Appendix Energy

Appendix A Completed Trend Analysis Framework

Table 1 Trend analysis

OIL	Probability of problem	Impact	Outlook
Net import dependence (1)	**Low** EU import dependence is considerable (86%). This is forcing the EU to continue thinking about mitigation measures in relation to disruption of oil supply. However, import dependence is not a problem in itself, because of well-functioning global markets.	**High** Import dependence affects the economic structure, infrastructure and policies, and has an impact on perceptions regarding energy security.	**Negative** Import dependence increases in a global/oil market that seems to become increasingly fragmented, combined with a potential deterioration of the political stability in some oil-producing countries.
Political stability in oil-producing countries (2)	**Moderate** Relative political stability in the key oil-producing countries (Russia, Norway, Saudi Arabia), but not in Libya, Iraq and Nigeria.	**Moderate** Liquidity and depth of the global oil market moderates the impact of disruption of a single supplier. However, there may be an effect on oil prices.	**Negative** The financial and economic effects of low oil prices may increase political instability in some countries; no improvement foreseen in the Middle East and North Africa.
Difficult political relations with oil-producing countries (3)	**Moderate** The relationship with the EU's largest supplier of oil, Russia, has deteriorated. The overall picture of relations with other suppliers shows little change.	**Moderate** Liquidity and depth of the global oil market moderates the impact of disruption of a single supplier.	**Stable** Neither further deterioration nor improvement in the relationship with Russia is to be expected within the given timeframe.

Limitations in import infrastructure (4)	**Low** Adequate handling capacity of ports and pipelines.	**High** Having adequate import infrastructure is essential.	**Stable** No significant change in near-term.
Limitations in storage capacity (5)	**Low** Sufficient storage capacity available (and storage facilities are full due to the market situation (oversupply, low prices)).	**Moderate** Storage is very relevant, but reliant on the availability of adequate import infrastructure.	**Stable** No significant change (but market situation could change).
Lack of diversification options (6)	**Low** Market is liquid and there are many potential oil suppliers to which the EU can turn in the event of disruption.	**High** Supply diversity is more important than a relationship (whether dominant or not) between a producer and the consumer at any given time.	**Stable** A number of vulnerable suppliers could see production decline, while the US has lifted its export ban on crude oil. Market will remain sufficiently liquid towards 2021.
NATURAL GAS	**Probability of problem**	**Impact**	**Outlook**
Net import dependence (7)	Moderate Import dependency is substantial and growing. This has drawbacks, but in itself import dependence is not a major concern (context matters, as with oil).	High Import dependency affects economic structure, infrastructure and policy-making, and has an impact on perceptions regarding energy security.	Negative Import dependency is expected to increase.
Internal political stability in supplier and/or transit countries (8)	**High** Transit of (significant quantities of) gas through Ukraine from Russia has proven to be problematic.	**High** Due to the greater degree of rigidity in gas markets and infrastructure (compared with oil), the impact of limited political stability of gas producing countries is greater than with oil.	**Negative** The financial and economic impact of low oil and gas prices may increase political instability in countries that are heavily dependent on oil and gas revenues, such as Russia.

Difficult political relations with suppliers (9)	**Moderate** In recent years, political relations with the EU's main gas supplier, Russia, have deteriorated; relations with other gas suppliers are good.	**High** Due to the greater degree of rigidity in gas markets and infrastructure (compared with oil), a difficult relationship with gas producing countries is a matter of greater concern than with oil.	**Stable** No reason to suppose either further deterioration or improvement in the relationship with Russia in the period under study.
Limitations in import infrastructure (10)	**Low** Overall, redundancy in import capacity in the EU exists, in terms of pipelines as well as LNG conversion facilities.	**High** Having access to sufficient import capacity is crucial.	**Positive** Import infrastructure is being developed further (capacity is increasing).
Limitations in storage capacity (11)	**Low** Overall, the EU has sufficient storage capacity, although the situation may be different at the level of some individual member states. Access to storage is sometimes a matter of concern.	**Moderate** Gas storage is an important aspect of gas infrastructure, but by itself can not be a full physical substitute for alternative gas supplies and import infrastructure.	**Stable** No significant change expected.
Lack of diversification options (12)	**Moderate** The gas market is not as liquid as the oil market, but in the period under study there is a relatively abundant supply of gas from various suppliers in the global market, providing options at the EU aggregate level. However, not all member states have the same degree of access to gas.	**High** Availability of alternative supply options is more important than a relationship (whether dominant or not) between a producer and the consumer at any given time.	**Positive** LNG (liquefied natural gas) from the US and elsewhere will become available to the European market.

COAL	Probability of problem	Impact	Outlook
Net import dependence (13)	**Low** 64% of coal consumption ('hard coal') in the EU-28 is imported.[a] Although the EU has significant coal reserves (a reserve/production ratio of 112 years), production is not competitive in the global market.[b]	**Moderate** Import dependency affects the economic structure, infrastructure and policy-making, and has an impact on perceptions regarding energy security. Compared to oil and gas, the coal market is relatively free from geopolitics.	**Stable** Both EU production and consumption of coal have shown a downward trend for years, and no change is expected in the period under study. The role of imported coal remains significant.
Limitations in import infrastructure (14)	**Low** Transport and trans-shipment capacity, ports facilities and rail transport are well developed in the EU. A number of Eastern European member states are relatively dependent on rail transport of coal from Russia (although this represents just 4.6% of total imports from Russia.)[c] In the event of a disruption, however, it is also possible to use (more expensive) road haulage. Storage of coal is relatively easy in ports and near power stations.[d]	**High** With a view to the significant role of imported coal, access to sufficient import capacity is crucial. No storage facility can eliminate the need for import infrastructure.	**Stable** No major problems are foreseen at the aggregate EU level. Moreover, work is being done to improve the German rail network, which will facilitate the flow of coal from Rotterdam to Duisburg,[e]
Lack of diversification options (15)	**Low** Sufficient diversification options exist in the global coal market. Markets are liquid and deep, and sufficient market participants are available.[f]	**High** Availability of alternative sourcing options is more important than a particular relationship (whether dominant or not) between a producer and consumer at a certain moment in time.	**Stable** No substantial changes are expected. Supply remains abundant during the period under study. US producers are looking for new markets. The market is competitive, which could also mean that suppliers collapse and disappear.

NUCLEAR	Probability of problem	Impact	Outlook
Front end of the nuclear fuel cycle (16)	**Low** The production of the nuclear fuel is technology-intensive. Controlling the steps in the fuel cycle is strategically more important than the extraction of natural uranium. EU member states have a strong position in the various steps in the fuel cycle.	**Low** On average, stocks are sufficient to allow the EU reactors to operate for three years without interruption.[g]	**Stable** Uranium as well as required enrichment services have been secured and ensured adequately by European energy companies for the period under study.[h]

