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Oil and Gas Dependence of EU-15 Countries

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Executive Summary

This study assesses the dependence of the EU-15 region on two key energy products: crude oil and natural gas. A set of dependence and vulnerability indicators is provided and discussed, covering total economy and industry-level energy intensities, import dependence, import diversification indices and electricity generation.

The region's most intensive users of natural gas with respect to GDP are the Netherlands, the UK, Belgium, Italy and Luxembourg. This however does not translate into immediate vulnerabilities for the Netherlands and the UK given their high domestic production levels. The same cannot be said however of Belgium, Italy and Luxembourg, which are therefore the most intensive users of imported natural gas with respect to their GDP levels. Concerning petroleum products, the most exposed countries overall are Luxembourg, Belgium and Portugal.

Within industry, the most exposed branch of activity is non-metallic minerals (e.g. cement, glass, ceramics) both for natural gas and for petroleum products. Particularly vulnerable country-specific industries include basic metals in Ireland and in Luxembourg, non-metallic minerals in almost all of the 15 countries, mining and quarrying in Denmark and Greece, and chemicals in Austria and Spain. The transport sector is however the most intensive user of petroleum products in all 15 countries, mainly due to road transportation.

Import dependence is very high, generally between 80 % and 100 %, for both oil and gas for most of the EU-15 countries. Furthermore it is set to grow from 0 % or close to 0 % up to very high ratios for the UK and Denmark by 2015. This shift will significantly increase the EU-15's total demand for imported oil and gas. The leading source of the EU-15's imports is Russia for both oil and gas, accounting for 26 % of non-EU oil and 33 % of non-EU gas in 2005. Norway is the second most important source of imports for both oil and gas (19 % and 25 % respectively), followed by Saudi Arabia and Libya in the case of oil and by Algeria and Nigeria in the case of natural gas. Overall, the EU-15 has a rather well diversified pattern of source countries. However several member states are highly dependent on a small number of sources. Excluding Norwegian imports, the countries with the least diversified import patterns for oil are Finland and Sweden, while those with the highest degree of diversification are Spain and France. For gas the least diversified are Finland and Germany, while the most diversified are, again, Spain and France.

In the report, a combined indicator for vulnerability is created which combines each country's import dependence and diversification with how efficiently it uses the fuel in question in its economy. Using this combined indicator, it is found that the most vulnerable countries with respect to petroleum products are Finland, Belgium and Greece, while the most vulnerable countries with respect to natural gas are Finland, Austria and Italy. The least vulnerable countries in both cases are first and foremost those with currently high North Sea extraction levels such as the UK, Denmark and, in the case of gas only, the Netherlands. Leaving those countries aside (while bearing in mind that their resources are running out), the least vulnerable countries are Spain and France in the case of petroleum products, and France and Ireland in the case of natural gas.

In terms of domestic electricity generation, the most intensive users of petroleum products are Portugal and Italy, while the most intensive users of natural gas are Luxembourg and the Netherlands. The least vulnerable countries are Finland and Luxembourg for petroleum products and France and Sweden for natural gas.

Bringing all these results together it is found that France is the "star performer" in the region in terms of energy security. This is thanks to a large share of nuclear power in primary energy supply, combined with a healthy degree of supply country diversification for oil and gas imports.

The other main insight from the study is that the EU-15 as a block is in a less vulnerable position than the average of its constituent parts. This result implies that the European Union's energy security can be boosted if it adopts a common energy policy with strong solidarity mechanisms between member states, notably through the promotion of increased energy network interconnection.

Introduction

This study addresses the issue of crude oil and natural gas dependence for the 15 "old" member states of the European Union, i.e. those countries that were members of the European Union (EU) on 30 April 2004. These countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

This group of 15 countries has traditionally been dependent on imported crude oil, as the corresponding reserves in the region have been much below what would be needed with respect to the region's consumption levels. This caused the region to be very strongly dependent on oil from the Middle East in the 1970s, a vulnerability which was laid bare during the oil shocks of that period. The region subsequently went through a comparatively stable period thanks to the following combination of favourable developments: first and foremost, the discovery and extraction of substantial amounts of both crude oil and natural gas from the North Sea region; second, a general drive to diversify sources of fossil fuel imports; and third, a reduction in overall energy intensity as well as in oil intensity of GDP, thus making the economies of the region less vulnerable to possible repetitions of the oil shocks of the 1970s.

These developments all contributed to strengthening the energy security position of the region. However a number of partly inter-related developments started to arise, especially over the 1993–2007 period, which have put the region on a potentially less secure path in terms of energy security. These are the following: first, a significant shift of the fuel mix in favour of natural gas (replacing especially coal) which was primarily driven by the availability of North Sea resources as well as by environmental concerns, accompanied by the absence or failure of a shift in the fuel mix away from crude oil; second and concomitantly, a significant reduction of North Sea reserves of both oil and gas; third, a long period of time with consistently low world market prices for crude oil, which partly also contributed to low natural gas prices and which lasted roughly from 1993 to 2005; and fourth and most recently, the rise of Russia both as a very important supplier of fossil fuels to the region and as a revived world power on Europe's doorstep which may be inclined to pursue interests that are at odds with some of the region's interests.

For a number of structural and technological reasons, notably the existence of a world market for crude oil (with minor price dispersion for the various types of crude oil) and the related fact that tanker (sea-bound) transportation of crude oil is widely available and cost-effective, there are important differences to bear in mind when analysing the energy security position of the region with respect to oil and with respect to natural gas, though the option of liquefied natural gas (LNG) somewhat counteracts the key differences. LNG notwithstanding, natural gas is typically shipped to the final consumers in the region by way of purpose-built pipelines. Just focusing on the most significant routes from reserves that lie outside of the region, a set of pipelines exists connecting Russia to Eastern and Central European countries and onwards to, especially, Germany, Italy, Austria and France, while another set of pipelines exists connecting Algeria to Spain and Italy and Libya to Italy.

Contrary to the situation of crude oil, the contracts that regulate the purchasing of gas from these pipelines are essentially long-term bilateral (i.e. country-to-country) contracts, each with different price-setting clauses. There is no spot market which could enable arbitrage, and buyer and seller typically find themselves in a situation of durable mutual dependence.

This study provides, on a country-by-country basis, the energy intensity, and fuel-specific intensities, of GDP, of industry, and of selected economic branches of activity. In addition, import dependence ratios by type of fuel, as well as an analysis of source country diversification, are provided. Vulnerability indicators are then presented and discussed. The study concludes with an analysis of electricity generation in the EU-15.

Intensity and Vulnerability Indicators for the EU-15

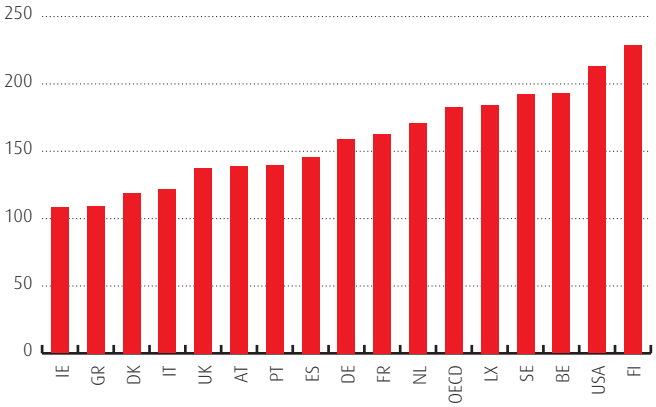
The most recently available IEA data (year 2005) for total real energy intensity for the 15 countries of the EU-15 region is shown in graph 1. Real energy intensity is here defined as the total primary energy supply (TPES)[1] of all energy products[2] together in thousands of tonnes of oil equivalent (ktoe) divided by real gross domestic product in constant purchasing power parity (base year 2000). For purposes of comparison, graph 1 also shows the indicator for the United States and for the OECD average.

There are sizeable differences in energy intensity among the group of 15 countries, with Finland being roughly twice as energy intensive as Ireland. With the exception of Finland all EU-15 countries have a lower energy intensity than that of the United States. What matters most in the context of the current study is specifically the dependence with respect to crude oil, petroleum products and natural gas. Crude oil is not used in any significant manner as a fuel for final consumption. Instead, the bulk of crude oil is refined into a number of petroleum products which are then used by various sectors of the economy (transport being the most important). Also, refining capacity is unevenly distributed across the region. Luxembourg for instance has no refining capacity and therefore does not use any crude oil at all but imports petroleum products from its neighbours instead. The Netherlands on the other hand has more refining capacity than its own consumption would require, and therefore has an annual use of crude oil which is also far above what its annual demand for petroleum products would imply, the difference being exported to its neighbours. In light of this, crude oil use per country is a somewhat misleading indicator, and we shall therefore use total final consumption of petroleum products per dollar of real GDP instead. As for natural gas, we will on the contrary look at primary energy supply of natural gas per dollar of real GDP given the non-existence of the refining issue and the importance of natural gas both for final use and for power generation. We start with natural gas as shown in graph 2.

There are significant differences across the region. Sweden and Greece use negligible amounts of natural gas in their energy product mix. A second group of countries may be defined including Portugal, Finland[3], France, Ireland and Denmark. In those countries natural gas is a relatively unimportant energy product. This is generally due to a less prevalent use of natural gas in industry and by households, but also due to a less prevalent use of natural gas in electricity generation, with coal, petroleum products, nuclear fuels and renewables as the main alternative inputs. Spain, Austria and Germany may be seen as intermediate cases, while the remaining countries may be seen as significant users of natural gas, namely Luxembourg, Italy, Belgium, the UK and the Netherlands. This structure may be explained from a historical viewpoint. The UK and the Netherlands in particular benefited from high domestic production levels of natural gas, translating into cheaply and easily available gas for their own economies. To a lesser extent Belgium and Luxembourg were also positively affected by the availability of North Sea resources.

Graph 1: **Real energy intensity**

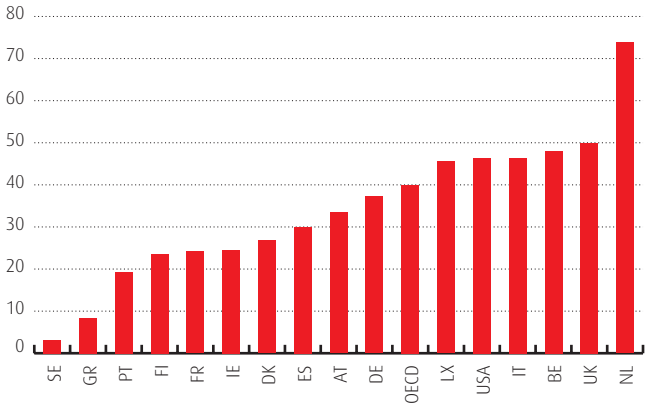
2005, ktoe per billion dollar of GDP at 2000 PPP



Source: IEA Energy Balances and own calculations

Graph 2: **Natural gas intensity**

2005, ktoe per billion dollar of GDP at 2000 PPP



Source: IEA Energy Balances and own calculations

1) Total primary energy supply is made up of indigenous production plus net imports minus international marine bunkers plus net changes in stocks.
2) This includes first and foremost coal, oil, gas, nuclear energy and renewables. Electricity is not a primary form of energy (it results from transforming one of the aforementioned energy products), and so appears within TPES indirectly, in addition to appearing directly in the form of net imports.
3) Finland is quite heavily reliant on renewables (23 % as compared to an OECD average of 6 %), in addition to having a sizeable nuclear component (17 %), which together explain the country's relatively low rankings in graphs 2 and 3 in spite of its high ranking in graph 1.

In graph 3 we can see the petroleum product intensity of each of the EU-15 countries as well as that of the OECD and the USA. The measure is taken as total final consumption of petroleum products divided by real GDP. By far the most intensive consumer is Luxembourg, though the data is partly distorted by cross-border "fuel tourism". Leaving Luxembourg aside, the major difference compared to natural gas is the fact that cross-country differences are substantially smaller. Certain EU-15 countries such as Belgium and Portugal have intensities close to that of the USA. Also, several of the countries that are heavily reliant on natural gas are found to be relatively less dependent on petroleum products, in particular Italy and the UK, while Belgium is found to be relatively strongly dependent on both types of energy products, alongside being one of the most energy-intensive economies in the region.

