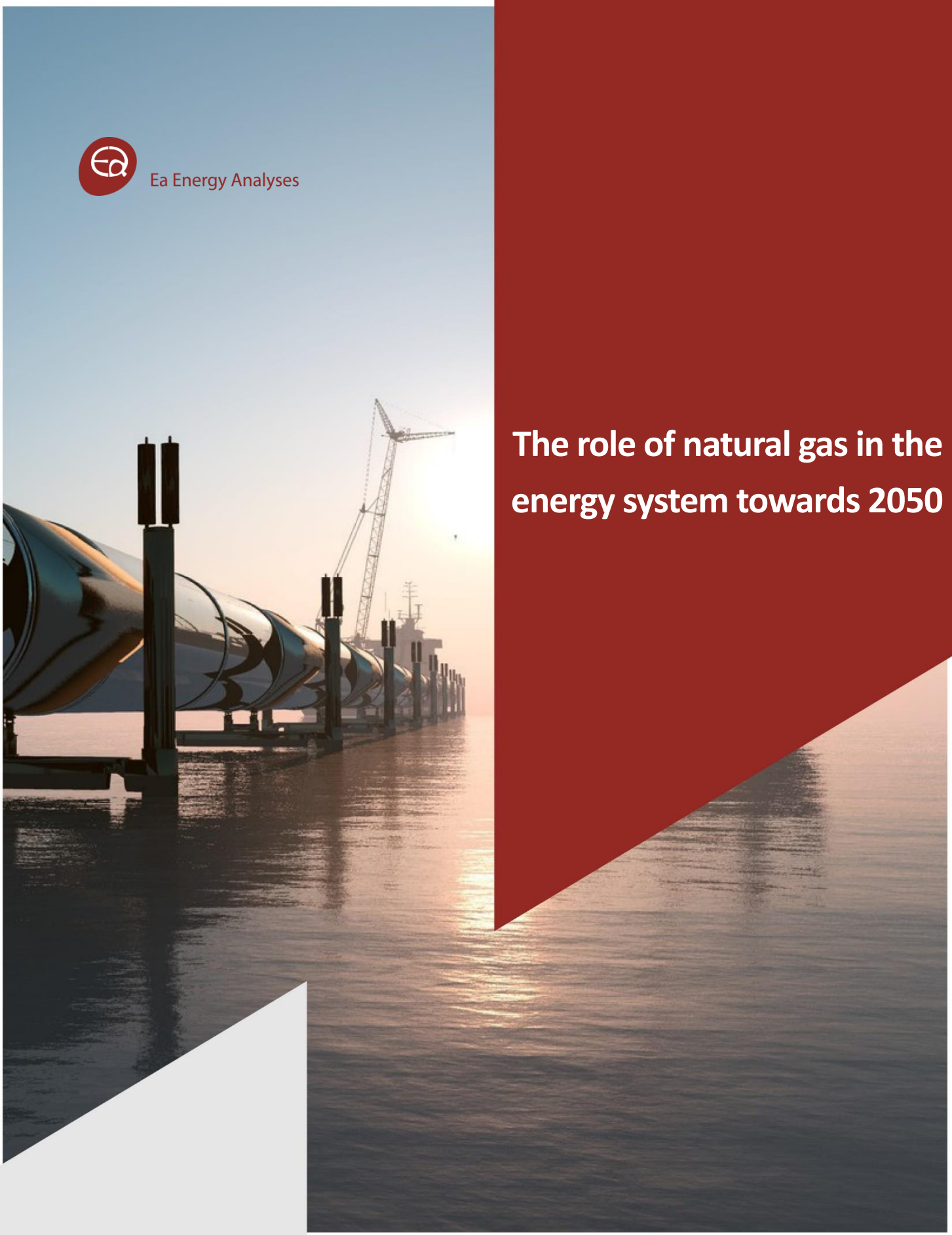
Ea Energy Analyses



The role of natural gas in the energy system towards 2050

June 2019

Ea Energy Analyses

Published by:

Ea Energy Analyses
Gammeltorv 8, 6. tv.
1457 Copenhagen K
Denmark
T: +45 60 39 17 16
Email: info@eaea.dk
Web: www.eaea.dk

Contents

1 Executive summary and conclusions

Natural gas has played a substantial role in the power sector, industry, and household heating in Denmark and in several other European countries for decades. Natural gas was in many cases first developed and taken into use for economic and security of supply considerations. Later, the use of natural gas was advanced due to the relatively low CO_2-emissions compared to coal and oil. The carbon footprint of natural gas is 25% lower than oil and 45% lower than coal. Depending on the origin of biomass, the carbon footprint of natural gas can even be lower than biomass seen in a 100-year perspective.

Due to its lower CO_2-emissions, relatively low costs, and the well-developed infrastructure natural gas is often considered to be an important stepping-stone away from coal and oil and towards carbon neutrality.

However, natural gas production in the EU is rapidly decreasing due to resource exhaustion and increasing extraction costs, and the EU is increasingly dependent on imports. Norway and Russia are the main suppliers of piped natural gas, while Qatar, Nigeria and Algeria are the main suppliers of LNG to the EU. During 2018 LNG imports from the USA rose dramatically and LNG is likely to become more important in the future.

Like in Denmark, natural gas is used in industry, households and the power sector in many EU countries, replacing coal and heavy and light fuel oil. Natural gas used in households can to some extent be replaced with heat pumps with no or moderate consumer price consequences, depending on national taxation policies. In many areas of industry, however, natural gas will in the coming decades be more difficult or even prohibitively expensive to replace – taking global competitiveness into consideration. Alternatives are biogas, electrofuels or direct electrification. Another alternative is to continue the use of natural gas combined with Carbon Capture and Storage (CCS). However, both electrofuels and CCS technologies face substantial R&D efforts before they can be considered commercially available technologies.