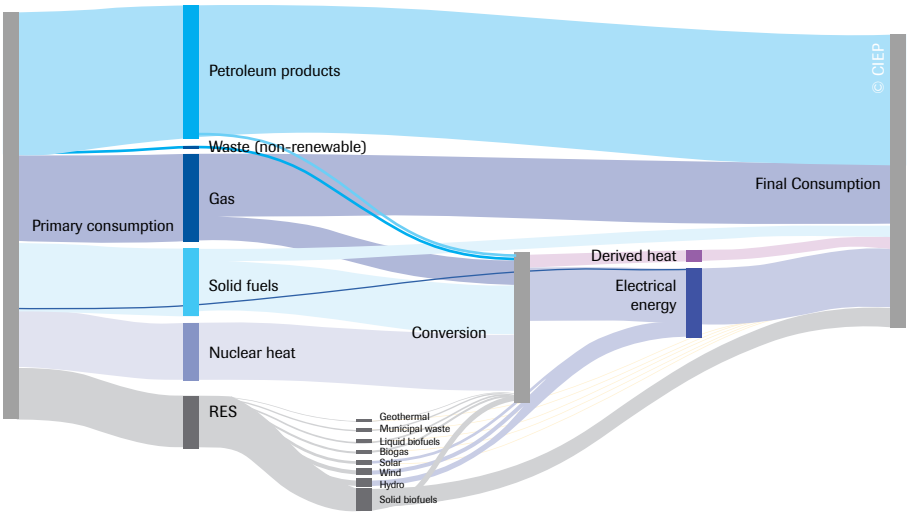
a Verein der Kohlenimporteure, *Import Coal Market at a Glance: Coking Imports,* 2015.
b BP, *Statistical Review of World Energy,* June 2016.
c See: Eurostat, *Statistical analysis of EU trade in energy products, with focus on trade with the Russian Federation*, Table 7, http://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Trade_in_energy_products.
d European Commission, *In-depth study of European Energy Security*, 2014, Commission Staff working document, SWD(2014) 330 final/3, 68-70.
e Verein der Kohlenimporteure, *Annual report 2014, Facts and Trends 2013/2014*.
f European Commission, *op. cit.*
g Euratom Supply Agency, *Annual Report 2015,* 36.
h *Ibid.*

Appendix B Explanation of key points in the trend analysis

Figure 1 shows the significance of oil and gas for final energy consumption (right), in combination with a substantial role for electrical power.[1] It should be noted that the greater part of EU electrical power is generated by thermal power stations fuelled by natural gas, coal (solid fuels), and nuclear heat (produced by nuclear fission in nuclear reactors). The figure shows that this conversion process is accompanied by significant conversion losses, with heat being generated as a waste product that has no further function. The most substantial energy losses occur in nuclear energy conversion processes, followed by coal and natural gas.

1 The EU currently imports 53% of all energy consumed. These energy imports represent 20% of total imports into the EU. The EU imports 90% of its crude oil needs, 66% of its natural gas, 42% of its coal and other solid fuels, and 40% of its uranium and other nuclear fuels. The EU is thus a net energy importer. See: European Commission, *Imports and secure supplies,* 22 November 2016, https://ec.europa.eu/energy/en/topics/imports-and-secure-supplies.

Figure 1 European final energy consumption in 2014[2]



A modest part of final energy consumption is supplied by renewable energy sources (RES), whether or not via the conversion to electricity. Solid biofuels are the largest source of renewable energy, usually locally produced wood used in heating in large parts of the EU. The role of emerging energy technologies such as solar and wind is still very limited as a proportion of final energy consumption.

Based on Figure 1, what are the key points for the detailed trend analysis in relation to security of energy supply? Considering the left side of the figure, it may be tempting to conclude that five energy sources must be included in this analysis: oil (petroleum products), gas, coal (solid fuels), nuclear energy (nuclear heat) and renewables (RES). However, RES is not a unitary form of energy; in fact, it is a collective name for a range of energy technologies, which all have specific characteristics. If analysed in isolation, single renewable energy sources are of limited relevance to European security of energy supply in the period to 2021.

The focus of the trend analysis is on the parts of the energy system that are the most relevant for the period under study. For this reason the analysis concentrates on oil, gas, coal and nuclear energy and not on the new technologies such as solar, wind, geothermal, etc.,

2 CIEP, based on Eurostat, 2014.

Obviously, any increase in RES capacity and production has the potential to reduce the weight of other sources of energy in total final energy consumption. However, a prospective decrease in consumption would not necessarily relax security of supply concerns associated with energy sources other than RES. The contrary may even be the case.[3] For instance, the introduction of new energy sources may create new security of energy supply challenges, caused by changes in the internal market (for instance, variable generation from solar and wind capacity can have an impact on the stability of the electricity systems; another example is the international competitiveness of refining activities in Europe and the implications this may have for the production of derivative oil products such as petrol, diesel, kerosene, etc.).

With respect to oil, gas, coal and nuclear energy, a further prioritisation has been implemented, and this is reflected in the analytical framework. In short, the analysis of coal and nuclear is more limited than the analysis of oil and gas.

Regarding nuclear energy, it is important to realise that it is often regarded as a domestic energy source. The main reason for this stems from the small quantity of raw material (uranium) required for the production of large quantities of nuclear power. Interruptions in the supply of raw material do not directly lead to security of energy supply issues, because fuel rods stay in reactors for years, and stocks are relatively simple to maintain. Nuclear fuel supply problems are of a significantly different nature than supply problems in relation to oil and gas.

The trend analysis in relation to coal is more extensive than the analysis of nuclear power, but still more limited than the analysis of oil and gas. There are various reasons for this. A significant quantity of coal (especially lignite) is produced in the EU. Moreover, most coal is used for electricity generation, for which alternative options exist. In general, a reserve margin in terms of power stations ensures a certain degree of redundancy in the electricity system. In other words, a temporary drop in coal supply from outside the EU can to some extend be mitigated through this redundancy – for example by using existing gas-fired power stations. Finally, the coal market is a well-developed and liquid global market where geopolitical considerations, concerns and disputes are only marginally present (partly due to geographically diversified supplies) among both energy consumers and energy producers.

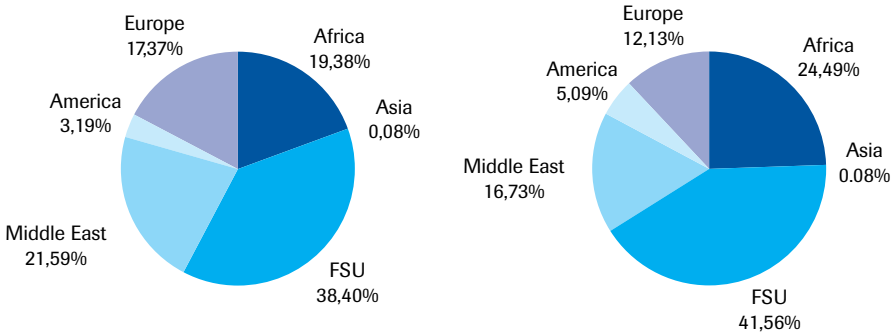
3 CIEP, *Security of Supply in the run up to the post-2020 period*, 2014, http://www.clingendaelenergy.com/inc/upload/files/Ciep_paper_2014-04.pdf.

Appendix C Trend Analysis for Oil

Oil accounts for about 34% of the EU energy mix, with the transport sector and the petrochemical industry as the main customers. The production and consumption of crude oil in the EU have been falling for years, but because consumption is decreasing much less rapidly, the share of imports in total EU oil demand is rising. Nevertheless, imports are falling in absolute terms. In 2005, the EU-25 imported more than 4.1 million barrels per day. In 2015, imports were 3.8 million barrels per day for the EU-28.

After a long period of relatively stable oil demand, consumption has decreased further since 2008, partly due to more efficient cars (stimulated by both government policy and relatively high oil prices in the previous five years) and partly due to decreased economic growth as a result of the financial and economic crisis. Oil and oil products are mainly consumed in the transport sector, aviation (kerosene), road freight (diesel) and passenger cars (diesel and gasoline), and petrochemicals, while demand is very limited in other sectors (e.g. power generation).