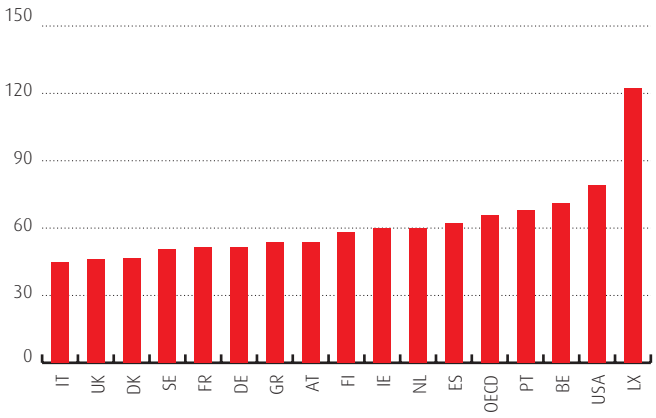
What do these indicators tell us in terms of vulnerability? In order to deepen the analysis, it is necessary to take into consideration the following questions: what share of each country's natural gas and crude oil comes from imports, where these imports come from, and which branches of the economy are the most intensive users of each main type of energy product. These topics are addressed in subsequent sections of this study. Also, it is useful to give a separate set of indicators and a discussion concerning electricity generation, given the importance of electricity as a source of energy both for productive activities throughout the economy as well as for households. This is the subject of a subsequent section.

Fuel intensity indicators for industry sectors

The intensity calculations shown earlier can be made at the level of specific industries in order to give a more precise picture of where exactly country vulnerabilities may lie. We begin with the petroleum products intensity and the natural gas intensity of industry as a whole (mining and quarrying plus the entire manufacturing industry) for each of the 15 countries of the region in 2005. The results are shown in Table 1. The intensities are expressed in thousands of tonnes of oil equivalent (ktoe) per billion Euro of output (production) at current prices[4].

Graph 3: **Petroleum product intensity**

2005, ktoe per billion dollar of GDP at 2000 PPP



Source: IEA Energy Balances and own calculations

"Greece and Portugal are the most petroleum product intensive in industry, Austria and Germany the least."

As can be seen, there are large differences between the countries of the region. This is partly due to the very different choices made in each country with respect to each industry's energy product mix, itself dependent on domestically available prices, but it is also due to intra-single market specialisation patterns which have led to very specific location patterns of industrial production by sub-industry. Furthermore overall energy efficiency also plays a role, itself partly driven by cross-country energy price differences. In any case, petroleum products intensity in industry is particularly high in Greece and Portugal, and particularly low in Belgium, Austria and Germany.

"Luxembourg and Spain are the most natural gas intensive in industry, Ireland and Sweden the least."

As for natural gas intensity, the most vulnerable countries are Luxembourg, Spain and the Netherlands, while the least vulnerable are Finland, Ireland and Sweden.

Table 1: **Ranking of EU-15 countries by energy product intensity in industry, 2005**

Country	Petroleum product intensity	Country	Natural gas intensity
Greece	38.9	Luxembourg	53.3
Portugal	20.2	Spain	29.6
Spain	11.8	Netherlands	27.3
Sweden	11.1	Belgium	22.6
United Kingdom	11.1	Italy	19.8
Finland	10.4	Austria	19.4
Netherlands	9.3	United Kingdom	19.3
Ireland	9.1	France	16.8
Denmark	8.3	Portugal	14.6
Luxembourg	8.1	Germany	14.3
France	7.9	Greece	10.2
Italy	7.6	Denmark	9.7
Belgium	5.8	Finland	7.0
Austria	4.8	Ireland	3.7
Germany	2.6	Sweden	1.9

Source: IEA Energy Balances, Eurostat and own calculations
Units: ktoe per billion Euro of output (production) at current prices

4) This choice is made due to the unavailability of appropriate industry-level PPP indices for the entire set of countries considered.

It is interesting to note that the rankings differ quite significantly from those for overall petroleum products and natural gas intensity. The main reason for this is that three key sectors in terms of energy consumption are not part of industry, namely transport, the residential sector (private and public housing and buildings), and the power generation sector.

Looking now at specific branches within industry, one expects to find the industries that are usually the most energy intensive in most countries, notably non-metallic minerals (cement, glass, ceramics), basic metals and chemicals. The results found confirm this general picture, though the approach used, differentiating by both country and sub-industry, enables a more refined selection. In total, 162 country-specific sub-industries were analysed. This was based on a breakdown of industry into 11 sub-industries for each of the 15 countries, leading to estimates for 165 country-specific sub-industries. Three of these had to be dropped due to data availability problems[5]. Tables 2 and 3 show the 20 most vulnerable industries in the EU-15 region in terms of petroleum products intensity and in terms of natural gas intensity respectively.

"Non-metallic minerals, basic metals and chemicals are the most sensitive industries with respect to oil and gas intensity."

Table 2: **Petroleum products intensive industries, top 20, EU-15, 2005**

Country	Industry	Petroleum product intensity
Ireland	Basic Metals	241.3
Greece	Non-Metallic Minerals	177.6
Portugal	Non-Metallic Minerals	148.7
Denmark	Mining and Quarrying	116.9
Greece	Non-specified Industry	106.7
Greece	Mining and Quarrying	100.1
Denmark	Non-Metallic Minerals	96.4
Ireland	Non-Metallic Minerals	92.3
Spain	Non-Metallic Minerals	76.2
Italy	Non-Metallic Minerals	73.8
Greece	Chemicals and Petrochemicals	72.3
Luxembourg	Mining and Quarrying	71.8
UK	Non-specified Industry	70.6
Greece	Basic Metals	60.6
France	Non-Metallic Minerals	55.9
Sweden	Non-Metallic Minerals	50.2
Luxembourg	Non-specified Industry	41.8
Spain	Mining and Quarrying	40.6
Greece	Total industry	38.9
Belgium	Non-Metallic Minerals	38.4

Source: IEA Energy Balances, Eurostat and own calculations
Units: ktoe per billion Euro of output (production) at current prices

5) Specifically: mining and quarrying in Austria, the Netherlands and Portugal.

Complete tables containing the intensities for all 162 country-specific sub-industries are available in Appendix A.

The labels for the industries are self-explanatory except for "non-specified industry", which is a heterogeneous grouping of 4 sub-industries. It includes rubber and plastics (NACE 25), medical, precision and optical instruments and watches and clocks (NACE 33), furniture and other manufactured articles not elsewhere classified (NACE 36), and recycling (NACE 37)[6].

As mentioned earlier, it is not surprising to find 9 of the 15 national non-metallic minerals industries among the 20 most petroleum products intensive industries in the EU-15. The second most frequently found industry is mining and quarrying (4 occurrences). In addition there seems to be a geographical pattern in evidence, i.e. that countries belonging to the geographical periphery of the region are over-represented. Greece appears six times in the table for example, whereas Germany, Austria and the Netherlands do not appear at all, while France, Italy, Belgium, Luxembourg and the UK each appear only once. This core-periphery effect, which has a bearing on product market competition and transport costs, may be further compounded by the smaller average size of the EU-15's periphery countries. Both effects (being on the periphery and being small) also have an impact on energy infrastructure, as natural gas is an especially attractive fuel if production facilities are located close to a pipeline terminal. This is much more like-

Table 3: **Natural gas intensive industries, top 20, EU-15, 2005**

Country	Industry	Natural gas intensity
Luxembourg	Non-specified Industry	249.3
Luxembourg	Basic Metals	126.7
Spain	Non-Metallic Minerals	118.0
Portugal	Non-Metallic Minerals	105.7
Netherlands	Non-Metallic Minerals	99.9
Italy	Non-Metallic Minerals	86.2
France	Non-Metallic Minerals	81.6
Germany	Non-Metallic Minerals	80.8
Austria	Chemicals and Petrochemicals	80.3
Spain	Chemicals and Petrochemicals	68.4
United Kingdom	Non-Metallic Minerals	58.5
Belgium	Chemicals and Petrochemicals	58.4
Austria	Non-Metallic Minerals	57.7
Denmark	Non-Metallic Minerals	52.6
Italy	Basic Metals	51.8
Denmark	Mining and Quarrying	51.6
Belgium	Non-Metallic Minerals	50.7
Spain	Mining and Quarrying	49.2
Netherlands	Basic Metals	49.1
Netherlands	Chemicals and Petrochemicals	46.8

Source: IEA Energy Balances, Eurostat and own calculationsUnits: ktoe per billion Euro of output (production) at current prices

6) This grouping comes as a result of the IEA's own chosen industry classification.

ly to be the case in core countries such as Germany, Austria, Belgium or the Netherlands than it is in countries of the periphery. This issue is illustrated in the case of the glass industry in Christie (2006)[7]. Conversely, the relative (financial) unattractiveness of such regions for gas pipeline development is what makes them less dependent on natural gas today, but it is also in some cases what makes them more dependent on petroleum products.

As was hinted at above, while the periphery of the EU-15 region was over-represented among petroleum products intensive industries, the reverse is true for natural gas intensive industries, as shown in table 3. The Netherlands appears three times among the top 20, Italy, Luxembourg and Belgium twice each. Again it is non-metallic minerals which is by far the most frequent occurrence in the top 20, appearing 10 times, i.e. two thirds of the region's national non-metallic minerals industries can be described as very natural gas intensive. Chemicals and petrochemicals also appears quite prominently in the ranking (4 occurrences), followed by basic metals (3 occurrences).

"Industry has become more petroleum product efficient in most countries."

Now that we have completed this overview of current vulnerabilities, it is appropriate to give some comments about recent trends in fuel intensities. Using time series for the indicators used above from 1995 to 2005, and correcting for changes in prices, it is possible to construct time series of real fuel intensity by country-specific sub-industry. Owing to data availability constraints the series thus constructed spans the period 1995–2004. An overview of that evolution is presented in graphs 4 (petroleum products) and 5 (natural gas).

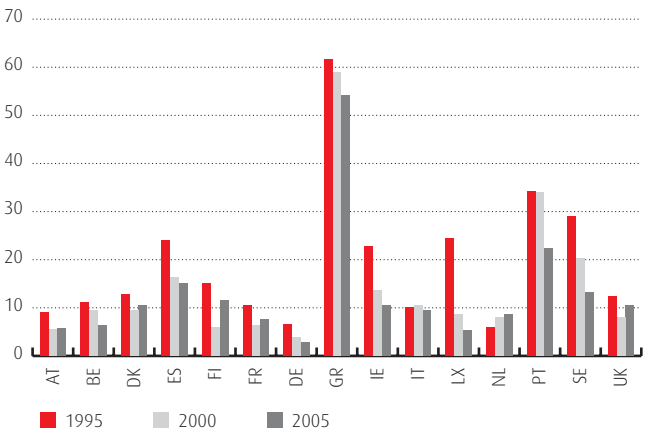
"But natural gas efficiency of industry has not improved significantly."

The broad evolution has been very positive in the case of petroleum products, less so however in the case of natural gas. However in interpreting these figures, it is important to recall that they each represent partial fuel intensities of fuels that are, to some extent, substitutes. Therefore a fall in one of these partial fuel intensities does not by itself imply that an overall improvement in energy efficiency has occurred. However where these indicators are useful is in helping us to gauge the recent direction of change of EU fuel demand patterns.

Finally we turn to the transport sector, which is generally much more petroleum product intensive than industry. The intensities are shown in table 4. Data on output for the transport sector was unfortunately not available for 2005, so the estimates refer to 2004. As can be seen, there are sizeable differences between countries, with Luxembourg, Portugal and Ireland more than 4 times more intensive than Denmark. However one important caveat should be borne in mind: fuel tourism is rather common inside the EU-15, i.e. individual as well as corporate vehicle owners fuelling up in neighbouring countries when petrol or diesel price differences make the additionally travelled distance worthwhile. Thus the results for Luxembourg (due to motorists from all its neighbouring countries) and Ireland (due to motorists from the UK, in particular Northern Ireland) may be higher than the true values. On the other hand the opposite should be true for Portugal (gasoline was cheaper in Spain in 2004). The result for Denmark should be free of distortions given that gasoline prices at the pump were virtually identical in Denmark and in Germany in that year.