The EU Commission has proposed a number of scenarios for how the EU can reach the goal of zero net emissions by 2050. Electrification is expected to play a major role and up to 50% of end-use is expected to be electricity in 2050, compared to 23% today. Thus, the role of fossil fuels, including natural gas, will be substantially reduced in end-use, replaced mainly by electricity, green gas, and electrofuels. However, the costs and pathways are uncertain.

The low price and the lower carbon emissions of natural gas and the already existing infrastructure are probably important reasons why natural gas still plays a role all the way towards 2050 in most of the scenarios – often in combination with Carbon Capture and Storage (CCS).

For the long term around 2050, one of the main questions is whether a combination of natural gas and CCS or carbon neutral electrofuels, will be able to deliver the most cost-efficient fuel for balancing purposes in the power sector and as cost-efficient fuel in process industry. Our current estimates indicate, that CCS technologies, if developed and implemented, could be the cost-effective option.

In the medium term (10 – 30 years), natural gas will certainly continue to be an essential energy carrier in EU, if the efforts to continuously reduce the dependence of coal and oil shall be successful.

2 Introduction

Natural gas emits less CO_2 than coal and oil

Natural gas has for many years played a substantial role in the energy mix of the Danish economy as well as in many other economies around the world. Natural gas is a relatively clean-burning fossil fuel, that emits less CO_2 per energy unit than coal or oil, and it has often been considered a possible stepping-stone towards the fossil free economy.

This report presents a short history of natural gas usage in Denmark, Germany, France and the Netherlands. The history forms a background that is helpful in the chapter following, where the role that natural gas plays in the European energy mix today and where supply might come from in the future is analyzed. Then follows an overview of current uses of natural gas, their possible replacements and an analysis of which areas of use natural gas is likely to have the highest value in the future.

Finally, the future role of natural gas in the energy systems of Europe is reflected on in the context of the 2050 scenarios for the European energy supply proposed by the EU Commission.

3 The recent history of natural gas in selected European countries.

This chapter describes the story of how natural gas came to be used in the energy systems of post oil-crisis Denmark as well as Germany, France and the Netherlands. These nations have been chosen due to their relevance in terms of energy consumption, energy infrastructure and general role in the European energy systems in both a historical and a current perspective. The reasons and rationales behind the expansion of natural gas use will be described, as well as the central policy issues facing these gas-using countries today.

3.1 Current events and the EU context

Energy has always played a significant role in the EU, all the way back to the initial precursor to the European Community, namely the Coal and Steel Community. The Coal and Steel Community established a central authority that oversaw the production and trade of steel and coal among six member countries, including Germany and France. From this first starting point European cooperation has since evolved substantially both in terms of scope and depth.

Energy and climate change have become increasingly important for European cooperation and national politics

Since that time, more and more areas of commerce and national interest have been made open to European competition. The first EU-directives mandating the liberalization of national power and gas companies and the dismantling of national monopolies were put forward in the mid 1990'ies and began to be put into effect at the national level around the turn of the millennium. Energy and climate change have since become increasingly important areas in the context of European cooperation and in the national policies of the member states.

In the last few years, 'green parties' have done well in many national elections, including recently in Denmark and Germany, as well as in the 2019-election to the European Parliament[1]. Also, weekly protests by elementary school students against climate change have been happening around the world[2]. In other words, there is a strong desire in the populace for actions that will deal with the risks from climate change. Such efforts are being undertaken to different degrees in different countries, that all have their own special circumstances and challenges to navigate.

[1] https://www.theguardian.com/politics/2019/jun/02/european-parliament-election-green-parties-success
[2] https://www.bbc.com/news/world-48392551

3.2 The history of natural gas in Denmark

The first oil crisis of 1973 made energy a central political topic

A defining moment in the history of energy planning in Denmark was the first oil crisis of 1973. On October 6th, 1973, on the Jewish holiday Yom Kippur, Israel was attacked by Egypt and Syria. The war and the ensuing embargo by OPEC countries against Western countries supporting Israel led to a drastic increase in the price of oil. For many years, Denmark had been almost entirely reliant upon oil for its primary energy consumption, with 95% of the final energy consumption being covered by imported oil[3].

The embargo led to an almost immediate tripling of oil prices which hit the Western economies hard. In Denmark, a number of political initiatives were taken to counter the effects of the sharp increase in oil prices. Car-free Sundays and a lowering of the speed limit among other energy saving initiatives became a reality in trying to reduce the impact of the oil crisis. The oil crisis demonstrated to people the importance of energy and its relation to economic growth and security.

New energy strategies were proposed in Denmark in 1976

In the wake of the 1973 oil crisis several energy commissions were instituted in Denmark, and in 1976 the first complete, national energy plan in Danish history was put forward by then Minister of Trade, Erling Jensen. At the same time the Danish Energy Authority was created. The 1976 Danish Energy Plan proposed a number of goals as well as concrete proposals for actions.

The short-term goals involved establishing strategic emergency supplies of oil, reducing dependency through energy savings, increased efficiency and finding long term solutions to the problem of finite energy resources. Some of the concrete proposals of the plan was the use of natural gas for heating, the expansion of the district heating system, and the conversion of central power plants to be coal-fired rather than oil-fired.

The second oil crisis of the 1980s helped push for the development of district heating system and a gas distribution network

A second oil crisis following the Islamist coup in Iran against the Shah in 1979, and a year later the Iraq-Iran war of 1980-88, saw yet another spike in the oil price towards new heights and a great push towards reducing independence on foreign oil imports. An agreement was made with the Danish Underground Consortium, which had exclusive drilling rights in Denmark, about delivering natural gas and a large build-up of the district heating system took place in the early 1980'ies. In the same period the gas-distribution grid was being established around the country. There was a political desire to utilize the North Sea natural gas, both for economic and security of supply reasons.

[3] Ea Energianalyse, 2007: "25 år med naturgas".