Figure 2 Oil imports from outside the EU in 2005 and 2015[4]



Even during the period of substantial North Sea oil production in the eighties and nineties of the last century, the EU was a net oil importer (from EU 6-12-15 to EU-28). With the decline of EU production since 1999, import dependence has significantly increased. In 2005, the United Kingdom (UK) and Norway still supplied approximately one-fifth of EU's oil (see Figure 2).

In 2015, about 90% of oil demand was imported from non-EU countries (3.8 million barrels per day), of which roughly 30% came from Russia (1.1 million barrels per day),

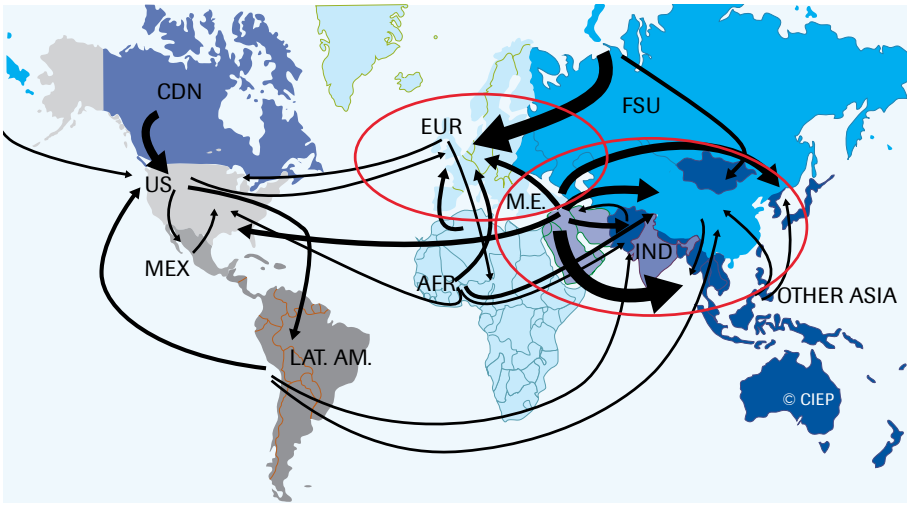
4 European Commission, DG Energy Registration of Crude Oil Imports and Deliveries in the European Union (EU28)

12% from Norway (446,000 barrels per day), slightly more than 8% from both Nigeria (320,000 barrels per day) and Saudi Arabia (308,000 barrels per day), slightly more than 7% from Iraq (281,000 barrels per day) and about 6% from Kazakhstan (243,000 barrels per day).

Aggregated by region, almost 25% of imports originated from Africa (949,000 barrels per day), about 17% from the Middle East (648,000 barrels per day), about 5% from the Americas (197,000 barrels per day) and nearly 42% from the Former Soviet Union (1.55 million barrels per day). Interestingly, the share of the Middle East in EU imports has decreased over this period (see Figure 3). Since the emergence of Asia as an important importer of oil, the international oil trade has become increasingly regionally concentrated. The Middle East has primarily become a supplier of oil to Asia, while the relative share of North America and the EU has declined.

The international oil market is very liquid (with plenty of trading opportunities and possibilities for hedging risks on financial markets) and due to developments such as the emergence of Brazilian sub-salt offshore oil, Canadian tar sands and light tight oil (LTO or shale oil), demand has become more geographically diverse in recent years. The recovery of Iraqi production and the return of Iran to the oil market have also broadened supply. In Africa, Angola has developed into a major supplier of oil alongside Nigeria. The new oil source LTO (or shale oil) has also rapidly developed from a marginal (costly) oil source into a mid-cost oil due to rapid developments in production technology and an optimalisation in the organization of production. Due to a period of relatively high oil prices, oil supply has grown faster than demand, resulting in an oil supply surplus since 2014, leading to big drops in oil prices, from an average of 110-120 dollars per barrel in 2014 to one of 40-50 dollars per barrel in 2016.

Figure 3 Significant regional concentration in crude oil trading[5]



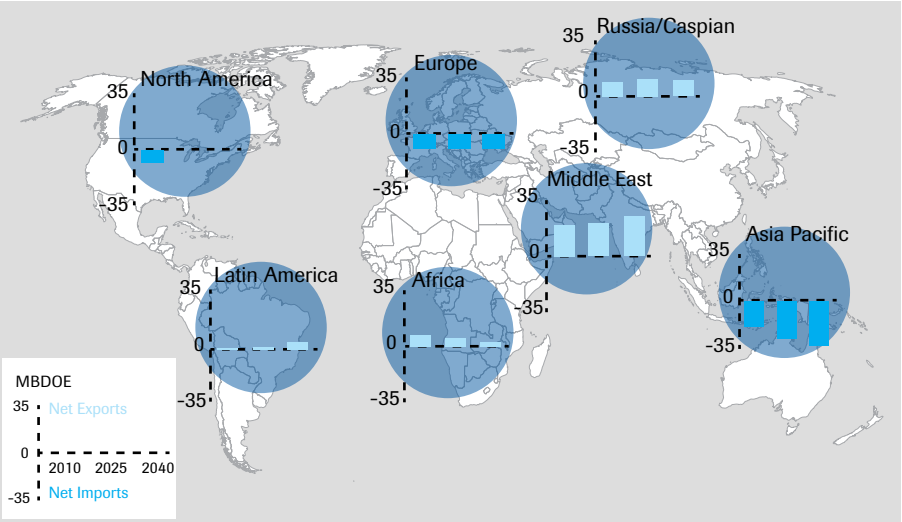
In the current buyer's market, the EU's security of energy supply is not at risk, as supply exceeds demand. However, with rising demand, especially in Asia, long investment lead times may bring about a shift to a seller's market. In such a market demand outstrips supply, the market becomes tighter and prices rise. The international market is nowhere near such a situation yet, but the significantly reduced investment levels in oil production that resulted from the low oil prices in 2015 and 2016 may cause scarcity in later years as the surplus is eliminated when new investments have not yet yielded any new oil. The longer the period of low prices lasts and investments fall relative to the level necessary to offset the natural decline of oil production from existing fields (the decline rate), the more likely it is that the temporary shortage will cause substantial price fluctuations. As demand for oil mainly relates to transport, the impact on the economy may be significant, depending on the economic cycle. In the current low growth and low inflation phase of the EU economy, the impact of a shift in the oil market will remain limited. Meanwhile, a rapid recovery of oil prices looks doubtful in 2017, making a transition from a buyer's to a seller's market not yet likely, despite some uncertainties.

Since absolute demand in the EU has been falling steadily for years (although lower oil prices may have fuelled additional demand which has not yet been processed in the statistics), a shift from a buyer's to a seller's market will not be caused by the EU. The development of demand in Asia and elsewhere in the world has more influence.

5 Figure designed by CIEP, 2016. Based on BP Statistical Review of World Energy 2015,

Figure 4 shows that Asia in particular will become increasingly reliant on imported oil. Asia already imports much more oil than the EU, with China as the largest oil importer in the world. Asia's demographic and economic growth is reflected in a widening trade deficit in oil. The future energy security discussion in the world will therefore focus increasingly on the needs of large countries such as China and India, and the extent to which they feel comfortable with the structure of the international oil market. By contrast, the EU has become a market follower, dependent on developments in supply and demand outside the EU.