Graph 4: **Petroleum products intensity of industry by country**

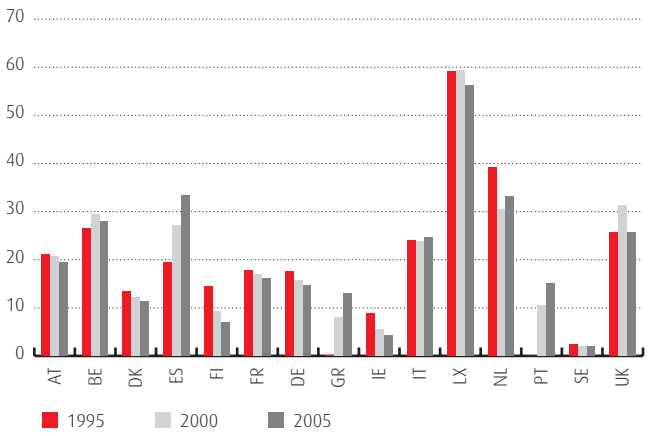
1995, 2000 and 2004



Source: IEA Energy Balances, Eurostat and own calculations
Units: ktoe per billion Euro of output (production) at current prices

Graph 5: **Natural gas intensity of industry by country**

1995, 2000 and 2004



Source: IEA Energy Balances, Eurostat and own calculations
Units: ktoe per billion Euro of output (production) at current prices

7) Christie E. (2006), "The Glass and Glass Products Industry", COMETR Project, December.

Table 4: **Petroleum product intensity of EU-15 transport sectors, 2004**

Country	Petroleum product intensity
Luxembourg	1034.3
Portugal	1033.6
Ireland	1024.3
Spain	745.4
Greece	723.3
Germany	644.5
France	594.5
United Kingdom	552.9
Belgium	520.1
Netherlands	488.4
Austria	482.6
Finland	457.5
Italy	453.6
Sweden	404.1
Denmark	215.6

Source: IEA Energy Balances, Eurostat and own calculations
Units: ktoe per billion Euro of output (production) at current prices

"National transport sectors in the EU-15 have very different petroleum product intensities, suggesting that more could be done to improve the European average."

Beyond these caveats, it remains the case that there are very significant differences between EU-15 countries. Geography, in particular population density and country size in square kilometres, are basic parameters that are fixed and that provide a basic level from which it may be difficult to depart. However the size of the differences suggests that much more could be done to improve petroleum product efficiency in a number of countries of the region.

Import dependence

Most EU-15 countries are strongly dependent, between 80 % and 100 % of total primary energy supply, on imports for both crude oil and natural gas. Tables 5 and 6 below give the details in terms of domestic production, imports and exports for each country, as well as for the EU-15 as a whole, the OECD as a whole and the USA (for comparative purposes). The quantities are in thousands of tonnes of oil equivalent. A positive sign for stock changes implies an increase in stocks. Net import dependence is defined as net imports (imports minus exports) plus withdrawals from stocks, divided by the country's total primary supply of the fuel in question.

"Most EU-15 countries are strongly import-dependent for both oil and gas."

Leaving Luxembourg aside, all but two of the EU-15 countries have a net import dependency of 90 % or above for crude oil. At the other extreme, the UK has a net import dependence of only 5 %, while Denmark is en-

Table 5: **Production, trade and import dependence for crude oil, ktoe, 2005**

Country	Production	Imports	Exports	Stock Changes	Total Primary Energy Supply	Net import dependence
Portugal	0	13,757	0	50	13,706	100 %
Sweden	0	20,683	562	184	19,937	100 %
Belgium	0	36,286	3,280	−155	33,161	100 %
Ireland	0	3,348	0	−38	3,386	100 %
Spain	169	61,385	0	99	61,455	100 %
Greece	92	20,053	918	−774	20,001	100 %
Finland	89	11,267	0	−180	11,536	99 %
France	1,314	84,144	45	−189	85,602	98 %
Netherlands	2,338	63,251	1,162	246	64,181	96 %
Germany	4,575	114,695	718	396	118,156	96 %
Italy	6,260	95,303	1,606	95	99,863	94 %
Austria	980	8,221	29	−174	9,346	90 %
EU-15	123,297	596,160	78,748	−165	640,874	81 %
United States	322,552	599,509	4,911	5,516	911,635	65 %
OECD Total	965,845	1,670,048	408,349	8,880	2,218,664	56 %
United Kingdom	88,464	60,909	56,307	388	92,677	5 %
Denmark	19,017	2,859	14,121	−112	7,866	0 %
Luxembourg	0	0	0	0	0	0 %

Source: IEA Energy Balances and own calculations

tirely self-sufficient and is in fact a net exporter, primarily to other EU countries. It should be noted here that the UK's oil reserves are running out, so the UK's net import dependence is set to rise markedly in the medium-run. According to BP (2007)[8], the UK's oil reserves should run out entirely by 2013 at current production levels. As for Denmark, its reserves are forecast to run out by 2016 at current production levels. The effect of the depletion of these EU resources will be significant. Just making a rough estimate based on 2005 production and primary supply data, the absence of British and Danish production would bring EU-15 production down to 123,297 – 88,464 – 19,017 = 15,816 ktoe. Given the EU-15's current primary supply, that would imply net imports of 640,874 – 15,816 = 625,058 ktoe which would equate to a net import dependence of 625,058/640,874 = 97.5 % by the middle of the next decade. One may further note that Norway's oil reserves are forecast to last only until 2015 at current production levels, so one should envisage a medium-run scenario with the EU-15 having to source virtually all of its oil from countries that are not currently embedded in the EU's institutions.

The pattern for natural gas is rather similar to the one for crude oil. Domestic production levels are however slightly higher on average, so that countries such as Germany, Italy and Austria end up with net import dependence ratios that are several percentage points lower. The EU-15 ratio is further brought down by the full self-sufficiency of the Netherlands, in addition to self-sufficiency in the case of Denmark, and near self-sufficiency in the case of the UK, as with crude oil. Similarly, the UK's reserves are running out (full depletion in 2012 at current production levels), as are those of Denmark (full depletion in 2014 at current production levels), leading to a rather substantial increase in EU-15 demand for imports in the medium-run. The reserves of the Netherlands are however more sizeable relatively to its production levels (full depletion in 2028 at current production levels), while those of Norway should last longer still. Using the same type of estimate as with oil, and focusing only on the medium-run scenario of the depletion of British and Danish reserves, one would obtain, based on the 2005 data, an EU-15 production level of 83,207 ktoe for a primary supply of 384,429 ktoe. This would lead to a net import dependence of 78 % by the middle of the next decade.

It is this very development, i.e. a substantial depletion of North Sea resources leading to an increased dependence on non-EU sources, which constitutes the structural backdrop to the current debate on the EU's energy security.

Table 6: **Production, trade and import dependence for natural gas, ktoe, 2005**

Country	Production	Imports	Exports	Stock Changes	Total Primary Energy Supply	Net import dependence
Finland	0	3,597	0	0	3,597	100 %
Luxembourg	0	1,178	0	0	1,178	100 %
Portugal	0	3,892	0	142	3,750	100 %
Sweden	0	842	0	0	842	100 %
Belgium	0	14,187	0	78	14,109	100 %
Spain	144	30,240	0	548	29,836	100 %
Greece	18	2,332	0	–3	2,353	99 %
France	828	41,612	903	552	40,984	98 %
Ireland	461	3,009	0	1	3,469	87 %
Italy	9,883	60,147	324	–925	70,631	86 %
Austria	1,403	8,122	836	428	8,261	83 %
Germany	14,220	73,510	7,795	–897	80,833	82 %
EU-15	171,388	272,515	59,679	–205	384,429	55 %
OECD Total	911,593	539,493	247,853	–8,207	1,211,440	25 %
United States	423,838	100,845	16,689	–1,417	509,411	17 %
United Kingdom	78,800	13,413	7,441	–102	84,874	7 %
Denmark	9,381	0	5,009	–26	4,398	0 %
Netherlands	56,249	16,435	37,370	1	35,314	0 %

Source: IEA Energy Balances and own calculations

8) BP (2007), "BP Statistical Review of World Energy", June 2007.

Imports by country of origin – crude oil

Looking at the EU-15 as a whole, and focusing only on crude oil imports originating from outside the current European Union (27 member states), we find the distribution of imports by source country to be as shown in table 7.

"Russia is the most important source of crude oil, followed by Norway, Saudi Arabia and Libya."

Russia is the most important source country with just over one quarter of the total, followed by Norway, Saudi Arabia and Libya. The EU-15's crude oil is thus sourced essentially from its "extended neighbourhood", i.e. the CIS, the Middle East and North Africa, with Sub-Saharan Africa (e.g. Nigeria, Angola) and the Americas (e.g. Mexico, Venezuela) playing only a minor role.

Table 7: **Crude oil imports into the EU-15 by source country, 2005**

Source country	Quantity (ths tonnes)	Share of total
Russia	134,096	25.8 %
Norway	97,340	18.7 %
Saudi Arabia	60,748	11.7 %
Libya	50,339	9.7 %
Iran	35,385	6.8 %
Algeria	22,642	4.4 %
Kazakhstan	22,296	4.3 %
Nigeria	18,618	3.6 %
Iraq	12,290	2.4 %
Mexico	10,647	2.0 %
Syria	8,987	1.7 %
Kuwait	7,621	1.5 %
Other	38,578	7.4 %

Source: Eurostat and own calculations

Does this distribution vary significantly between individual EU-15 countries, and if so, are there EU-15 countries that are more or less vulnerable to potential future supply shocks in terms of the pattern of source countries? An answer to that question requires at least two components: first, what does the distribution of shares of source countries look like? Is it strongly concentrated on a small number of countries or is it rather well diversified? And second, which are the most important source countries? A third component, which is crucial but not part of the remit of this report, would then be to assess the nature and level of risk with respect to potential future supply shocks for each source country.

Several measures of diversification may be considered. In this report the choice is to use the Herfindahl-Hirschman concentration index (HHI), which is typically used to measure market power concentration (for instance when assessing whether the merger of two firms will adversely affect competition). HHI is equal to the sum of the squared shares of each source country, and is thus between 0 (an infinite number of source countries each holding a share of zero) and 1 (one source country holding 100 %). To back this up, a second indicator is also used: the sum of the shares of the two most important source countries. The rankings obtained from these two indicators are very similar, as shown in table 8.

"Denmark, Ireland and Finland have the highest source country concentration for imports of crude oil."

Table 8: **Crude oil import concentration, EU-15 countries, 2005**

Importer	HHI	First source	Share	Second source	Share	Cumulative share
Denmark	1.00	Norway	100.0 %	–	–	100.0 %
Ireland	1.00	Norway	100.0 %	–	–	100.0 %
Finland	0.88	Russia	93.5 %	Kazakhstan	4.2 %	97.7 %
United Kingdom	0.57	Norway	74.4 %	Russia	10.1 %	84.5 %
Sweden	0.40	Russia	51.0 %	Norway	35.9 %	87.0 %
Belgium	0.30	Russia	47.8 %	Saudi Arabia	18.8 %	66.6 %
Greece	0.29	Russia	32.3 %	Saudi Arabia	31.1 %	63.4 %
Germany	0.23	Russia	40.3 %	Norway	18.3 %	58.6 %
Netherlands	0.19	Russia	31.7 %	Saudi Arabia	23.8 %	55.4 %
Austria	0.18	Russia	28.9 %	Kazakhstan	20.1 %	49.0 %
Italy	0.15	Libya	26.1 %	Russia	20.6 %	46.8 %
EU-15	0.14	Russia	25.8 %	Norway	18.7 %	44.5 %
Portugal	0.11	Algeria	23.1 %	Brazil	10.4 %	33.5 %
France	0.11	Norway	20.7 %	Saudi Arabia	13.3 %	34.0 %
Spain	0.10	Mexico	15.4 %	Russia	14.6 %	30.0 %

Source: Own calculations

The most vulnerable countries in terms of source country distributions are Denmark and Ireland which each import 100 % of their (non-EU) oil from Norway, with Finland, the UK and Sweden also appearing as strongly vulnerable. At the opposite end, Portugal, France and Spain have well diversified source country distributions and may be considered to be weakly vulnerable. However it seems fair to assume that Norway poses a substantially lower potential risk in terms of security of supply. Beyond the country's high levels of transparency and accountability, one may also argue that Norway's status as a member of the EU's single market (through its membership of the European Economic Area), of NATO and of the IEA all provide solid political and institutional guarantees to EU-15 countries.