In 1987 climate change started to be taken seriously politically

Before 1987, energy plans had been concerned first and foremost with security of supply and economics, but with the release of the Brundtland Commission's report on the environment, climate change began to become a concern that was taken seriously in the energy planning. Decentralized combined heat and power plants were pushed towards use of natural gas through changes in the tariff structure, in order to reduce CO_2-emissions and the environmental impacts of the power sector. The new mantra was "sustainability" and natural gas was viewed as a necessary and efficient way of reaching that goal.

Natural gas finds use especially in industry and domestic heating

The use of natural gas for heating purposes continued in the nineties and expanded to several hundred thousand homes being supplied with the now cheaper natural gas, where before they had been using oil to supply their heat need. In industry, natural gas also found substantial use for heating purposes, where it began replacing coal and oil. By 2005 the energy gas consumption peaked at a level of approximately 192 PJ[4]. The development of natural gas consumption in Denmark since 1990 until 2018 can be seen in the figure below.

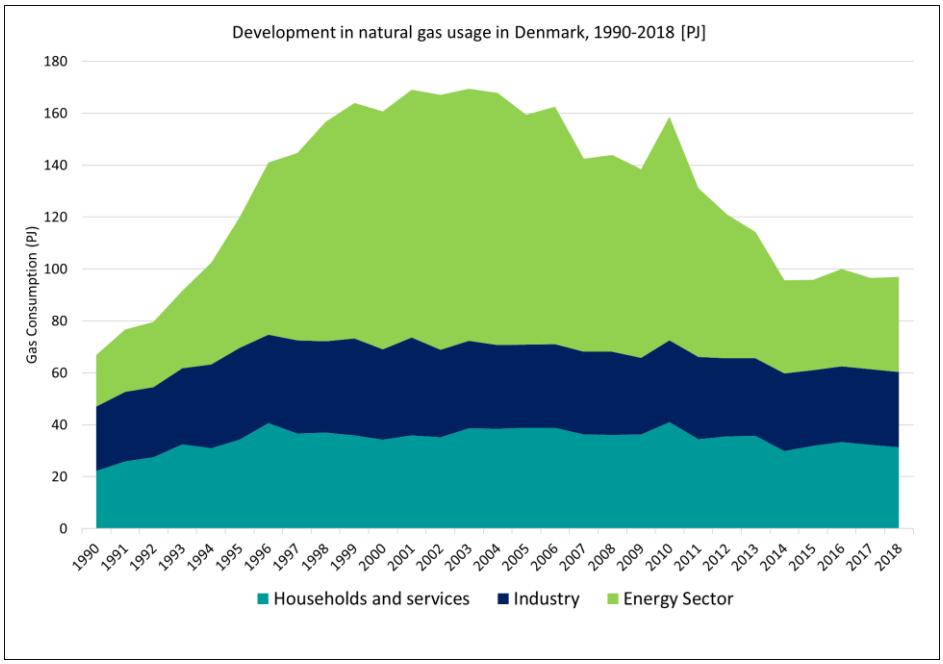


Figure 1: Development in natural gas usage in Denmark, 1990-2018. Source: Ea Energy Analyses.

[4] The Danish Energy Agence "Energistatistik 2016".

Gas as part of the fuel mix in the power generation peaked in 2010

As can be seen from the graph above, the use of natural gas in the energy sector took off dramatically by the turn of the millennium, and remained at a high level until after 2010, where more district heating plants started to replace natural gas combined heat and power (CHP) with biomass boilers and biomass CHP. The gas infrastructure remains in place, however, and can therefore be used in the future if necessary. The table below shows the development of power generation sources in Denmark.

Fuel	1994	2000	2005	2010	2014	2015	2016
Oil	7%	12%	4%	2%	1%	1%	1%
Natural gas	6%	24%	24%	20%	6%	6%	7%
Coal	83%	46%	43%	44%	34%	25%	29%
Waste, non renewable	1%	2%	2%	2%	2%	3%	2%
Renewable energy	4%	15%	27%	32%	56%	66%	60%

Table 1: The development of power generation sources in Denmark. Source: Danish Energy Authority, Energy Statistics 2016.

The Danish gas-market is liberalized

After the turn of the millennium the Danish natural gas market has been liberalized and the approximately 400.000 natural gas customers are now allowed to choose their preferred commercial gas distribution service. Since the peak of natural gas consumption in 2005, natural gas consumption has been steadily declining, mostly due to the expansion of the district heating system and mandated conversion, although the level of consumption seems to have stabilized in the last years. In 2018, a united Danish Parliament agreed that Denmark should be a zero net-emission society independent of fossil fuels by 2050.

3.3 The history of natural gas usage in Germany, France and the Netherlands.

Germany is shutting down its nuclear power plants and are transitioning away from coal by massive investments in renewables and increased natural gas consumption

Germany is the single largest consumer of natural gas in the EU. In the past, coal and oil completely dominated the energy mix in Germany. Natural gas started being used in the seventies and expanded after the oil crisis. Coal, oil and natural gas remain the most important sources of primary energy with oil supplying 34%, natural gas 23% and coal 21%, with renewables supplying 14% and nuclear power down to 6%. Today 50% of households are heated with natural gas. 90% of natural gas is imported, with 40% of total imports coming from Russia, 29% from the Netherlands and 21% from Norway[5].

[5] https://www.eia.gov/beta/international/analysis.php?iso=DEU

Following the accidents at the Japanese Fukushima nuclear power plant and the increased focus on climate change, Germany has decided to rapidly transition away from coal and nuclear, and while renewables are expected to supply the vast majority of the future energy needs of Germany, there are also expectations that natural gas usage will have to increase to implement this plan. Russia and Germany are currently working on finishing the Nord Stream 2-pipeline, that will supply more natural gas to the German market from Russia. In the past few years, German consumption of natural gas has increased to make up the shortfall of nuclear and coal power plants.

France is highly dependent on nuclear power and natural gas – about 14% is supplied by natural gas

France is the fourth largest consumer of natural gas in the EU. France was heavily dependent on coal in the period after the second World War. During the 1960'ies falling real oil prices led to a large expansion in the use of oil, and when the oil crisis hit in 1973 two-thirds of energy consumption in France was supplied by oil. Following the oil crisis France took large steps towards reducing the role of imported foreign oil by expanding natural gas and, in particular nuclear power.