Figure 4 Outlook for import/export trade balance in oil for various regions[6]



Before the rise of shale oil (or LTO), the US was also becoming increasingly dependent on imported oil. The US strongly 'stimulated' producing countries to keep oil freely tradable (instead of bilateral agreements between two state oil companies), while also protecting the security of maritime choke points on oil and gas routes (i.e. the Strait of Hormuz, the Strait of Malacca, the Suez Canal, the Bosphorus and the Panama Canal). The EU was able to benefit from US policy and obtain relatively easy (and cheap) access to oil. Despite the greater degree of self-sufficiency of the US, keeping international oil markets open has remained a priority due to a mismatch between the chemical composition of the new US supply (LTO is a relatively light oil type) and the configuration of the US refining industry. These refineries require oil grades from home and abroad to be blended to achieve an optimal composition for processing. The United States has

6 ExxonMobil, *Energy Outlook: A View to 2040,* 2014.

therefore retained an interest in the free international crude oil and oil products market, because it both imports and exports oil. Incidentally, an interesting surplus situation has currently arisen in oil products trading. US both imports and exports oil products, depending on the configuration of local networks and demand. The EU exports gasoline and imports diesel. In part stemming from the taxation of passenger car fuels in the past, there is a mismatch in demand for gasoline and diesel in the EU and the output of current EU refineries. A diesel surplus has also arisen in China, ensuring continued growth in exports to the EU. While crude oil markets are becoming more regionally concentrated, the markets for oil products are currently becoming less concentrated.

It is clear that the strategic importance of oil and import dependence is high on the political and economic agenda of large Asian countries. Every year, import dependency and the concentration of imports in terms of geographical origin increases. Asian import volumes from the Middle East have become very large indeed, and this is reflected in the increasingly close relations between these countries. Once, the OECD countries were the main markets for OPEC, but today the Asian countries have taken over that role. Naturally, Asian countries are therefore increasingly taking the lead in safeguarding the oil supply. Whether the interests of the EU will also be taken into account, as was the case in the period when the US mainly took the lead, is uncertain. The cost of securing oil supplies (in terms of forming closer relations with producing countries and monitoring maritime chokepoints) will increase if the US scales back or completely abandons its proactive role in this respect.

Until 2021, the EU's energy security will encounter few problems. However, vigilance is called for. The relatively large share of Russian oil in the EU's imports and its preferred quality for EU's refining base would probably be hard to replace with other sources from the international market. On the other hand, the Russian government is much more dependent on revenue from oil exports than from gas exports or any other product or tax revenue, which means that a disruption of trade with the EU is not likely to be initiated by Russia. This is especially true as its ability to export to Asia will be limited in scope between now and 2021.

The position of the Dutch refining industry

The Netherlands has an extensive refining sector that both supplies European petrochemical companies and exports gasoline and other oil products to neighbouring European countries and to outside the EU-28. The Netherlands is also a transit country for crude oil and oil products to neighbouring countries. The oil flows entering the Netherlands therefore must be regarded in a regional context related to the large refining sector (in the ports of Rotterdam and Amsterdam), transit traffic to Germany and Belgium and exports of oil products to the global market. The Netherlands (together with the port of Antwerp) is a hub for oil in NW Europe. Domestic oil consumption is modest in comparison to the oil economy of the Netherlands. The size of the Dutch oil and oil products economy places extra responsibility on the Dutch government regarding the EU's security of energy supply policy.

Appendix D Trend Analysis for Gas

The share of natural gas in final energy consumption in the EU is 23.5% (2013). Gas is mainly consumed by the electricity sector, the residential sector (heating) and industry. Production in the EU has been falling for several years, first at a rapid pace in the UK and more recently in The Netherlands due to the desire to limit the risk from earthquakes. Gas consumption in the EU has reached 426 Bcm in 2015, up from 409 Bcm in 2014.[7] This recovery follows a prolonged period of falling gas demand and prices[8]. Volumes imported from outside the EU have also decreased in absolute terms since 2010[9], as domestic production has so far decreased less than demand[10]. In relative terms, imported gas now covers approximately 70% of consumption in the EU.[11]

7 Eurogas data (estimates for 2016 and final data for 2015 refer to 2015 and 2014, respectively).

8 According to Eurostat and Eurogas data, demand for natural gas has fallen by about 100 bcm since 2010, dropping by 50 bcm in 2014 alone; according to Platts data, the average European import tariffs have shrunk by a factor of three since 2012.

9 The reduction in imports is divided almost equally across the various pipeline suppliers, with Russia maintaining a market share of approximately 30% of consumption and 40% of imports. Imports of LNG have decreased at a higher tariff, thanks in part to greater flexibility and the ability to re-export a certain proportion.

10 Gas production in the EU fell by about 52 bcm between 2010 and 2015 (BP, *op. cit.*). The Netherlands in particular produced 27.5 bcm less than in 2010, and production in the UK fell by 17.4 bcm.

11 Franza, L. 2016. 'Developments in Gas Supplies to Europe: a March 2016 Update', *Clingendael International Energy Programme (CIEP)*, March.

In this context, it would be intuitive to think that concerns on security of gas supply in Europe should have diminished in the last five years. To the contrary, as is made clear by the political debate[12], these have markedly increased after 2013, leading to initiatives such as the Winter Package, the Gas Stress Tests, and the Energy Union.[13] Since – as mentioned – Europe is presently oversupplied, these security concerns do not stem from scarcity of supply.[14]

It is now necessary to assess whether this trend holds in the next five years. It is too early to tell whether the demand recovery of 2015 marks a reversal of the trend observed since 2010. As a matter of fact, a comparison of scenarios from major institutions reveals great uncertainty on future gas demand in the EU.[15] On the other hand, there is consensus on the fact that, with EU domestic production declining at a faster rate than in the past owing to the cap on extraction from Groningen and maturing fields elsewhere, the EU's gas imports will probably increase towards 2021 (see Figure 5).[16]

12 Skalamera, M. 2015. 'Energy Security in the Wake of the Ukraine Crisis: Getting the Real Threats Right', *Harvard University,* Global Policy Essay.

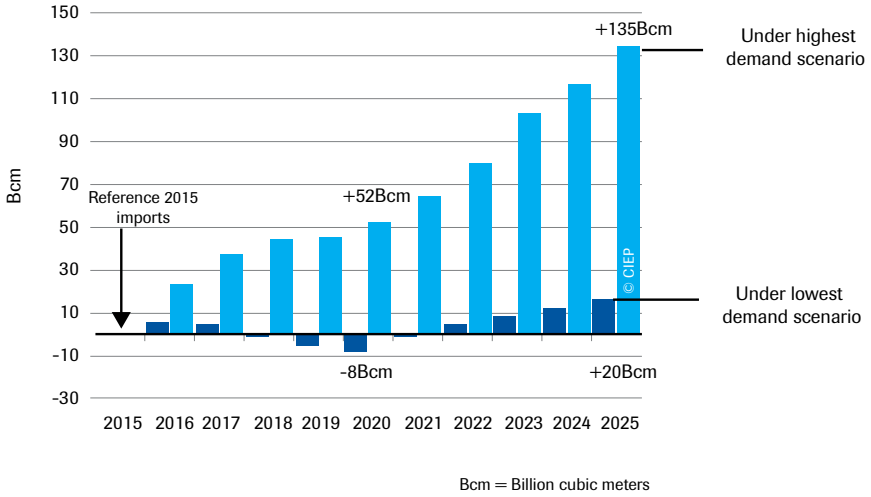
13 Rutten, D. 2015. 'CIEP Briefing Paper on the Energy Union', *Clingendael International Energy Programme (CIEP),* April.