Table 9: **Extra-EEA crude oil imports, country concentration index, 2005**

Importer	HHI – extra-EEA
Finland	0.917
Sweden	0.654
Belgium	0.358
Germany	0.290
Greece	0.287
Netherlands	0.227
United Kingdom	0.207
Austria	0.181
Italy	0.163
EU-15	0.154
Portugal	0.117
Spain	0.108
France	0.107

Source: Own calculations

We therefore choose to focus only on the exports that come from outside of the European Economic Area (EEA). Recalculating the indices, we find the ranking shown in table 9.

Denmark and Ireland do not appear as they source all of their crude oil from within the EEA. Now the most vulnerable countries are (by far) Finland and Sweden, and the least vulnerable are Portugal, Spain and France. The full structure of import shares for the EU-15 countries is shown in table B1 in appendix B.

Chained import vulnerability indicator – crude oil

How can we combine the data presented earlier on import dependence and the concentration index presented above? We propose that these indices can be chained, i.e. multiplied one by the other, in order to yield an overall measure of vulnerability relating to imports. Considering the two extreme cases, a country would have a vulnerability index of 1 (or 100 %) if it had an import dependence ratio of 100 % (it must import all of its fuel needs) in addition to having a concentration index of 1, i.e. that all of its imports comes from one country. Conversely, a country would have a vulnerability index of 0 (or 0 %) either because it is entirely self-sufficient and hence doesn't import any fuel at all, or because it has an infinitely diversified "portfolio" of source countries. Naturally, this latter case is purely theoretical, but it serves to illustrate how both variables enter the chained index that we propose. We furthermore insert the intermediate step of multiplying by the share of imports that originate from outside of the European Economic Area (EEA). Implicitly this means that we consider that dependence on imports from within the EEA poses no energy security problem at all. The other implicit property of our indicator is that we do not differentiate between non-EEA source countries. Given two hy-

Table 10: **Oil import vulnerability index, EU-15 countries, 2005**

Country	Net import dependence	Share of extra-EEA imports	Share of non-EEA oil in oil supply	Source country concentration index (HHI)	Oil import vulnerability index
Finland	99 %	84 %	84 %	0.92	0.77
Sweden	100 %	45 %	45 %	0.65	0.29
Greece	100 %	100 %	100 %	0.29	0.29
Belgium	100 %	79 %	79 %	0.36	0.28
Germany	96 %	69 %	66 %	0.29	0.19
Netherlands	96 %	76 %	73 %	0.23	0.16
Austria	90 %	97 %	87 %	0.18	0.16
Italy	94 %	96 %	90 %	0.16	0.15
Portugal	100 %	96 %	96 %	0.12	0.11
Spain	100 %	93 %	93 %	0.11	0.10
EU-15	81 %	74 %	60 %	0.15	0.09
France	98 %	73 %	72 %	0.11	0.08
United Kingdom	5 %	25 %	1 %	0.21	0.002
Denmark	0 %	0 %	0 %	0.00	0.00
Ireland	100 %	0 %	0 %	0.00	0.00

Source: Own calculations

pothetical countries, A and B, if each have the same import dependence ratio, and if A imports 80 % of its oil from Russia and 20 % from Saudi Arabia (for example) while B imports 80 % of its oil from Nigeria and 20 % from Iran, both would have an identical vulnerability index.

Table 10 shows our chosen vulnerability index for each of the 15 countries of the region. Net import dependence multiplied by the share of imports from outside the EEA (extra-EEA imports) yields the share of a country's primary supply of crude oil that comes from outside the EEA. This is then multiplied by the source country concentration index.

"Finland is the most vulnerable EU-15 country with respect to crude oil imports."

Finland is by far the most vulnerable country in the region, as it has both a high import dependence ratio and a highly concentrated source country structure, the overwhelming share of its imports coming from Russia. Next in the ranking are Sweden, Greece and Belgium with similar index values. The least vulnerable countries are Denmark (because it doesn't import any oil) and Ireland (because all its imports come from within the EEA).

The index value for the EU-15 as a whole is lower than the arithmetic average of the indices of the 15 individual countries. This is due to the fact that a union automatically has a more diversified source country pattern than the average of its constituent parts. This is more than just a theoretical curiosity: energy security is an area in which having a union between countries is an asset that has the potential of promoting the security position of the constituent countries. However the question that immediately arises is how well the union works, i.e. how good is the union at risk- and burden-sharing among its members. If that capacity is zero, then the true level of vulnerability of a group of countries is in fact the average of the vulnerabilities of its constituent parts. On the other hand if the union is as good at risk- and burden-sharing as are regions within a traditional nation-state, then one may consider that the union is "like a country", and then the vulnerability indicator for the union which is calculated above is a fair and accurate assessment. The practical reality is of course somewhere between these two extremes. A number of solidarity mechanisms exist, both in the context of IEA membership and in the context of EU membership. Member states have an obligation of solidarity towards one another in case of supply disruptions, for example. A more refined quantitative assessment of these issues would be beyond the scope of this report. However the general issue of how to move actual overall vulnerability closer to the Union average is briefly addressed in the final section of this report.

Imports by country of origin – natural gas

We now turn to natural gas imports by country of origin. As noted earlier, Denmark and the Netherlands have a net import dependence of zero with respect to natural gas (though there is roughly balanced trade in natural gas between the Netherlands and Germany, which we will ignore). According to Eurostat data[9] for 2005, Ireland and Sweden furthermore import gas only from other EU-15 countries. Leaving these countries aside, and given the inherently more sensitive nature of natural gas in the energy security debate, we give below the source country shares for all of the remaining EU-15 countries, as well as for the EU-15 as a whole. This is presented in tables 11 and 12.

"Russia is the most important source of natural gas, followed by Norway and Algeria."

Table 11: **Natural gas imports by country of origin, 2005, part I**

Country	EU-15	Belgium	Germany	Greece	Spain	France
Russia	32.6 %	8.0 %	53.1 %	83.6 %	0.0 %	23.3 %
Norway	25.4 %	43.1 %	40.9 %	0.0 %	6.3 %	27.6 %
Algeria	22.4 %	30.3 %	0.0 %	16.4 %	43.3 %	19.1 %
Other / unallocated	7.9 %	18.7 %	6.0 %	0.0 %	0.2 %	17.3 %
Nigeria	4.4 %	0.0 %	0.0 %	0.0 %	15.7 %	9.0 %
Libya	2.1 %	0.0 %	0.0 %	0.0 %	2.7 %	0.0 %
Egypt	2.0 %	0.0 %	0.0 %	0.0 %	10.1 %	3.7 %
Qatar	2.0 %	0.0 %	0.0 %	0.0 %	13.9 %	0.0 %
Oman	0.7 %	0.0 %	0.0 %	0.0 %	5.1 %	0.0 %
Trinidad and Tobago	0.3 %	0.0 %	0.0 %	0.0 %	1.2 %	0.0 %
Malaysia	0.1 %	0.0 %	0.0 %	0.0 %	0.8 %	0.0 %
United Arab Emirates	0.1 %	0.0 %	0.0 %	0.0 %	0.7 %	0.0 %
Total (extra-EU)	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Source: Eurostat and own calculations

9) The Eurostat data does have one caveat though: for reasons that are not entirely clear, a small share of gas imports are not allocated to any specific source country. Rather than speculate about these unallocated amounts we simply present the shares as directly calculated from the data.

Table 12: **Natural gas imports by country of origin, 2005, part II**

Country	Italy	Luxembourg	Austria	Portugal	Finland	United Kingdom
Russia	36.0 %	0.0 %	70.0 %	0.0 %	100.0 %	0.0 %
Norway	8.8 %	0.0 %	11.6 %	0.0 %	0.0 %	95.9 %
Algeria	42.3 %	0.0 %	0.0 %	61.9 %	0.0 %	3.5 %
Other/unallocated	5.6 %	100.0 %	18.4 %	0.0 %	0.0 %	0.0 %
Nigeria	0.0 %	0.0 %	0.0 %	38.1 %	0.0 %	0.0 %
Libya	6.9 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Egypt	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Qatar	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Oman	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Trinidad and Tobago	0.4 %	0.0 %	0.0 %	0.0 %	0.0 %	0.7 %
Malaysia	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
United Arab Emirates	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Total (extra-EU)	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Source: Eurostat and own calculations

Russia is the largest supplier of natural gas to the EU-15, accounting for just under a third of non-EU natural gas imports. Norway is in second place with around one quarter, closely followed by Algeria with 22.4 %. As with oil, source country patterns differ strongly between EU-15 countries. Finland sources 100 % of its natural gas imports from Russia. Another case of strong concentration is the UK, with 95.9 % of its imports coming from Norway. Spain, the UK and (apparently) Luxembourg do not import any Russian natural gas at all. Greece and Austria on the other hand are strongly reliant on Russia for their gas imports, while Portugal is strongly reliant on Algeria. Italy, Belgium, Germany and Portugal are almost wholly reliant on two main suppliers each, while Spain and France have the most diversified (least concentrated) source country patterns. This can be seen from table 13 where we show the Herfindahl-Hirschman concentration index for the countries of the region. Denmark, Sweden, Ireland and the Netherlands are excluded for the reasons mentioned earlier. It is also necessary to exclude Luxembourg. It is unfortunately not clear from the Eurostat data whether the unallocated import flows are attributable to one or several source countries, and whether or not some or all of those countries are EEA countries. The country with the least well diversified source country pattern is Finland (100 % from Russia). Germany, the UK and Greece also have quite strongly concentrated patterns. France and Spain on the other hand have well diversified source country patterns and correspondingly low concentration indices.

Table 13: **Extra-EEA natural gas imports, country concentration index, 2005**

Country	HHI
Finland	1.00
Germany	0.82
United Kingdom	0.73
Greece	0.73
Austria	0.67
Portugal	0.53
Belgium	0.41
Italy	0.38
EU-15	0.30
Spain	0.28
France	0.25

Source: Own calculations

Chained import vulnerability indicator – natural gas

We computed the same indicator as we did for crude oil, i.e. by chaining import dependence with the share of extra-EEA imports and with the concentration index. The results are shown in table 14.

"The most vulnerable country for natural gas imports is again Finland."

The most vulnerable country is again Finland, only this time vulnerability is 100 %. Greece's vulnerability is also high, as with crude oil. Portugal also has a relatively high vulnerability index. The vulnerability indices for Denmark, Ireland, the Netherlands and Sweden are of course zero (no extra-EEA imports).

Combined vulnerability indicators

Earlier we looked at the petroleum products intensity and the natural gas intensity of GDP for the countries of the region. In themselves, these intensities are a good indication of countries' vulnerability to pure price shocks. If the markets for oil and gas functioned under perfect competition, and if it were possible to instantly correct for supply disruptions from any given supplier by switching to other suppliers, then those indicators would be sufficient. However this is of course not the case in practice, hence the presentation of import vulnerability indicators in this report. However at this stage it seems desirable to try to combine the fuel intensity of GDP indicators with the import vulnerability indicators. We therefore develop a more comprehensive indicator by chaining fuel intensity of GDP with our chosen import vulnerability indicator in order to yield an overall fuel vulnerability indicator.

"Combined vulnerability for crude oil is highest for Finland, Belgium, Greece and Sweden."

Our chosen combined vulnerability indicator is defined as real fuel intensity of GDP, in thousands of tonnes of oil equivalent (ktoe) per billion US dollar of GDP at constant (year 2000) purchasing power parity (PPP), multiplied by the corresponding import vulnerability index. The indicator thus obtained has the same measurement unit as the fuel intensity indicator. The results are shown in tables 15 and 16 for petroleum products and for natural gas respectively.