France has very few domestic natural gas resources and import the vast majority of its supplies from other countries[6] – notably the Netherlands, Norway and Russia. In addition to this, France also imports a substantial amount of liquefied natural gas (LNG), primarily from Algeria and has been constructing additional LNG capacity in the last few years. Around 14% of the energy consumption in France is supplied with natural gas[7].

In the Netherlands 41% of energy consumption is supplied by natural gas, and gas is expected to continue to play an important role in the green transition

The history of natural gas usage in the Netherlands took off with the discovery of a giant on-shore gas-field in 1959, which sparked a boom in the natural gas exploration and extraction industry in the years that followed. In the following years, the Netherlands also started exporting to other European Western European countries in large quantities. By that time, natural gas had become almost the sole fuel used for domestic heating and cooking. By 1972 natural gas consumption had risen to 50% of total energy consumption.

In the late 1980s, European energy markets started to undergo liberalization, and by 2005 the state-owned natural gas company Gasunie was split up. Public concerns about earth tremors from the Groningen field due to overproduction, political and public desire to curb CO_2-emissions and decisions to secure long-term supplies of natural gas have led to large reductions in natural gas of

[6] https://www.eia.gov/beta/international/analysis.php?iso=FRA
[7] https://www.planete-energies.com/en/medias/close/france-s-overall-energy-mix

almost 50% from 2013. Today, 41% of energy consumption in the Netherlands is supplied with natural gas[8]. In 2018, the Netherlands became a net importer for the first time. The Dutch state-owned energy agency EBR states, that natural gas will continue to play a substantial role in Dutch energy policy in the areas of heating and industrial processes, as the Netherlands moves towards a fossil-free future[9].

[8] https://longreads.cbs.nl/trends18-eng/economy/figures/energy/
[9] https://www.ebn.nl/en/energy-transition/our-dutch-gas/

4 The supply and demand-structure of natural gas in Europe today

In this chapter the structure of supply and demand of natural gas in Europe will be covered in some detail, focusing first on consumption, then production and lastly import opportunities and gas reserves. The purpose is to illustrate the current and future structure of supply and demand of the European natural gas market.

EU-natural gas consumption is approximately at 15,000 PJ (in 2016)

The consumption of natural gas rose from around 11.200 PJ in 1990, peaked around 17.400 PJ in 2010, falling in the years after and in 2016 rising to close to 15.000 PJ. Gas consumption from households and services rose slightly in relative terms from 38% of total natural gas consumption in 1990 to 43% in 2016. Industry and agriculture accounted for around 38% of total natural gas consumption in 1990 and fell to 23% in 2016. The power sector accounted for 21% of natural gas consumption in 1990 and has since risen to 33% in 2016. Natural gas consumption in the power sector was highest in the 2000's and started to get phased out after 2010.

Following the 2014 disaster at the Fukushima nuclear power plant, however, German nuclear plants were decommissioned, and natural gas use picked up to cover the supply shortfall. Natural gas consumption in transport, fishing and other has decreased from around 2 % in the 1990'ies to approximately 1% in the last years. The figure below shows the development of natural gas consumption by sector for the EU-28 countries:

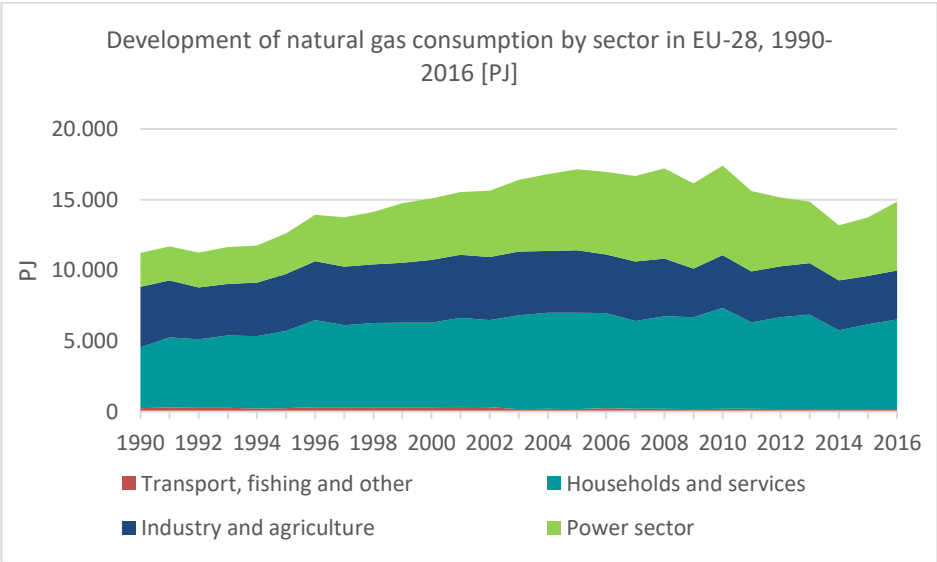


Figure 2: Development of natural gas consumption by sector in EU-28, 1990-2016. Source: Eurostat.

In the period 2014-2018, Danish natural gas consumption has dropped 5%, while gas consumption of other European countries rose substantially

The countries that today consume the most natural gas are Germany, United Kingdom, Italy, France and the Netherlands, with Germany, UK and Italy accounting for more than 50% of total EU-consumption[10]. In the period 2014-2018 Germany has increased its' natural gas consumption by 12%, UK by 15%, Italy by 17%, France by 13% and the Netherlands by 6%. By contrast, natural gas consumption in Denmark fell by 5% during the same period.