14 CIEP, *Presentation at CIEP/Nogepa Gas Day*, 8 September 2016, http://www.clingendaelenergy.com/files.cfm?event=files.download&ui=2E601A86-5254-00CF-FD03CD6852746B36.

15 Pisca, I. 2016. 'Outlook for EU Gas Demand and Import Needs to 2025', *Clingendael International Energy Programme (CIEP)*, September.

16 *Ibid.*

Figure 5 Estimated increase in gas import requirements[17]



However, it is unlikely that this will lead to shortages in the EU gas market. Supply on the international LNG market is abundant and Russia has substantial spare capacity in terms of production (more than 100 bcm)[18]which can be brought to market without much new investment. Moreover, Europe disposes of the infrastructure necessary to accommodate all its additional import needs. In fact, only 45 of the 190 Bcm[19] in regasification capacity are currently utilized, and there are also 75 Bcm[20] of unutilized pipeline capacity (although technical, regulatory and political factors may limit access to physically available capacity). We can thus conclude that scarcity of supply and (physical) infrastructure constraints will not be a security issue in a 2021 horizon.

Because of lower domestic production, Europe's import dependence (measured in relative terms) is set to increase towards 2021. It is important to underline that higher

17 Relative to the 2015 import level; figure designed by CIEP, 2016.

18 Rogers, H.V. 2016. 'Asian LNG Demand: Key Drivers and Outlook', *Oxford Institute for Energy Studies (OIES)*, April, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2016/04/Asian-LNG-Demand-NG-106.pdf.

19 CIEP, calculations based on GIIGNL data, 2016.

20 CIEP, calculations based on IEA Gas Trade Flow (GTF) data, 2016.

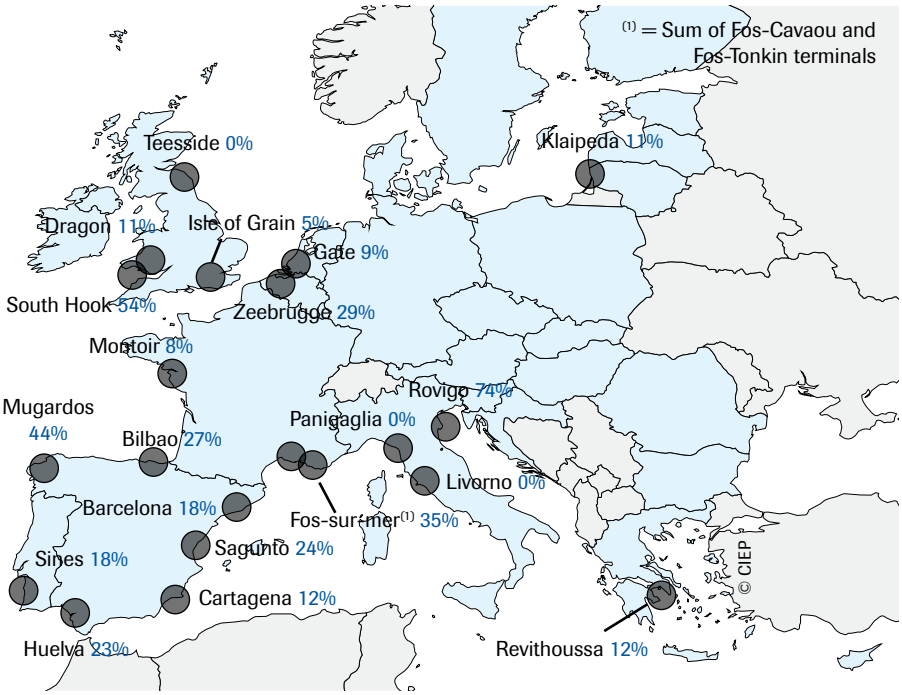
import dependence is not in itself a risk for security of supply.[21] Concerns only arise when rising gas import dependence is accompanied by one or more of the following: a.) overreliance on gas in the energy mix; b.) dependence on one dominant gas supplier or route and c.) lack of optionality to switch to an alternative supplier or route in case of a disruption. These elements are particularly critical for gas trade, given the larger depth and liquidity of other commodity markets relative to the gas market. Gas has in fact often been described as a commodity that is particularly exposed to security risks due to its limited substitutability.[22]

This is the case in some Eastern European member states, particularly those that receive Russian gas through Ukraine. It is possible that these countries will grow increasingly uncomfortable about gas import dependence towards 2021. As such, they are likely to seek ways to reduce the role of gas in their energy mixes, diversify supply or create more optionality by building new infrastructure. They are also going to influence the agenda in Brussels with consequences for the whole of the EU. Western EU member states have more diversified supplies and optionality (see Figure 6), but this does not mean that security of supply concerns are absent there.

21 In an ideal situation, if there are no political or technical disruptions to trade and both sides are satisfied with the commercial terms, an increase in import dependence does not correspond to an increased safety risk. On the contrary, such an increase may shape commercial and political relations in the long term and translate economic interdependence into a higher level of political cooperation.

22 Nordhaus, W. 2009. 'The Economics of an Integrated World Oil Market', *Venice International Energy Workshop*, June; 'From the international trade perspective, the gas market appears poorly integrated globally, and much less integrated than oil or coal markets' in Allsopp, C. and Stern, J. 2012. 'The future of gas: what are the analytical issues related to pricing?' in Stern, J. (ed.) 2012. 'The Pricing of Internationally Traded Gas', *Oxford University Press*; Victor, D., et al. 2004. 'Natural Gas and Geopolitics: From 1970 to 2040', *Cambridge University Press*.

Figure 6 LNG conversion capacity in the EU[23]



Average utilization rate of EU LNG terminals (2015 est.): 23%
BCM = Billion cubic meters

Installed: 190 Bcm
Utilized: 45 Bcm
Available: 145 Bcm

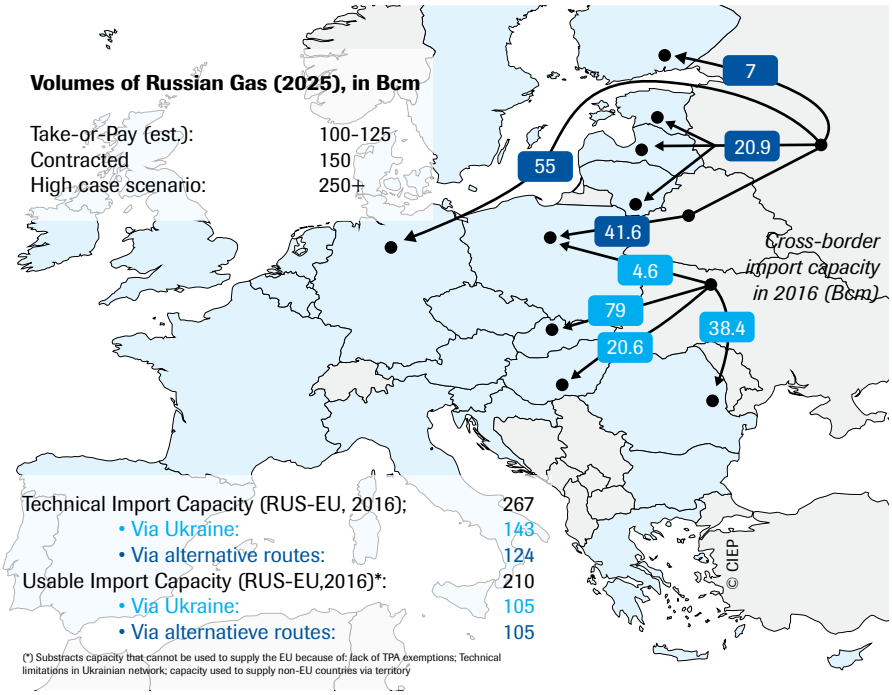
As shown by Gas Stress Tests, a disruption in Russian gas supply through Ukraine poses serious security risks to Italy and Central-Eastern Europe. A total disruption in Russian gas supply (imaginable only in case of a further and drastic fallout in EU-Russia relations due to disagreements on the status of Ukraine) would have far-reaching consequences on the whole Continent. Although incentives to avoid a crisis are high – as proven by the self-restraint adopted by the EU, Ukraine and Russia in managing the crisis so far[24] – political instability in transit countries (particularly Ukraine) and tense relations between Europe and Russia are at present the most serious risk to security of European gas supply. The outlook for these risks to 2021 seems stable, as the conflict in Ukraine appears to be gradually 'freezing' and disagreements about the status of Crimea (and related sanctions) are unlikely to be solved. Finally, political risk is quite