In the case of petroleum products the indicator we propose is in a sense a mixed indicator and is a result of a compromise solution. We chain the import dependence of crude oil with the petroleum products intensity of GDP, rather than with the crude oil intensity of GDP. This choice, which is consistent with what was presented earlier, is made in order to avoid distortions due to the location of refining capacity in the EU-15. As for the results, we find that the most vulnerable countries with respect to the security of supply of crude oil are Finland, Belgium, Greece and Sweden. The least vulnerable are the UK, Denmark and Ireland. However as was noted previously the situation and ranking of both the UK and Denmark are set to change dramatically over the next 10 years. A more interesting example, therefore, would seem to be France, which in spite of high import dependence and not particularly low petroleum products intensity of GDP has a low combined vulnerability level. This is primarily due to its low source country concentration index, i.e. to its well-diversified source country pattern. The situation of the EU-15 as a whole is similar.

Table 14: **Natural gas import vulnerability index, EU-15 countries, 2005**

Country	Net import dependence	Share of extra-EEA imports	Share of non-EEA gas in gas supply	Concentration index (HHI)	Gas import vulnerability index
Finland	100.0 %	100 %	100.0 %	1.00	1.00
Greece	99.2 %	100 %	99.2 %	0.73	0.72
Portugal	100.0 %	100 %	100.0 %	0.53	0.53
Austria	83.0 %	88 %	73.4 %	0.67	0.49
Germany	82.4 %	46 %	38.2 %	0.82	0.31
Italy	86.0 %	81 %	69.3 %	0.38	0.26
Spain	99.5 %	94 %	93.2 %	0.28	0.26
Belgium	100.0 %	37 %	36.5 %	0.41	0.15
France	98.0 %	61 %	59.5 %	0.25	0.15
EU-15	55.4 %	59 %	32.5 %	0.30	0.10
United Kingdom	7.2 %	3 %	0.2 %	0.73	0.002
Denmark	0.0 %	0 %	0.0 %	0.00	0.00
Ireland	86.7 %	0 %	0.0 %	0.00	0.00
Netherlands	0.0 %	0 %	0.0 %	0.00	0.00
Sweden	100.0 %	0 %	0.0 %	0.00	0.00

Source: Own calculations

Table 15: Combined vulnerability indicator – crude oil

Country	Net import dependence	Share of extra-EEA imports	Source country concentration index (HHI)	Petroleum products intensity of GDP	Combined vulnerability indicator – crude oil
Finland	99 %	84 %	0.92	58.0	44.5
Belgium	100 %	79 %	0.36	71.1	20.1
Greece	100 %	100 %	0.29	53.6	15.3
Sweden	100 %	45 %	0.65	50.4	14.7
Netherlands	96 %	76 %	0.23	60.1	9.9
Germany	96 %	69 %	0.29	51.5	9.9
Austria	90 %	97 %	0.18	53.8	8.5
Portugal	100 %	96 %	0.12	68.1	7.7
Italy	94 %	96 %	0.16	44.6	6.6
Spain	100 %	93 %	0.11	62.2	6.2
EU-15	81 %	74 %	0.15	52.3	4.8
France	98 %	73 %	0.11	51.5	4.0
United Kingdom	5 %	25 %	0.21	45.9	0.1
Denmark	0 %	0 %	0.00	46.5	0.0
Ireland	100 %	0 %	0.00	59.9	0.0

Source: Own calculations, Units: ktoe per billion US dollar of GDP at 2000 PPP (last two columns)

Table 16: Combined vulnerability indicator – natural gas

Country	Net import dependence	Share of extra-EEA imports	Source country concentration index (HHI)	Natural gas intensity of GDP	Combined vulnerability indicator – natural gas
Finland	100 %	100 %	1.00	23.5	23.5
Austria	83 %	88 %	0.67	33.4	16.4
Italy	86 %	81 %	0.38	46.4	12.2
Germany	82 %	46 %	0.82	37.3	11.6
Portugal	100 %	100 %	0.53	19.3	10.2
Spain	100 %	94 %	0.28	30.0	7.8
Belgium	100 %	37 %	0.41	48.0	7.2
Greece	99 %	100 %	0.73	8.3	6.0
EU-15	55 %	59 %	0.30	37.2	3.6
France	98 %	61 %	0.25	24.2	3.6
United Kingdom	7 %	3 %	0.73	49.9	0.1
Denmark	0 %	0 %	0.00	26.7	0.0
Ireland	87 %	0 %	0.00	24.6	0.0
Netherlands	0 %	0 %	0.00	73.8	0.0
Sweden	100 %	0 %	0.00	3.1	0.0

Source: Own calculations, Units: ktoe per billion US dollar of GDP at 2000 PPP (last two columns)

"Combined vulnerability for natural gas is highest for Finland, Austria, Italy and Germany."

In the case of natural gas, the most vulnerable countries are Finland, Austria, Italy and Germany. The least vulnerable countries are the UK, Denmark, Ireland, the Netherlands and Sweden. Each of these has a combined indicator of zero or relatively very close to zero for different reasons. The UK, Denmark and the Netherlands have significant domestic production of natural gas. Ireland and Sweden do not, but they import all of their needs from within the EEA. In addition, Sweden's energy product mix relies overwhelmingly on products other than natural gas.

"The region's star performer is France."

Given foreseeable medium-run developments with respect to North Sea reserves, which will push the UK, Denmark and the Netherlands into much more vulnerable territory, the region's star performer is again France: in spite of an import dependence of almost 100 %, the country's well-diversified source country pattern and somewhat below-average natural gas intensity of GDP lead to a very favourable combined vulnerability indicator.

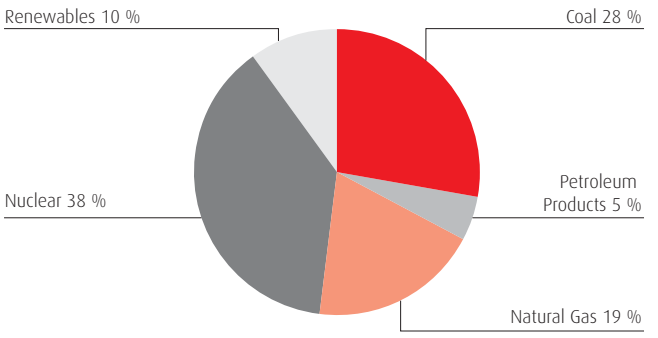
Electricity generation in the EU-15

Electricity represents an important component of final energy consumption and may be generated using petroleum products (not crude oil) or natural gas. In addition, coal is still used to a significant extent in certain EU-15 countries, especially Germany, while nuclear fuels account for a large share of electricity generation in France, Belgium and Sweden. As a whole, the EU-15 distribution of fuel use in electricity generation for the year 2005 is as shown in Graph 6.

Nuclear fuels are the most important type of fuel for electricity generation in the EU-15, accounting for 38 % of the energy value of all fuel inputs in 2005. The chief contributing country to this is France, which accounts for around 50 % of the EU-15's nuclear electricity generation. The second most important is coal, the chief contributing countries being Germany and the UK. Natural gas comes in third place with 19 %. The main contributing countries to the EU-15 total are the UK and Italy, followed by Germany, Spain and the Netherlands.

Graph 6: **Fuel mix in electricity generation**

% of total, EU-15, 2005



Source: IEA Energy Balances and own calculations
Note: Shares calculated based on energy content of inputs

Turning now to the fuels that interest us in this study, it is interesting to look at which countries use petroleum products (respectively natural gas) the most in their domestic electricity generation industries. Table 17 provides the percentages and rankings for each country in turn. As can be seen, Portugal, Italy, Greece and Ireland are the countries that rely the most on petroleum products. However the highest share found (Portugal) is only 22.3 %. Luxembourg, the Netherlands, Italy and Ireland are the countries that most rely on natural gas for their electricity generation.

What are the most recent trends in electricity generation in the EU-15? And how do these trends indicate responses to energy security concerns? To answer these questions we look at recent data from the EU-15's three largest economies: Germany, France and the United Kingdom. These three countries are chosen not only because of their size, but also because they provide illustrations for three completely different approaches to guaranteeing security in electricity generation.

France has a very high reliance on primary electricity, in particular nuclear electricity. As shown in Table 18, the share in total electricity generation from thermal plants (e.g. gas-fired or coal-fired) has fluctuated around 10 %–11 % of the total in recent years without any discernable trend.

Table 17: **Share of petroleum products and of natural gas in electricity generation**

Country	Petroleum Products	Country	Natural Gas
Portugal	22.3 %	Luxembourg	90.1 %
Italy	16.6 %	Netherlands	54.3 %
Greece	16.0 %	Italy	45.0 %
Ireland	15.8 %	Ireland	41.4 %
Spain	9.8 %	United Kingdom	31.2 %
Austria	5.1 %	Austria	29.0 %
EU-15	4.8 %	Portugal	26.8 %
Denmark	4.5 %	Denmark	26.0 %
Netherlands	2.8 %	Belgium	20.2 %
Germany	2.7 %	Spain	20.0 %
Belgium	2.1 %	EU-15	18.9 %
France	1.9 %	Finland	14.7 %
United Kingdom	1.2 %	Germany	12.4 %
Sweden	1.1 %	Greece	12.4 %
Finland	1.1 %	France	3.9 %
Luxembourg	0.0 %	Sweden	0.7 %

Source: IEA Energy Balances and own calculations

Table 18: **Electricity generation (TWh) in France by energy source**

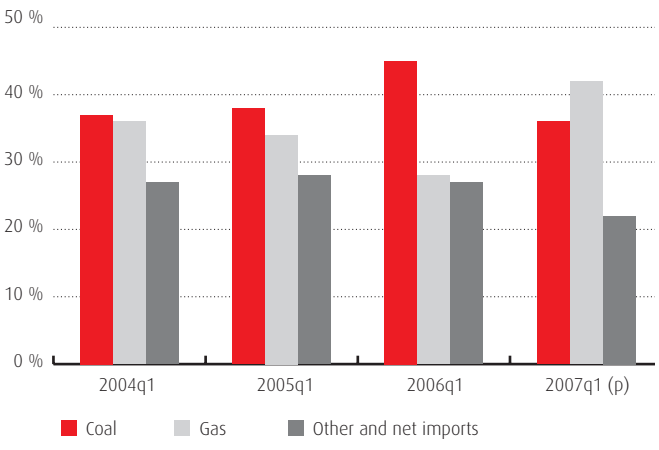
Year	Total	Nuclear	Thermal	Hydro and renewables	Share of thermal
2002	535	417	53	66	10 %
2003	542	421	57	65	11 %
2004	550	428	57	65	10 %
2005	550	430	63	57	11 %
2006 (p)	549	429	57	63	10 %

Source: INSEE, Observatoire de l'Energie
Notes: (p) = preliminary

Thanks to its important nuclear-power capacity, France is shielded from supply shocks with respect to both oil and gas as far as its domestic electricity production is concerned. This also applies to its domestic consumption of electricity, given that France is a net exporter of electricity.

The case of the UK is completely different, as the UK's electricity generation relies on three important sources, namely coal, gas and nuclear. Petroleum products-based electricity generation plays a very minor role, as do renewables. This structure is very responsive to changes in relative prices, in particular between gas and coal. This in turn is made possible due to the more liberalised market structure one finds in the UK, whereby domestic gas prices result from transactions on a relatively liquid market, which is not the case in many mainland European countries. The results can be seen from Graph 7, which shows the breakdown of UK electricity supply according to its source for the first quarter[10] of each year from 2004 to 2007. The price of coal was high relative to that of gas in 2003–2004, leading to more electricity generation from gas-fired plants. The situation then reversed as gas prices rose relatively to coal prices (partly due to the link between gas prices and oil prices).

Graph 7: **Electricity generation**
(% of total) by energy source in the UK



Source: DTI, Energy Trends
Notes : (p) = preliminary

This development started slowly in 2005 and accelerated strongly in 2006, showing a strong rise in the use of coal for electricity generation and a drop in the use of gas for the same purpose. However the preliminary data for the first quarter of 2007 indicates that this trend is now being completely reversed, because it is now gas that is cheap relative to coal. As we can see, gas-fired generation is now the most important type of electricity in the UK. Gas has also taken up the slack left from the steady reduction in nuclear electricity generation.