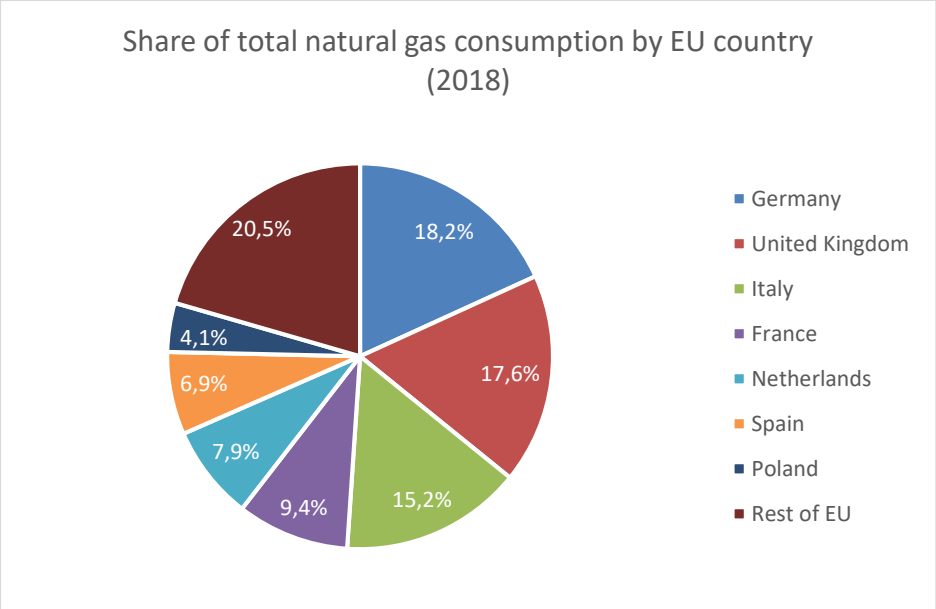


Figure 3: Share of total natural gas consumption by EU country (2018). Source: Eurostat.

EU-coal consumption is substantial. Replacing coal in the power should be a high priority.

In comparison, coal consumption was substantially higher than natural gas consumption in the EU-28 countries in 1990, but has since declined as natural gas, renewables, and nuclear has taken over. The largest use of coal by far is in the power sector, as can clearly be seen from the graph below. Since coal is a very polluting and CO_2-emitting source of fuel, replacing the coal in the power sector should be a high priority.

[10] See Appendix A for a table of natural gas consumption by country.

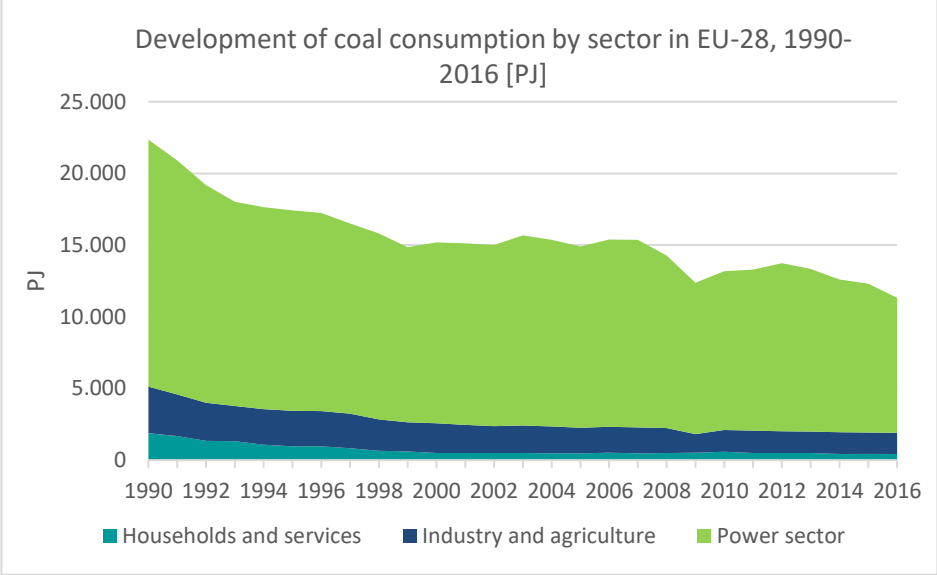


Figure 4: Development of coal consumption by sector in EU-28, 1990-2016. Source: Eurostat.

EU Natural gas production is rapidly declining

Natural gas production in the EU-28 countries have been declining since the peak around 2000, as shown in the figure below.

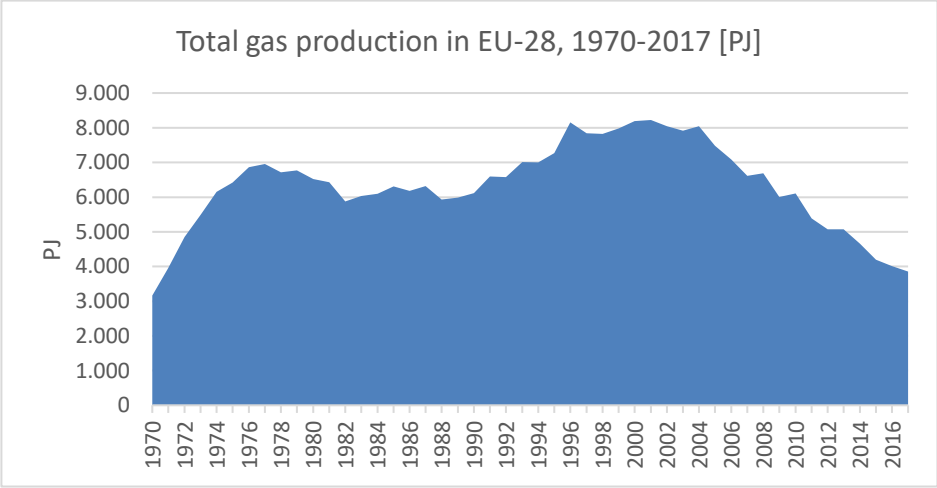


Figure 5: Total gas production in EU-28, 1970-2017. Source: BP Statistical Review 2018.