23 CIEP, based on GIIGNL data.

24 Stulberg, A. 2015. 'Out of Gas? Russia, Ukraine, Europe and the Changing Geopolitics of Natural Gas', *Problems of Post-Communism*, 62(2),114.

high in Algeria and very high in Libya,[25] exposing supplies to Southern Europe to political instability.

Figure 7 Possible Russian gas supplies (annual volumes) and import capacity through Ukraine and via other routes[26]



Not because of scarcity of capacity, but rather due to tensions around Ukraine, diversification of routes would be beneficial for security of supply. Russia is promoting an expansion of Nord Stream-2 and the construction of a southern pipeline (either Turk Stream or one of its alternatives) but political opposition to new Russian pipelines in the EU may block or delay these projects beyond 2021. On the other hand, diversification options that are politically supported by the EU (such as new supply lines from Azerbaijan, Turkmenistan, Iraqi Kurdistan, Iran and the East Mediterranean) are unlikely to materialize in the next decade, let alone by 2021. The first reason is that these pipelines are capital intensive and thus require substantial investments – in a context where no market player is willing to take long-term commitment owing to pronounced

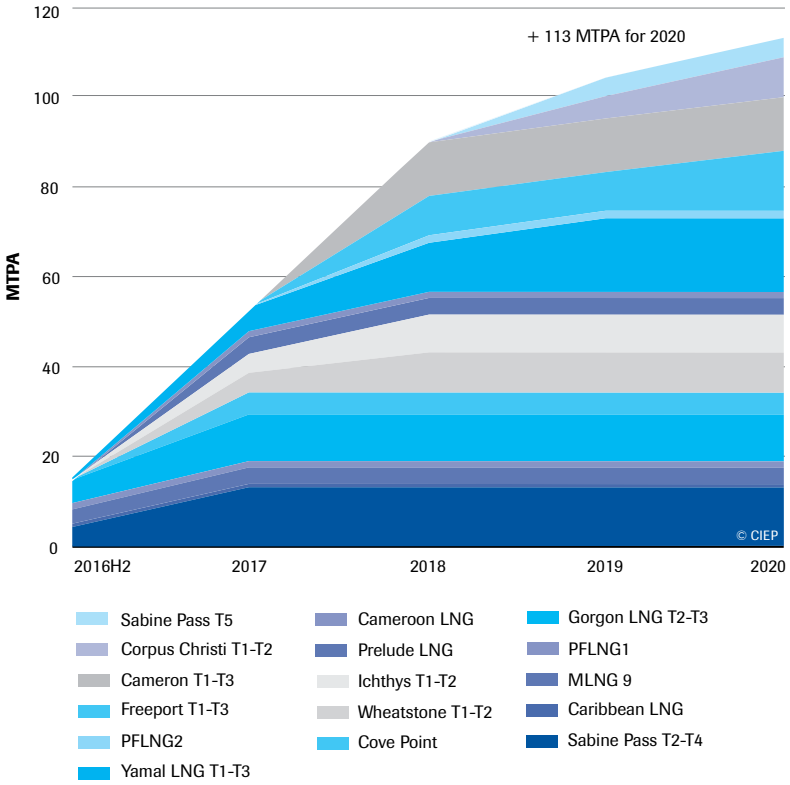
25 World Bank's Worldwide Governance Indicators.

26 CIEP, calculations based on IEA GTF data.

import demand uncertainty. The second is that, even if projects were to become economic viable, geopolitical hurdles would complicate them.[27] Country-specific issues also need to be solved.

LNG, finally, both enjoys political support in the EU as a source of supply diversification and is pushed by global market dynamics towards the EU. It will thus play a positive contribution in terms of security of gas supply towards 2021.

Figure 8 LNG liquefaction capacity increase from projects under construction[28]



27 Franza, L. 2016. 'Outlook for Gas Imports from New Suppliers into the EU to 2025', *Clingendael International Energy Programme (CIEP)*, September.

28 CIEP analysis based on data from company websites.

Appendix E Trend Analysis for Coal

Coal production in the EU is still substantial (see Table 2).[29] However, EU member states import a significant quantity of coal to meet their total demand. Roughly half of consumption is met by domestic production.[30]

Coal (solid fuels) cover a spectrum of solid fossil fuels, which vary in calorific values, moisture content, etc. For instance, in addition to 'regular' hard coal, there is also lignite (brown coal). Lignite has a lower energy value than regular coal, which means a higher CO2-intensity per kilowatt hour of electricity. Lignite continues to be used in substantial quantities for electricity production, especially in Germany and Poland; it is produced in the same large quantities in the countries concerned. There is no international market for lignite, due to the nature of the material: transporting it is expensive relative to its energy value.

Hard coal is mainly used for electricity production. For coal (apart from lignite) there is a well-functioning global market, with various price benchmarks including ARA (Amsterdam-Rotterdam-Antwerp).

China is by far the largest producer of coal, but also the largest consumer. Chinese coal is therefore hardly traded internationally. In the United States too, most of the output is consumed nationally, but some American coal does find its way to the global market (and the EU), especially since the shale gas revolution. India is also a major producer, but also India's output mainly satisfies domestic demand.

29 The EU has substantial coal reserves, with a reserve/production ratio of 112 years. However, these reserves are costly and by no means always economical to extract. Given the low import prices, it is often cheaper to import coal.

30 European Commission, *Security of Supply Study,* 2014, 62.

Table 2 Coal producers and coal exporters[31]

Coal producers (Mt)				Coal exporters (Mt)			
	2012	*2013*	*2014*		*2012*	*2013*	*2014*
China	3532.5	3843.6	3747.5	Indonesia	387.4	427.9	410.9
US	932.3	903.7	916.2	Australia	301.5	336.1	375.0
India	602.9	610	668.4	Russia	131.7	140.8	155.5
Australia	430.8	458.9	491.2	US	114.1	106.7	88.3
Indonesia	444.5	487.7	470.8	Colombia	83.3	80.2	80.3
Russia	329.4	326	334.1	South Africa	76	74.6	76.4
Poland	258.6	256.3	253.2	The Netherlands	13.7	31.9	38.7
Kazakhstan	197	191	186.5	Canada	34.8	39.1	34.5
Colombia	144.1	142.9	137.1	Kazakhstan	32.7	33.8	28.9
Canada	120.5	119.6	115.5	Mongolia	20.9	18.4	19.3
Turkey	89	85.5	88.6	North Korea	12	16.7	15.6
Others	682.6	650.3	613.5	Others	66.4	68.5	60.2
World	**7763.9**	**8075.5**	**8022.5**	**World**	**1274.5**	**1374.7**	**1383.6**

The largest exporters of coal are Australia and Indonesia. Russia, the US, Colombia and South Africa also play an important role. The Netherlands is a transit country and therefore regularly appears in the trade rankings, although no coal is produced in the Netherlands.