In the case of Germany, coal has traditionally been the most important source, while gas has been, and still is, rather unimportant. However nuclear energy is also quite important in Germany, accounting for just under 30 % of electricity generation in the country, while coal accounts for a bit more than 50 % (roughly evenly split between hard coal and brown coal). The most recent trend in Germany's mix of sources for electricity generation is shown in Table 19. The changes are much less drastic than those seen in the UK case, as Germany's power-generation sector is rather less flexible and so responds to price changes more slowly and less drastically. The recent change, which is small, indicates a slight increase in the use of coal and a slight fall in the use of gas when comparing the fourth quarter of 2006 to the fourth quarter of 2005. In addition, the trend in investment in Germany seems to favour coal-fired plants over other types of facilities. Two forces contribute to this development: oil prices (which affect gas prices) may remain high; furthermore, energy security concerns have made a comeback, while Germany is abundant in brown coal. At the same time, there are concerns that such a trend would make environmental targets, notably CO_2 emissions targets, impossible to achieve in future, so that there is also ongoing political lobbying against the current investment trend.

Table 19: **Electricity generation (% of total) in Germany, by energy source**

	2005q4	2006q4
Nuclear	29.9 %	29.6 %
Coal (hard and brown)	51.8 %	52.4 %
Gas	11.3 %	10.9 %
Other	7.0 %	7.2 %
Total	100.0 %	100.0 %

Source: Statistisches Bundesamt Deutschland

10) This is done in order to include the most up-to-date data that is available, which is the data for the first quarter of 2007. Then, comparisons must be made with the first quarters of previous years, not with entire past years, in order to strip out seasonality effects.

The conclusion of this section on electricity generation is that the three countries discussed have adopted completely different structures and strategies with respect to electricity generation. Each approach has its advantages and drawbacks with respect to energy security concerns, as well as with respect to environmental concerns.

France is, strictly from an energy security perspective, by far the most secure country. Its reliance on domestic nuclear electricity generation is an effective shield against oil price fluctuations and natural gas supply concerns. Nevertheless, France's heavy reliance on nuclear power does raise broader security issues, as well as environmental ones. The United Kingdom is a completely different case. While nuclear power does provide, in a sense, a partial safety cushion, the main feature of the UK structure is its highly flexible nature in being able to switch between coal and natural gas. This enables a smoothing effect with respect to price shocks. However this does not shield the UK from future import dependence for natural gas when its reserves run out in the course of the next decade. As for Germany, nuclear power also plays the role of a safety cushion, but the main feature is Germany's reliance on coal, notably domestically-produced coal. This is good from an energy security viewpoint, but much less so from an environmental viewpoint.

"A combination of the French and British models would seem ideal: more nuclear power, and flexible fuel-switching capabilities for thermal power."

The main lesson from this comparison is that there are several possible strategies for enhancing energy security on the demand side. However if one takes CO_2 targets seriously the German model seems less desirable, while a combination of the French and British models would seem ideal, i.e. a high share of nuclear power combined with flexible fuel-switching capabilities for fossil-fuel-based facilities. In this respect it would be wise for those EU member states that are more sceptical with respect to nuclear energy to initiate a properly fact-based domestic political debate in which the environmental and security risks of the various available options are assessed in a rigorous manner.

Conclusions

In this report a combined indicator for vulnerability was created which combines each country's import dependence and diversification with how efficiently it uses the fuel in question in its economy. Using this indicator, it was found that the most vulnerable countries with respect to petroleum products are Finland, Belgium and Greece, while the most vulnerable countries with respect to natural gas are Finland, Austria and Italy. The least vulnerable countries in both cases are first and foremost those with currently high North Sea extraction levels such as the UK, Denmark and, in the case of gas only, the Netherlands. Leaving those countries aside (while bearing in mind that their resources are running out), the least vulnerable countries are Spain and France in the case of petroleum products, and France and Ireland in the case of natural gas. Combining these results with those on electricity generation, it is possible to formulate a number of key conclusions.

First, the EU-15 is entering a period of potentially important change. This is due to the combined challenge of depletion of North Sea resources and of climate change mitigation. This combined challenge raises a number of important questions, in particular for the United Kingdom, Denmark and the Netherlands. The steady depletion of these countries' own reserves means that key strategic energy policy decisions must be taken now, and that these decisions must account for an important share of future total primary energy supply. For example, the UK has recently announced that it would promote large investments in wind power, in addition to acquiring an entire new generation of nuclear power-stations, while simultaneously increasing its import capabilities for natural gas, both gaseous and LNG. As argued in the report, France is the "star performer" of Western Europe in terms of energy security, in part thanks to its reliance on nuclear energy. The UK's recent decisions suggest that the energy security benefits of such a choice have been recognised. The EU-15 may to some extent therefore be part of the ongoing "nuclear revival" which is evident at the global level, in spite of objections from environmental groups. The latter are however not without influence, as increased commitments to renewable energy are in evidence across the EU, though it remains to be seen whether the EU can make good on its announced targets.

Second, the importance of Russia and Norway as key suppliers of both oil and natural gas to the EU-15 is clearly established, while the importance of the former, particularly with respect to natural gas, is likely to continue and perhaps to increase, given developments in the North Sea. Third, a number of countries are potentially quite vulnerable to supply shocks, in particular Finland (for both types of fuel), and to a lesser extent Austria in the case of natural gas. This implies that a number of steps should be taken to reduce vulnerability in concert with other EU countries.

Fourthly and finally, it is remarkable that the overall energy security position of the EU-15 as a block is much more favourable than the average of its constituent parts. What this implies is that national vulnerabilities can be mitigated if the European Union develops a unified and coherent common energy policy which favours a healthy degree of supply source diversification with strong solidarity mechanisms between member states, notably through the promotion of increased energy network interconnection.

Appendix A: Fuel intensities of industries

Table A1: Petroleum products and natural gas intensities of EU-15 industries, part I

Country	Industry	Petroleum products intensity	Natural gas intensity	Country	Industry	Petroleum products intensity	Natural gas intensity
Austria	Basic Metals	1.9	36.4	Austria	Paper, Pulp, Print.	3.6	32.6
Belgium	Basic Metals	3.3	41.8	Belgium	Paper, Pulp, Print.	4.0	8.9
Denmark	Basic Metals	8.4	19.5	Denmark	Paper, Pulp, Print.	2.1	10.5
Finland	Basic Metals	15.1	6.9	Finland	Paper, Pulp, Print.	16.5	29.9
France	Basic Metals	2.4	25.0	France	Paper, Pulp, Print.	2.7	25.8
Germany	Basic Metals	2.4	44.1	Germany	Paper, Pulp, Print.	2.4	26.6
Greece	Basic Metals	60.6	37.9	Greece	Paper, Pulp, Print.	14.6	7.1
Ireland	Basic Metals	241.3	0.0	Ireland	Paper, Pulp, Print.	0.7	0.0
Italy	Basic Metals	4.1	51.8	Italy	Paper, Pulp, Print.	4.7	36.2
Luxemb.	Basic Metals	1.5	126.7	Luxemb.	Paper, Pulp, Print.	0.0	0.0
Netherl.	Basic Metals	0.5	49.1	Netherl.	Paper, Pulp, Print.	0.0	26.0
Portugal	Basic Metals	28.5	35.9	Portugal	Paper, Pulp, Print.	17.8	8.7
Spain	Basic Metals	17.2	42.7	Spain	Paper, Pulp, Print.	6.4	38.4
Sweden	Basic Metals	32.2	3.0	Sweden	Paper, Pulp, Print.	29.4	1.4
UK	Basic Metals	3.5	40.5	UK	Paper, Pulp, Print.	1.3	16.0
Austria	Chemicals and P.	3.7	80.3	Austria	Textile and Leather	5.7	13.6
Belgium	Chemicals and P.	5.1	58.4	Belgium	Textile and Leather	0.5	12.7
Denmark	Chemicals and P.	2.9	10.0	Denmark	Textile and Leather	4.1	15.2
Finland	Chemicals and P.	30.7	5.0	Finland	Textile and Leather	22.3	7.2
France	Chemicals and P.	27.7	27.3	France	Textile and Leather	3.8	46.2
Germany	Chemicals and P.	0.7	40.5	Germany	Textile and Leather	4.1	15.1
Greece	Chemicals and P.	72.3	22.7	Greece	Textile and Leather	11.5	3.9
Ireland	Chemicals and P.	3.0	2.4	Ireland	Textile and Leather	27.2	0.0
Italy	Chemicals and P.	9.5	38.4	Italy	Textile and Leather	3.2	13.1
Luxemb.	Chemicals and P.	5.3	0.0	Luxemb.	Textile and Leather	0.0	0.0
Netherl.	Chemicals and P.	30.1	46.8	Netherl.	Textile and Leather	0.0	21.9
Portugal	Chemicals and P.	35.5	16.6	Portugal	Textile and Leather	4.2	12.3
Spain	Chemicals and P.	15.2	68.4	Spain	Textile and Leather	9.4	18.3
Sweden	Chemicals and P.	16.2	5.8	Sweden	Textile and Leather	14.4	2.5
UK	Chemicals and P.	2.6	45.3	UK	Textile and Leather	6.9	34.4
Austria	Food and Tob.	4.1	21.5	Austria	Transport Equip.	9.1	3.4
Belgium	Food and Tob.	5.2	15.7	Belgium	Transport Equip.	0.0	4.7
Denmark	Food and Tob.	8.6	11.0	Denmark	Transport Equip.	3.6	5.3
Finland	Food and Tob.	6.6	4.5	Finland	Transport Equip.	5.5	0.0
France	Food and Tob.	4.4	20.0	France	Transport Equip.	0.4	6.0
Germany	Food and Tob.	4.1	14.9	Germany	Transport Equip.	0.6	3.4
Greece	Food and Tob.	11.1	7.8	Greece	Transport Equip.	15.8	0.0
Ireland	Food and Tob.	7.3	9.8	Ireland	Transport Equip.	4.9	0.0
Italy	Food and Tob.	7.3	17.3	Italy	Transport Equip.	0.0	0.0
Luxemb.	Food and Tob.	9.9	0.0	Luxemb.	Transport Equip.	0.0	0.0
Netherl.	Food and Tob.	0.4	30.8	Netherl.	Transport Equip.	0.3	4.2
Portugal	Food and Tob.	13.3	5.3	Portugal	Transport Equip.	0.2	5.2
Spain	Food and Tob.	6.5	12.2	Spain	Transport Equip.	2.4	4.9
Sweden	Food and Tob.	9.7	9.3	Sweden	Transport Equip.	1.9	0.4
UK	Food and Tob.	3.3	22.9	UK	Transport Equip.	1.5	8.7

Source: IEA Energy Balances, Eurostat and own calculationsUnits: Thousands of tonnes of oil equivalent (ktoe) per billion Euro of output at current prices

Table A2: Petroleum products and natural gas intensities of EU-15 industries, part II