United Kingdom and the Netherlands are by far the largest EU-producers of natural gas, with Romania as a very distant third. The Netherlands, in particular, is a large natural gas exporter and has been for many years. The graph below shows the primary production of natural gas by EU countries today.

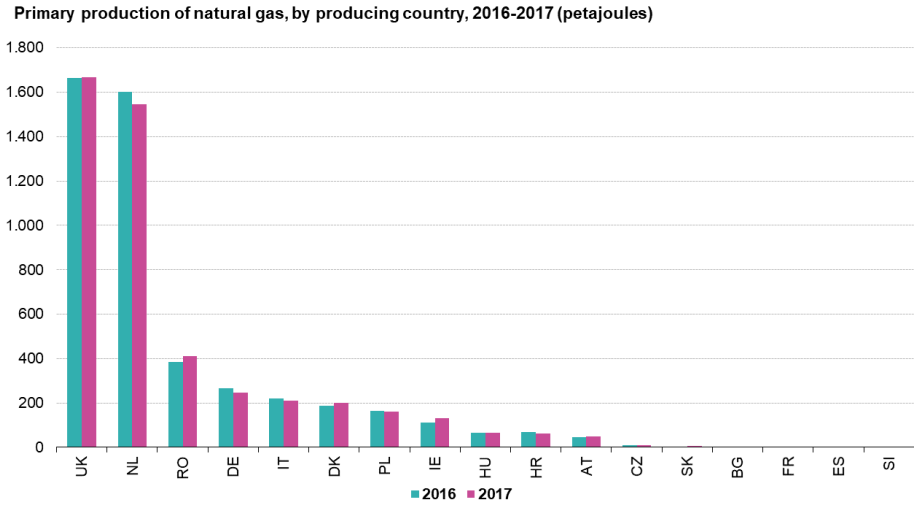


Figure 6: Primary production of natural gas by producing country, 2016-2017. Source: Eurostat.

With the decline in EU production of natural gas and increased or steady demand, an increasing amount of natural gas must be imported from outside of the EU.

The largest exporters of natural gas to the EU are Russia and Norway

The largest supplier to the EU at large is Russia followed by Norway. There are however large individual differences in the import composition for different countries. Germany, who is the largest consumer of natural gas, is highly dependent on imported natural gas, in contrast to the UK which, as the second largest consumer, is also the largest producer. Germany imports around 90% of its natural gas, with 40% of total imports coming from Russia, 29% from the Netherlands and 21% from Norway. Denmark has for a long time been a net-producer of natural gas but has in recent years begun to import more and more Russian natural gas. The figure below shows the country of origin for extra-EU import of natural gas.

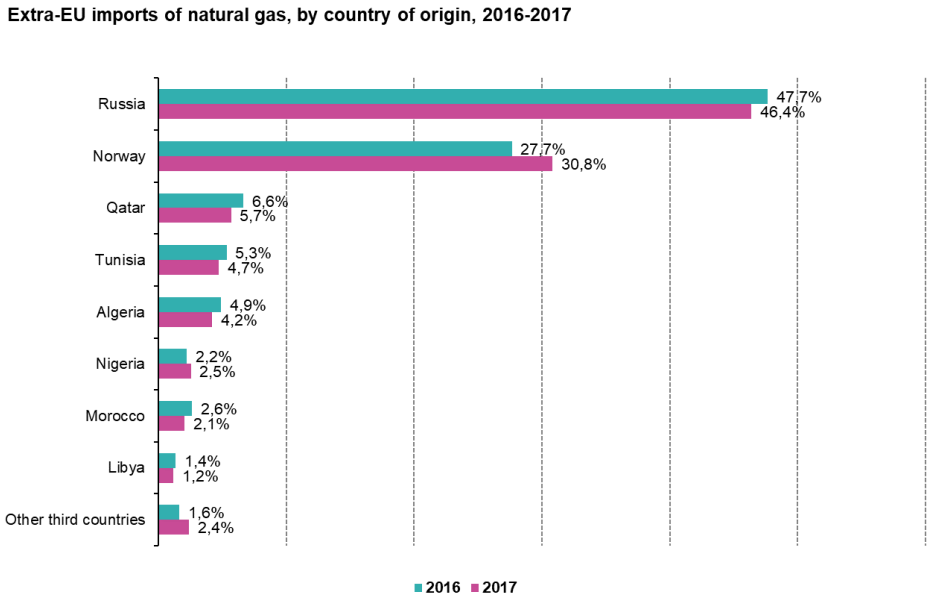


Figure 7: Extra-EU imports of natural gas by country of origin, 2016-2017. Source: Eurostat.

The world's largest natural gas reserves exist in Russia

Russia is the largest exporter of natural gas to the EU, and has by far the largest proven reserves in the world at almost 48 trillion cubic meters. Norway is the second largest exporter to the EU but has comparatively small reserves of around 1,8 trillion cubic meters. The second largest natural gas reserves among the main exporters of natural gas to the EU are held by Qatar which has proven reserves 24 trillion cubic meters. The Netherlands and the UK have merely approximately 0,8 trillion cubic meters and 0,2 trillion cubic meters, respectively. Denmark, by comparison, has a mere 0,01 trillion cubic meters of proven natural gas reserves.

World Energy Outlook expects the EU to have to seek additional natural gas imports by 2025 to make up for reduced nuclear and coal generation capacity

The EU-natural gas reserves are minute relative to the non-EU countries reserves and it seems likely that imports therefore will keep increasing in the coming years. World Energy Outlook expects[11] that the EU will have to seek additional imports equaling up to a third of consumption by 2025 to make up the shortfall of retired nuclear and coal power plants and diminishing domestic production. The table below shows the proven natural gas-reserves in billion cubic meters for the top exporter countries to the EU, as well as a few EU countries of interest.