Coal is also still used for heating purposes in parts of the EU. For instance, in Germany – especially in the East but also in some rural Western regions – this fuel is still important for residential heating.

Although the coal market is a global one, economic factors (namely transport costs) have in practice led to two markets, known as the Atlantic Basin and the Pacific Basin. The EU obtains its coal particularly from countries which are favourably positioned with respect to the Atlantic Basin, such as Colombia, the US, but also Russia and South Africa.[32] However, in the event of relative scarcity in the Atlantic Basin, coal trade flows shift and demand in the Atlantic Basin can also be met with supply from the Pacific Basin, for example from Australia and Indonesia.

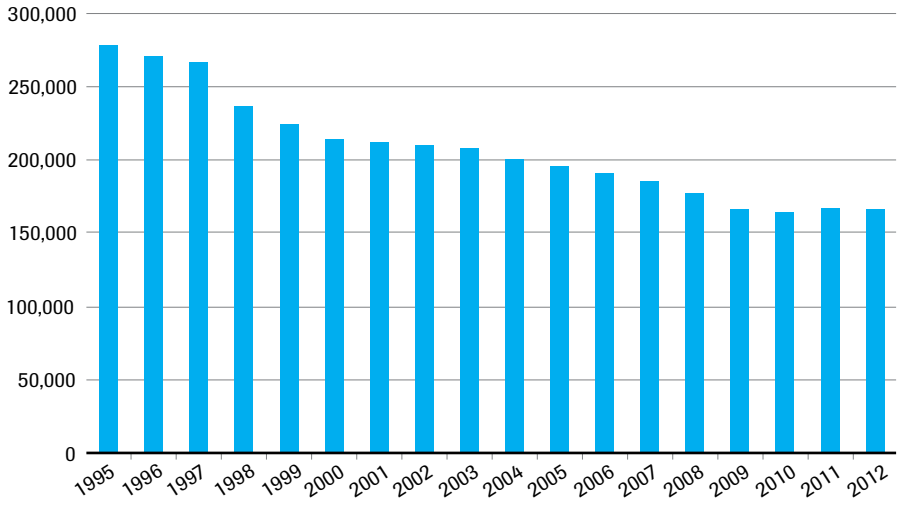
31 IEA, *Coal Information,* 2015.

32 Colombia, Russia and the US are the three largest exporters to the EU, each with about 25% of EU imports. Although Australia and Indonesia are the leading exporters worldwide, these countries only account for a marginal part of EU imports. South Africa is well positioned geographically to serve both basins.

Fuelled by the enormous growth in demand for coal in China, there has been worldwide investment in new coal production in recent years. Recently, however, world demand for coal stagnated, leaving a current surplus on the global market for coal.

The global market remains sensitive to Chinese policy initiatives that affect demand for imports. Fluctuations in coal consumption, but also in production in China, have a significant impact on the global supply/demand balance. Nevertheless, problems on the global market are not foreseen in the period under study. It is more likely that the global market will remain in surplus rather than turning into a tight market.

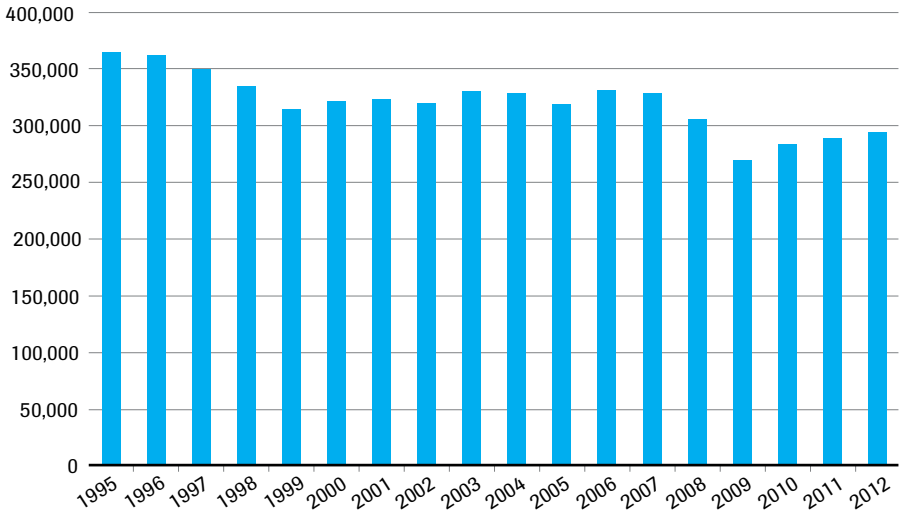
Figure 9 Production of solid fuels in the EU[33]



Because coal emits substantially more CO2 emissions than natural gas when it is burned, climate policy potentially has a moderating effect on the use of coal, if CO2 capture and storage fails to get off the ground. Moreover, because coal production in the EU cannot really compete on the global market, the downward trend in coal production in the EU is likely to continue. If electricity in the EU continues to be produced on a significant scale from coal, this may imply increasing import dependency. Given the nature of the global market, however, this is not a major issue.

33 European Commission, *Security of Supply Study,* 2014.

Figure 10 Consumption of solid fuels in the EU[34]



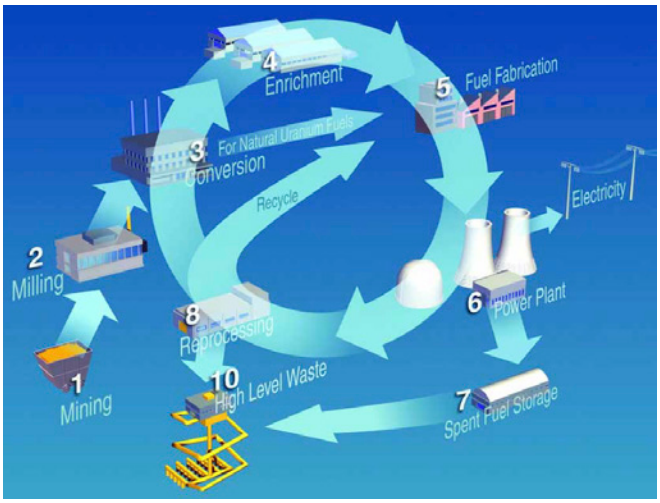
The coal infrastructure linking the EU with the global market is well developed. Ports, trans-shipment and rail links present no obstacle. Only in Eastern Europe there may be a high degree of local dependence on imports by rail, which in the event of a disruption could lead to supply problems. However, in the event of a crisis it is possible to revert to (more expensive) road transport. Finally, it is worth emphasising again that coal is used mainly for electricity generation. In the electricity system, there is a certain degree of redundancy, which means that reduced availability of coal could be offset to some extent by using another form of power generation, for example natural gas.