Country	Industry	Pet. Prod. Int.	Nat. Gas Int.	Country	Industry	Pet. Prod. Int.	Nat. Gas Int.
Austria	Machinery	1.2	3.4	Austria	Wood and Prod.	4.1	11.6
Belgium	Machinery	0.9	0.1	Belgium	Wood and Prod.	0.0	5.1
Denmark	Machinery	3.1	4.6	Denmark	Wood and Prod.	6.7	2.4
Finland	Machinery	0.6	0.1	Finland	Wood and Prod.	6.8	1.1
France	Machinery	2.0	5.0	France	Wood and Prod.	3.2	0.0
Germany	Machinery	1.6	3.9	Germany	Wood and Prod.	3.6	7.9
Greece	Machinery	1.3	0.4	Greece	Wood and Prod.	2.5	1.0
Ireland	Machinery	2.3	0.0	Ireland	Wood and Prod.	7.4	0.0
Italy	Machinery	2.7	9.0	Italy	Wood and Prod.	0.0	0.0
Luxemb.	Machinery	0.0	0.0	Luxemb.	Wood and Prod.	0.0	0.0
Netherl.	Machinery	11.8	7.1	Netherl.	Wood and Prod.	0.4	6.3
Portugal	Machinery	3.1	1.7	Portugal	Wood and Prod.	7.6	3.1
Spain	Machinery	2.5	6.0	Spain	Wood and Prod.	6.0	14.5
Sweden	Machinery	2.4	0.2	Sweden	Wood and Prod.	3.9	0.0
UK	Machinery	0.9	7.8	UK	Wood and Prod.	1.2	0.0
Austria	Mining and Quarr.	NA	NA	Austria	Total industry	4.8	19.4
Belgium	Mining and Quarr.	12.2	1.7	Belgium	Total industry	5.8	22.6
Denmark	Mining and Quarr.	116.9	51.6	Denmark	Total industry	8.3	9.7
Finland	Mining and Quarr.	14.8	0.0	Finland	Total industry	10.4	7.0
France	Mining and Quarr.	23.5	8.8	France	Total industry	7.9	16.8
Germany	Mining and Quarr.	14.5	29.7	Germany	Total industry	2.6	14.3
Greece	Mining and Quarr.	100.1	0.0	Greece	Total industry	38.9	10.2
Ireland	Mining and Quarr.	22.0	11.6	Ireland	Total industry	9.1	3.7
Italy	Mining and Quarr.	8.5	5.6	Italy	Total industry	7.6	19.8
Luxemb.	Mining and Quarr.	71.8	0.0	Luxemb.	Total industry	8.1	53.3
Netherl.	Mining and Quarr.	NA	NA	Netherl.	Total industry	9.3	27.3
Portugal	Mining and Quarr.	NA	NA	Portugal	Total industry	20.2	14.6
Spain	Mining and Quarr.	40.6	49.2	Spain	Total industry	11.8	29.6
Sweden	Mining and Quarr.	24.2	0.0	Sweden	Total industry	11.1	1.9
UK	Mining and Quarr.	20.0	0.0	UK	Total industry	11.1	19.3
Austria	Non-Met. Min.	18.1	57.7	Austria	Construction	28.4	1.6
Belgium	Non-Met. Min.	38.4	50.7	Belgium	Construction	1.7	1.8
Denmark	Non-Met. Min.	96.4	52.6	Denmark	Construction	5.8	0.2
Finland	Non-Met. Min.	36.7	18.1	Finland	Construction	15.7	0.0
France	Non-Met. Min.	55.9	81.6	France	Construction	5.2	1.4
Germany	Non-Met. Min.	28.2	80.8	Germany	Construction	2.1	0.6
Greece	Non-Met. Min.	177.6	21.4	Greece	Construction	10.7	0.0
Ireland	Non-Met. Min.	92.3	11.1	Ireland	Construction	0.0	0.0
Italy	Non-Met. Min.	73.8	86.2	Italy	Construction	0.4	0.0
Luxemb.	Non-Met. Min.	8.4	0.0	Luxemb.	Construction	5.8	0.0
Netherl.	Non-Met. Min.	3.2	99.9	Netherl.	Construction	1.7	1.3
Portugal	Non-Met. Min.	148.7	105.7	Portugal	Construction	10.8	0.2
Spain	Non-Met. Min.	76.2	118.0	Spain	Construction	0.8	0.2
Sweden	Non-Met. Min.	50.2	5.3	Sweden	Construction	0.0	0.0
UK	Non-Met. Min.	12.0	58.5	UK	Construction	0.7	0.8
Austria	Non-spec. Ind.	1.2	6.2	Italy	Non-spec. Ind.	4.1	9.1
Belgium	Non-spec. Ind.	20.7	5.9	Luxemb.	Non-spec. Ind.	41.8	249.3
Denmark	Non-spec. Ind.	2.8	5.5	Netherl.	Non-spec. Ind.	0.3	10.1
Finland	Non-spec. Ind.	24.6	0.0	Portugal	Non-spec. Ind.	0.2	3.5
France	Non-spec. Ind.	5.2	4.2	Spain	Non-spec. Ind.	5.4	39.4
Germany	Non-spec. Ind.	3.4	5.0	Sweden	Non-spec. Ind.	11.6	1.2
Greece	Non-spec. Ind.	106.7	4.5	UK	Non-spec. Ind.	70.6	10.7
Ireland	Non-spec. Ind.	7.1	9.2				

Source: IEA Energy Balances, Eurostat and own calculationsUnits: Thousands of tonnes of oil equivalent (ktoe) per billion Euro of output at current prices

Appendix B: Oil imports by source country

Table B1: **Crude oil import shares by (non-EU) source country, 2005**

Source	EU-15	BE	DE	GR	ES	FR	IT	NL	AT	PT	FI	SE	UK
Russia	25.8 %	47.8 %	40.3 %	32.3 %	14.6 %	12.4 %	20.6 %	31.7 %	28.9 %	0.0 %	93.5 %	51.0 %	10.1 %
Norway	18.7 %	9.8 %	18.3 %	0.0 %	5.0 %	20.7 %	3.7 %	12.8 %	0.0 %	1.9 %	2.3 %	35.9 %	74.4 %
Saudi Arabia	11.7 %	18.8 %	4.4 %	31.1 %	10.8 %	13.3 %	14.1 %	23.8 %	14.8 %	8.9 %	0.0 %	0.0 %	2.6 %
Libya	9.7 %	0.2 %	13.6 %	6.9 %	10.5 %	5.8 %	26.1 %	0.9 %	4.2 %	5.4 %	0.0 %	0.0 %	1.1 %
Iran	6.8 %	16.1 %	0.5 %	28.6 %	8.4 %	8.8 %	10.7 %	4.2 %	6.9 %	2.7 %	0.0 %	4.1 %	0.0 %
Algeria	4.4 %	0.0 %	4.8 %	0.0 %	3.6 %	6.9 %	3.3 %	5.7 %	0.3 %	23.1 %	0.0 %	0.0 %	3.2 %
Kazakhstan	4.3 %	0.0 %	7.8 %	0.3 %	0.0 %	11.0 %	3.4 %	1.0 %	20.1 %	6.5 %	4.2 %	0.0 %	0.0 %
Nigeria	3.6 %	1.1 %	2.2 %	0.3 %	12.2 %	3.7 %	1.7 %	3.1 %	16.0 %	10.0 %	0.0 %	0.9 %	0.6 %
Iraq	2.4 %	0.9 %	0.0 %	0.6 %	5.0 %	1.9 %	6.6 %	1.4 %	0.0 %	7.5 %	0.0 %	0.0 %	0.0 %
Mexico	2.0 %	0.0 %	0.0 %	0.0 %	15.4 %	0.0 %	0.1 %	0.0 %	0.0 %	8.3 %	0.0 %	0.0 %	0.9 %
Syria	1.7 %	0.2 %	3.6 %	0.0 %	0.9 %	1.6 %	2.9 %	0.6 %	2.2 %	0.0 %	0.0 %	0.0 %	1.4 %
Kuwait	1.5 %	0.2 %	0.0 %	0.0 %	0.0 %	3.1 %	0.3 %	9.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Other	1.4 %	0.4 %	0.4 %	0.0 %	3.9 %	1.1 %	0.7 %	1.9 %	0.0 %	7.6 %	0.0 %	0.0 %	1.9 %
Angola	1.4 %	1.5 %	0.2 %	0.0 %	2.9 %	5.5 %	0.2 %	0.3 %	0.0 %	1.1 %	0.0 %	0.0 %	0.1 %
Venezuela	1.3 %	2.9 %	1.4 %	0.0 %	1.9 %	0.2 %	0.0 %	1.9 %	0.0 %	0.0 %	0.0 %	8.0 %	2.9 %
Azerbaijan	1.1 %	0.0 %	1.0 %	0.0 %	0.0 %	1.7 %	3.2 %	0.0 %	4.4 %	0.0 %	0.0 %	0.0 %	0.0 %
Cameroon	0.7 %	0.1 %	0.0 %	0.0 %	2.9 %	0.5 %	1.2 %	0.4 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Brazil	0.5 %	0.0 %	0.5 %	0.0 %	0.2 %	0.4 %	0.0 %	0.8 %	0.0 %	10.4 %	0.0 %	0.0 %	0.0 %
Egypt	0.3 %	0.0 %	0.6 %	0.0 %	0.0 %	0.1 %	0.8 %	0.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.6 %
Tunisia	0.3 %	0.0 %	0.3 %	0.0 %	0.9 %	0.3 %	0.1 %	0.3 %	2.3 %	0.0 %	0.0 %	0.0 %	0.0 %
UAE	0.2 %	0.0 %	0.0 %	0.0 %	0.0 %	0.2 %	0.0 %	0.0 %	0.0 %	6.6 %	0.0 %	0.0 %	0.2 %
Gabon	0.1 %	0.0 %	0.0 %	0.0 %	0.3 %	0.4 %	0.0 %	0.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Congo	0.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.6 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Turkey	0.1 %	0.0 %	0.0 %	0.0 %	0.5 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Ukraine	0.0 %	0.0 %	0.0 %	0.0 %	0.1 %	0.0 %	0.2 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Congo, DR	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.1 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Total extra-EU27	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Total (ths tonnes)	519,587	28,083	94,696	18,699	58,552	77,640	89,315	53,486	7,630	12,913	9,143	13,985	50,225

Source: Eurostat and own calculations

Notes: Ireland and Denmark (not shown) import 100 % of their (non-EU) crude oil from Norway. The quantities were 2500 and 2720 thousand tonnes respectively in 2005. Luxembourg does not use crude oil at all as it has no refining capacity.

Country codes: BE = Belgium, DE = Germany, GR = Greece, ES = Spain, FR = France, IT = Italy, NL = Netherlands, AT = Austria, PT = Portugal, FI = Finland, SE = Sweden, UK = United Kingdom.

Appendix C: Transport and storage indicators

Table C1: Security stockholdings of petroleum products by category

Country	Assessed	Category I		Category II		Category III		Total	
		Days (1)	1000 t	Days (1)	1000 t	Days (1)	1000 t	Days (1)	1000 t
Belgium	30.06.07	142	682	67*	2,455	232	740	87	3,877
Denmark	30.06.07	127	482	117	1,143	432	566	147	2,191
Germany	30.06.07	127	7,664	110	18,862	178	2,968	119	29,494
Greece	30.06.07	98	1,083	100	2,345	110	846	102	4,274
Spain	31.07.07	122	2,423	98	10,307	149	2,588	107	15,318
France	30.06.07	117	3,252	104	15,051	201	1,831	111	20,134
Ireland	31.07.07	96	449	106	1,527	114	407	105	2,383
Italy	31.07.07	103	3,275	96	8,311	271	5,876	125	17,462
Luxembourg	30.06.07	98	120	92	616	100	1	93	737
Netherlands	31.07.07	217	2,427	158	4,795	11,998	1,560	211	8,782
Portugal	30.06.07	161	740	111	1,884	167	816	130	3,440
UK	30.06.07	99	3,698	88**	7,469	850	1,674	103	12,841
Austria	30.06.07	151	754	98	2,060	337	1,012	132	3,826
Sweden	30.06.07	115	1,279	95	1,475	301	1,124	127	3,878
Finland	30.06.07	116	596	155	1,950	160	667	147	3,213
EU-15 Total	N.A.	121	28,924	103	80,250	230	22,676	118	131,850

Source: DG Energy web-site, data as available on 6 November 2007.
Key: * not in compliance (90-day rule); ** preliminary data; (1) equivalent volume in terms of days of consumption;

Category I: Motor spirit and aviation fuel of gasoline type
Category II: Gasoil, diesel oil, kerosene and jet-fuel
Category III: Fuel oils

Table C2: Underground gas storage capacities by country, 2004/2005

Country	Number of facilities	Total working volume (mn m³)
Germany	42	19,179
Italy	10	17,415
France	15	11,643
Netherlands	3	5,000
UK	4	3,267
Austria	4	2,820
Spain	2	1,981
Denmark	2	820
Belgium	1	550
Ireland	1	210
Sweden	1	9
EU-15 Total	85	62,894

Source: International Gas Union (2006), "Underground Storage of Gas", June.
Comment: the EU-15's total primary energy supply (TPES) in natural gas was 384,429 thousands of tonnes of oil equivalent. Assuming an average gross calorific value for natural gas of 39,000 kilojoules per cubic metre (Russian natural gas has an average GCV of 38,231, Algerian 42,000 and Norwegian 39,520), one finds an estimate of EU-15 TPES in natural gas of 412,700 million cubic metres. In other terms, total underground gas storage capacity amounts to approximately 55 days of consumption at 2005 levels. This suggests that more should be done to increase this total capacity, e.g. up to a total of 90 days of consumption.