[11] https://www.iea.org/newsroom/news/2019/march/a-long-term-view-of-natural-gas-security-in-the-european-union.html

Proven natural gas reserves by country (2018, EIA)	
Country	**Natural gas - proved reserves (billion cubic meters)**
Russia	47.805
Qatar	24.072
Nigeria	5.475
Algeria	4.504
Norway	1.782
Libya	1.505
Ukraine	1.104
Azerbaijan	991
Netherlands	801
United Kingdom	176
Morocco	94
Belarus	92
Germany	40
Denmark	13

Table 2: Proven natural gas reserves by country (2018, EIA).

Export of LNG to the EU from America has increased by 272% in 2018

Countries like Norway and Russia supply the EU with natural gas via pipelines and can therefore not re-direct supply to other bidders without massive investments in new infrastructure. Countries like Qatar, Nigeria and Algeria, however, who supply their gas in the form of LNG, can redirect that supply to other bidders who might offer more. The USA has been dramatically increasing their exports of LNG to the EU during 2018, by 272% up to almost 11 billion cubic meters by the end of 2018[12]. LNG is a growing market that is likely to become increasingly important to the energy supply of the EU in years to come.

In short, there are several supply opportunities for natural gas (pipeline and LNG) that could allow for the EU to meet demand over the coming decades. Pricing, security of supply and carbon footprint of the different supply options will probably be important parameters for the future supply mix. For the long-term supply matrix alternatives to all the fossil fuels, including natural gas, gain increased focus. This is investigated in the next chapters.

[12] https://ec.europa.eu/energy/sites/ener/files/eu-us_lng_trade_folder.pdf

5 Alternatives to natural gas

In a future (near) carbon-neutral energy and transport system, the consumption of natural gas is projected to be significantly reduced and confined only to the applications, where it is most difficult to replace with a green alternative and therefore has the highest value to the energy system. In the table at the end of this chapter, we have provided an overview of the current use of energy within different sectors/applications, and indications of how a future green supply of energy could be organized. The table also includes an assessment of the sectors where natural gas the highest value.

Biomass cannot be expected to fully replace fossil fuel-consumption

For many applications, natural gas may theoretically be replaced by different forms of biomass; solid biomass for production of heat and gaseous or liquid biomass as input for thermal processes, engines or turbines. However, the availability of biomass on a global scale is limited, and biomass can therefore not be expected to replace today's consumption of fossil fuels. The cheapest and most abundant green sources of energy are expected to be solar power and wind power, including large-scale offshore wind deployment. To utilize these energy sources, electrification of energy demand becomes a key measure. For some applications, electrification provides a very efficient utilization of energy. For example, electric heat pumps supplying low temperature heat for individual heating or supplying district heating systems can deliver 3-4 units of heat for each unit of electricity consumed. Similarly, electric vehicles are 3-4 times more efficient than their fossil counterparts.

Liquid or gaseous fuels might be considered for heavy transport but involves considerable energy costs

However, in some applications, such as high-temperature industrial processes and certain modes of heavy transport (such as long-haul trucking, aviation and much of maritime transport), it is likely that liquid or gaseous fuels are required due to either their combustion characteristics or their high energy density. Electricity may be converted to liquid or gaseous fuels, but this process involves considerable capital costs for electrolyzer and methanization facilities and considerable energy costs. Thus, one unit of electricity would typically yield around 0.6 units of synthetic fuel and the cost of synthetic fuels produced from electricity is deemed to be rather high, around 90 -100 €/MWh. By comparison the price of natural gas typically varied around 15-20 €/MWh during the last 10 years.

Hydrogen and Carbon Capture Storage (CCS) could be viable options but require large point sources with a steady base load consumption

An alternative to producing synthetic fuels from green electricity is to decarbonize the natural gas through carbon capture and storage. This can be done in several ways. One option is to split the natural gas into hydrogen and CO_2 and subsequently store the captured CO_2 underground, for example in empty gas fields in the North Sea. The output of the process, hydrogen, which is sometimes termed blue hydrogen, can then be used to replace natural gas. Another option is to equip industrial facilities using natural gas with carbon capture and storage (CCS) equipment. In this case, the CO_2 produced from the combustion of the natural gas is captured and stored away. For this solution to be economically feasible, large point sources with a steady base load consumption of natural gas is required.

According to the IEA there are 18 large-scale CCUS (Carbon Capture Utilisation and Storage) facilities operating globally today. The majority of these plants are associated with industrial processes that create relatively pure streams of CO_2 in normal operation, such as natural gas processing, producing hydrogen from fossil fuels and manufacturing bioethanol. There are only two large-scale CCUS flue gas **power generation plants** in operation: The Boundary Dam project in Saskatchewan, Canada, and the Petra Nova Carbon Capture project in Texas, United States. Both use post-combustion capture technology on coal plant retrofits. Moreover, seven large-scale CCS-projects in the power sector are in early development.

CCS has yet to show a major breakthrough but is considered an important tool for carbon neutrality in IEA scenarios and in several EU Climate Strategy scenarios.

CCS has yet to have a major breakthrough. Nevertheless, the International Energy Agency sees CCS as vital for reducing emissions in its zero carbon scenarios. Likewise, the EU Climate Strategies also incorporate the utilization of CCS on natural gas in order to reach their climate goals (see chapter 6). According to an IPCC Special Report on Carbon dioxide Capture and Storage[13] the cost of abating CO_2- from a base-load natural gas power plant using CCS technology is approximately 35 – 77 EUR per ton of CO_2 relative to a similar power plant without CCS. Since 1 MWh of natural gas results in the emission of approx. 0.21 ton of CO_2, this corresponds to a cost increase of around 7 – 16 EUR per MWh of natural gas (1 USD = 0.89 EUR). Adding the fuel cost of natural gas, total energy costs would amount to some 19 – 31 EUR/MWh. This indicates that applying CCS on large scale facilities using natural gas is likely to be a cost-effective CO_2-abatement measure relative to producing synthetics fuels from green electricity.