34 European Commission, *Security of Supply Study,* 2014.

Appendix F Trend Analysis for Nuclear Energy

The production of nuclear fuel, which is used in EU nuclear reactors, is technology-intensive. Control of the steps in the fuel cycle is strategically more important than extracting natural uranium, especially because uranium is supplied from various countries. EU member states have acquired a strong position with regard to controlling the steps in the fuel cycle. Nevertheless, sufficient investment in new mining capacity continues to be needed in order to ensure long-term availability of uranium.[35]

Figure 11 Nuclear fuel cycle[36]



The sourcing of the nuclear fuel begins with the extraction of (natural) uranium.[37] Extraction takes place in several countries, with Kazakhstan as the leading producer. Other producers are Canada, Australia, Niger, Namibia, Russia, Uzbekistan, the United States, China and a number of small producers.

35 Euratom Supply Agency, *Report on Nuclear Fuel Security of Supply,* June 2015.

36 IAEA, *Nuclear Energy and the IAEA: Fostering the Efficient and Safe Use of Nuclear Power,* https://www.iaea.org/sites/default/files/ne0606.pdf.

37 In addition to the extraction of natural uranium, use is also made of recycled material, for example from nuclear weapons.

Table 3 Commercial UF6 conversion facilities in 2015 (tons of uranium per year)[38]

Company	Nameplate capacity (tU in the form of UF6)	Share of global capacity
Atomenergoprom (Rosatom) (Russia)	12500	21%
Cameco (Canada)	12500	21%
ConverDyn (US)	15000	25%
Comurhex (Areva) (France)	15000	25%
CNNC (China)	4000	7%
Ipen (Brazil)	100	1%
Total	**59100**	**100%**

Conversion of natural uranium (through milling) to U3O8 and then to gaseous uranium hexafluoride (UF6) is carried out mainly by Atomoenergoprom (Russia), Cameco (Canada and United Kingdom), ConverDyn (United States), Comurhex (Areva; France) and CNNC (China).[39] Subsequent enrichment activities are mainly performed by four operators,[40] namely Atomenergoprom (Russia), Urenco (Netherlands, Germany, United Kingdom), Areva-GBII (France) and CNNC (China).[41]

Table 4 Commercial enrichment facilities in 2015 (tons of uranium per year)[42]

Company	Nameplate capacity (tU in the form of UF6)	Share of global capacity
TVEL/Tenex (Russia)	26600	47%
Urenco (UK, Germany, Netherlands, US)	19100	21%
Areva-GBII (France)	7000	25%
CNNC (China)	4220	7%
Others (CNEA, INB, JNFL)	175	1%
Total	**57095**	**100%**

38 Euratom Supply Agency, *Annual Report 2015,* 20.

39 European Commission, Euratom Supply Agency, and Nuclear Observatory. 'Nuclear Fuel Cycle – Front-end, Conversion',http://ec.europa.eu/euratom/observatory_segments_c.html.

40 If enriched uranium is not used (for example, in the Canadian CANDU reactors) the UF6 step is not necessary; the U3O8 is converted into UO2.

41 European Commission, Euratom Supply Agency and Nuclear Observatory. 'Nuclear Fuel Cycle – Front-end, Enrichment',http://ec.europa.eu/euratom/observatory_segments_e.html.

42 Euratom Supply Agency, *Annual Report 2015*, 21.

Final production of fuel elements then takes place in the EU (France, Germany, Spain, Sweden and the UK), Russia, the United States and a number of other countries, often under license from the major suppliers.[43]

Supplies to EU nuclear reactors are generally diversified. However, four countries, namely Bulgaria, the Czech Republic, Hungary and Slovakia, only have VVER reactors, which are entirely dependent for their fuel supply on one supplier (Atomenergoprom). In addition, two of the four reactors in Finland are of the same type, and thus depend on the same supplier, although they only represent 10% of national electricity production.

In the EU, the Euratom Supply Agency has a legal duty to monitor and safeguard the supply security of nuclear fuel. Uranium and the necessary enrichment services have been secured and ensured adequately by EU energy companies for the period under study.[44] Moreover, on average, energy companies' stocks are sufficient to allow the EU reactors to operate for three years without interruption.[45] This point may be the most important one that positively affects the supply security of nuclear-generated electricity relative to electricity generation from coal and gas. Although fuel supply is also not an immediate concern with a number of renewable technologies (solar, wind), the variability of weather conditions means that these technologies are indirectly dependent on the availability of conventional fuels, because spare capacity (mostly based on coal and gas) can only be used when the availability of such fuels is guaranteed.[46]

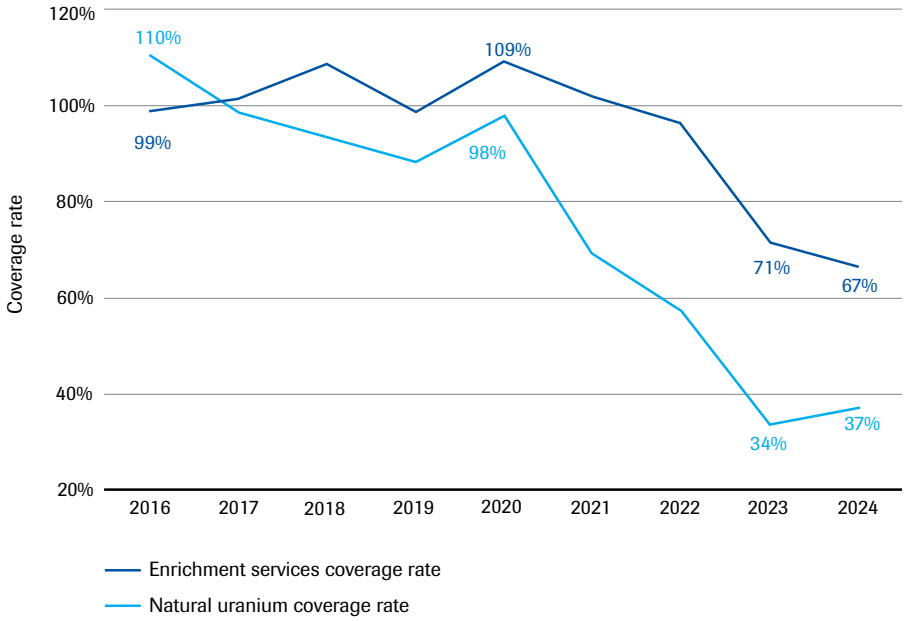
43 European Commission, Euratom Supply Agency, Nuclear Observatory. 'Nuclear Fuel Cycle – Front-end, Fabrication', http://ec.europa.eu/euratom/observatory_segments_f.html

44 Euratom Supply Agency, *op. cit.,* 36.

45 Euratom Supply Agency, *op. cit.,* 36.

46 See the method used by ENTSO-E to determine the '*system adequacy*' and '*generation adequacy*' of the European electricity system (ENTSO-E, *Scenario Outlook & Adequacy* Forecast, 30 June 2015; ENTSO-E, *Yearly Statistics & Adequacy Retrospect 2014*, 5 February 2016).

Figure 12 Extent to which European needs for uranium and enrichment services are already covered[47]



In the EU, around 130 reactors are operational in the commercial production of electricity. The assessment presented here reveals that external (political) shocks would only have a limited effect on that production. The main risk to nuclear security of energy supply is not so much external as internal: as the EU's nuclear reactor fleet is aging, reactor outages and permanent closures will increasingly lead to the reduced availability of nuclear energy. This is especially the case in the long term, beyond the period under study.

47 Euratom Supply Agency, *Annual Report 2015*.