[13] https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_chapter8-1.pdf

Sector	Current supply	Future green supply	Highest value of natural gas
Individual heating	Natural gas, oil, biomass boilers, heat pumps.	Heat pumps District heating Hybrid heat pumps using green gas for peaking.	X
District heating	Combined heat and power from biomass, coal and natural gas. Boilers: biomass, natural gas, solar heating, industrial surplus heat.	Heat pumps Geothermal Biomass Boilers/CHP Industrial surplus heat Solar heat	
Industry, low temperature	Gas, oil, biomass, direct electricity, district heating	Heat pumps District heating	
Industry, high temperature	Gas, oil, coal, biomass, direct electricity	Direct electricity Biomass Green gas Natural gas with CCS	XX
Industry, direct process	Coal, gas	Biomass Green gas Natural gas with CCS	XXX
Light transport	Diesel, gasoline	Electricity	
Heavy transport on land	Diesel	Biodiesel Bio-LNG Electric vehicle (conceptual) Electric high-ways (conceptual)	XXX
Aviation	Kerosene	Biokerosene Hydrogen (conceptual) Electricity (short distance, conceptual) LNG (conceptual)	Wild card
Maritime	Fuel oil LNG	Bio-LNG Biodiesel	XXX
Power, base-load	Coal, biomass, natural gas, hydro (imported)	Biomass/waste with CCS	Wild card
Power, green	Wind, solar, biomass	On and offshore wind Solar PV	
Power, flexibility	Gas, coal, biomass, import/export	Import/export Demand response incl. sector integration Electricity storage	XX

Table 3: Overview of the current use of energy within different sectors/applications, and indications of how a future green supply of energy could be organized.

6 Energy scenarios for the EU towards 2050 – the role of natural gas

In this chapter we will examine the role that natural gas might play in the future energy mix based on comprehensive scenarios published by the EU-commission.

In November 2018, in preparation for COP24 in Poland, The EU commission published Communication 773: “A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy”. The publication outlines possible pathways for a European transition to net-zero greenhouse gas emissions by 2050. The pathways frame possible and necessary developments from 2030 to 2050 achieving the Paris Agreement temperature objectives.

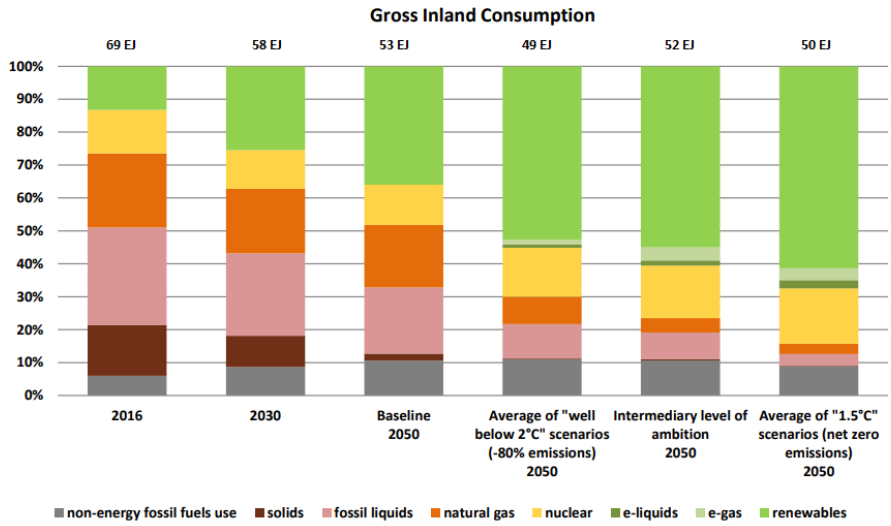


Figure 8: Possible pathways for a European transition to net-zero greenhouse gas emissions by 2050. Source: EU Commission, 0218: Communication 773.

The 2050-scenarios projects that fossil fuels are phased out except for in the transport sector and natural gas in the power sector

In the green scenarios fossil fuels are phased out towards 2050 except for remnants of fossil liquids mainly in the transport sector and natural gas mainly in the power sector. The transition to net-zero emissions is driven by electrification in all sectors, increased focus on energy efficiency, development and deployment of green liquids and gases, new energy storage technologies and carbon capture and storage (CCS). Green gases are biogas, hydrogen and e-gases.

Figure 31: Total gas consumption per gas type

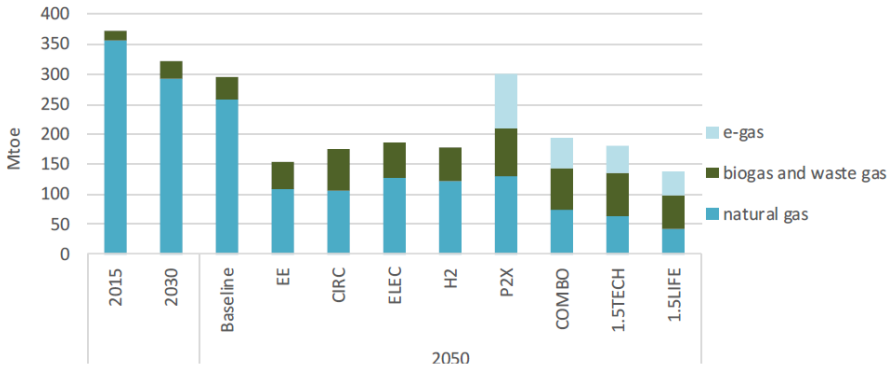


Figure 9: Total gas consumption per gas type in the scenarios from the EU Commission. Source: Eurostat (2015), PRIMES

As seen in the figure above, the role of gas, including natural gas, varies substantially across the scenarios in 2050; expressing uncertainty about efficiency and future competitiveness of the different green technologies.

Wind and solar have been developed greatly, but uncertainties remain concerning substitution for gas in the electricity sector

In recent years the competitiveness of wind and solar technologies have developed substantially, but large uncertainties still prevail concerning substitution for natural gas in the electricity sector (flexibility and security of supply) and in industry (price) and for fossil liquids in transport, especially aviation. As an example, the optimal balance between natural gas with CCS and green gas is unclear at present, when maintaining the global competitiveness of European industry as a priority.