Table C3: Exports of crude oil from the Former Soviet Union, by type of route

Millions of barrels per day	2006q3	2006q4	2007q1	2007q2	Shares 2007q2	Latest data: Average of July and August 07	Countries of origin
Black Sea	2.27	2.08	2.30	2.23	35 %	2.07	KAZ, RUS, AZE
Baltic Sea	1.49	1.43	1.58	1.60	25 %	1.54	RUS
Arctic and Far East	0.20	0.19	0.29	0.30	5 %	0.41	RUS
Ceyhan (BTC pipeline)	0.22	0.38	0.43	0.58	9 %	0.68	AZE
Total seaborne	4.18	4.08	4.60	4.71	75 %	4.70	ALL
Druzhba pipeline	1.23	1.19	1.17	1.13	18 %	1.05	RUS (mostly), KAZ
Other routes	0.38	0.45	0.47	0.46	7 %	0.44	ALL
Total exports	5.79	5.72	6.24	6.30	100 %	6.18	ALL
Total (mn tonnes)	290	286	312	315	100 %	309	ALL

Source: IEA Oil Market Report, 11 October 2007 (constructed from estimates by Petrologistics Ltd and IEA)Note: the data excludes intra-CIS trade, e.g. Russian exports of crude oil to Ukraine

Comment: the Baku-Tbilisi-Ceyhan (BTC) pipeline is progressively being used to capacity. The August 2007 throughput was 0.72 million barrels per day, as against a full capacity of 1 million barrels per day.

Table C4: Selected existing and planned oil pipelines for Westbound CIS resources

Name	Origin	Destination	First stage capacity	Second stage capacity	Existing vs. Planned	Notes
Baku-Tbilisi-Ceyhan (BTC)	Baku (AZE) (Caspian)	Ceyhan (TUR) (Med.)	1.0	1.5	E	1
Trans-Caspian Oil Pipeline	Aktau (KAZ) (Caspian)	Baku (AZE) (Caspian)	0.5	–	P	2
Samsun-Ceyhan Pipeline (SCP)	Samsun (TUR) (Black S.)	Ceyhan (TUR) (Med.)	1	1.5	P	3
Western Early	Baku (AZE) (Caspian)	Supsa (GEO) (Black S.)	0.115	–	E	4
Caspian Pipeline Consortium (CPC)	Tengiz (KAZ)	Novorossisk (RUS) (Black S.)	0.61	1.4	E	5
Druzhba	Russian oil fields	Central Europe	1.3	1.5	E	6
Druzhba-Adria Pipeline Integration	Druzhba pipeline	Omisalj (HRV) (Med.)	0.1	0.3	P	7
Burgas-Alexandroupolis (BA)	Burgas (BGR) (Black S.)	Alexandroupolis (GRC) (Med.)	0.3	0.7	P	8
Pan European Oil Pipeline (PEOP)	Constanta (ROU) (Black S.)	Trieste (ITA) (Med.)	1.2	–	P	9
Albania-Macedonia-Bulgaria (AMBO)	Burgas (BGR) (Black S.)	Vlore (ALB) (Med.)	0.75	–	P	10
Odessa-Brody	Odessa (UKR) (Black S.)	Gdansk (POL) (Baltic)	0.18–0.28	0.9	E	11
Baltic Pipeline System (BPS)	Russian oil fields	Primorsk (RUS) (Baltic)	0.24	1.3	E	12
Druzhba-Ventspils	Russian oil fields	Ventspils (LVA) (Baltic)	NA	NA	E	13
Druzhba-Butinge / Mazeikiu	Russian oil fields	Butinge (LTU) (Baltic)	NA	NA	E	14

Source: EIA, media reports, company web-sites.

Units: capacities are expressed in millions of barrels per day.

Notes:

1) Started operating 2006, should utilise full capacity ~ 2009; second stage depends on Aktau-Baku pipeline or other options for Kazakh oil.
2) Accord signed between AZE and KAZ; But KAZ-RUS relations are complex. A core element of the "New Great Game" between Russia and the West.
3) Construction started in April 2007. Expected start of operation in 2010. Purpose is to ship both Russian and Caspian oil to the Mediterranean. Other names: SCCOP – Samsun-Ceyhan Crude Oil Pipeline and Trans Anatolian Pipeline (TAP);
4) Of limited use due to new BTC pipeline; we do not list the Baku-Novorossisk pipeline for the same reason;
5) Second stage delayed due to Russian disagreement on transit fees
6) The Druzhba pipeline separates into two main branches in Eastern Europe. The northern branch goes to Poland and Germany. The southern branch goes to Slovakia, Hungary and the Czech Republic. The Druzhba-Adria project would connect with the southern branch. An expansion is planned for 2010.
7) Status unclear, though current Ukrainian Presidency is in favour.
8) Trilateral agreement signed between Russia, Greece and Bulgaria in March 2007. Likelihood of completion very high, with construction to start in 2008 and operation scheduled to start in 2011. Should primarily ship Russian crude to the Eastern Mediterranean.
9) Now seems very likely to go ahead as planned after Croatia, Italy, Romania, Serbia, and Slovenia signed a joint agreement to start construction in April 2007.
10) High likelihood of going ahead. Trilateral agreement ratified by parliaments, 80 % of financing secured, support from the EU and the USA.
11) Initially the idea was to bring Caspian oil to Poland and the Baltic Sea, i.e. a supply diversification project by-passing Russia. Russian pressure on Ukraine resulted in the pipeline being used in the reverse direction, taking Russian oil from Druzhba at Brody down to Odessa. The most recent development is that the initial plan may go ahead after the signing of multilateral agreements was announced by Ukraine at the Vilnius Conference in October 2007 involving Ukraine, Poland, Lithuania, Azerbaijan and Georgia. Finally an additional branch through Slovakia to the Czech Republic is also under consideration.
12) Launched in 2001, second stage completed April 2006; Primorsk is ice-free only around 260 days per year and would not have made sense in Soviet days
13) Traditionally Russia's main Baltic outlet, traffic now strongly reduced due to BPS alternative and poor relations with Russia.
14) Temporarily used by Russia as a partial alternative to Ventspils. Rocked by multiple supply disruptions by Russia. Supply totally cut off since mid-2006. The refinery at Mazeikiu (the only one in the Baltic states), now gets oil by tanker arriving at Butinge. The pipeline branch from Russia will likely remain closed.

Table C5: Gazprom's westbound export pipelines

Pipeline name(s)	Transits through	Destination	Current capacity	Planned capacity
Soyuz and Brotherhood	Ukraine	Slovakia, Hungary, Romania	130	130
Northern Lights[1)]	Belarus, Ukraine	Poland, Slovakia	25	25
Trans-Balkan	Ukraine, Moldova	Bulgaria, Turkey, Balkans	20	20
Finland Connector	–	Finland	20	20
Yamal-Europe	Belarus	Poland, Germany	28	28
Blue Stream[2)]	Black Sea	Samsun (TR) (Black Sea)	16	16
Nord Stream[3)]	Baltic Sea	Greifswald (D) (Baltic Sea)	–	55
South Stream[4)]	Black Sea, Bulgaria	Italy and Austria	–	30
Total Capacity[5)]			239	324

Sources: www.gazprom.com, DGO and Forschungstelle Osteuropa, media reports
Units: billions of cubic metres per year.
Notes:
1) The complete Northern Lights has a larger capacity deeper in Russia. Part of it branches off into Yamal-Europe. Here we refer to the remaining branch which starts in Belarus and heads down south into Western Ukraine / Eastern Slovakia.
2) An extension running from Turkey into Europe is under consideration (competes with Nabucco).
3) Construction has started on the Russian side (on land). Environmental concerns are leading to a complex debate for the German-Russian consortium behind the project, notably a recent change in the planned under-sea route the pipeline should take. If all goes to plan the first of two parallel lines should operate from 2010 (27.5 bcm) and the second from 2012 (a further 27.5 bcm per year). An initial option of extending the line to the UK through Belgium and The Interconnector has been replaced by an option to extend to the Netherlands, including an option to supply the UK through the BBL pipeline. Options of branches to Sweden and Kaliningrad are also under consideration. Poland and the three Baltic States voice strong opposition to the entire project.
4) South Stream would have two branches. One running through Greece and onto Southern Italy, and another running through Romania, Hungary and Slovenia and then onto Northern Italy, with a smaller branch running to Austria. A Memorandum of Understanding between Italy and Russia was signed in June 2007.
5) The total capacities shown may be compared to current Gazprom export volumes, which were of 193 billion m3 in 2004 for the entire market served by the set of pipelines listed in the table. That market is the whole of Europe (including Ukraine, Belarus, Moldova and Turkey). However some additional capacity is used up by Central Asian natural gas (e.g. from Turkmenistan) which transits through Russia and then through the pipelines above onto European markets.

Table C6: Westbound pipelines for (non-Russian) Caspian gas

Pipeline name	Origin	Transits through	Destination	Current capacity	Planned capacity	Notes
Central Asian Center	Turkmenistan	Uzbekistan, Kazakhstan, Russia	Soyuz and Brotherhood	44	55–90	1
South Caucasus Pipeline	Baku (AZE)	Georgia, Turkey	Erzerum (TUR)	16	16	2
Trans-Caspian Pipeline	Turkmenistan, Kazakhstan	Caspian Sea	Baku (AZE)	–	30	3
Nabucco Project	Erzerum (TUR)	Turkey, Bulgaria, Romania, Hungary	Austria	–	30	4
White Stream	Georgia	Black Sea, Ukraine (Crimea)	Poland or Romania	–	8–32	5
Turkey-Greece Pipeline	Turkey	Marmara Sea	Greece	7	11	6
Greece-Italy Pipeline	Greece	Mediterranean	Italy	–	9–10	7
Trans Adriatic Pipeline (TAP)	Greece	Albania, Adriatic	Italy	–	10	8

Sources: EIA, media reports, company web-sitesUnits: billions of cubic metres per year.
Notes:
1) Russia has signed new agreements with Kazakhstan and Turkmenistan in May 2007 for renovation and expansion. The pipeline could reach the planned capacity of 55 bcm per year by 2010, while even more ambitious expansions (up to 90 bcm per year) are also under discussion.
2) First deliveries started in December 2006.
3) would then be connected to the South Caucasus Pipeline
4) consortium led by OMV; if all goes to plan: construction starts in 2008, completed in 2011. In competition with Russian extension of Blue Stream.
5) The pipeline would branch off the existing South Caucasus Pipeline close to Tbilisi and thus expand and diversify the export route for Azerbaijani (and potentially other Caspian) natural gas. Extensions of capacity up to 32 bn m3 would be considered if the Trans-Caspian Pipeline is built.
6) This pipeline has recently been completed, and an expansion to 11 bcm per year is planned for 2012, with the expectation of allocating 8 bcm to Italy which would be carried either by the Greece-Italy Pipeline or by the Trans Adriatic Pipeline.
7) Construction should start in 2008 and operation in 2011. The goal is to bring Caspian gas (through Turkey and Greece) to Italy.
8) In many ways this project competes with the Greece-Italy Pipeline. It also has roughly the same time frame.

Table C7: Selected North Sea and Baltic pipelines and interconnectors

Pipeline name	Connected countries	Current capacity	Planned capacity	Notes
Norpipe	Norway to Germany	14	14	
Europipe I	Norway to Germany	18	18	
Europipe II	Norway to Germany	24	24	
Franpipe	Norway to France	15	15	
Zeepipe	Norway to Belgium	13	13	
Tyra West – F3 Pipeline	Denmark to Netherlands	5.5	5.5	
Vesterled	Norway to UK	12	12	
Langeled	Norway to UK	20	20	
The Interconnector	UK and Belgium	25.5	25.5	1
BBL (Balgzand Bacton Line)	Netherlands to UK	15	15	2
Baltic Pipe	Denmark and Poland	–	5	3
Skanled	Norway to Sweden and Denmark	–	7–8.75	4
Baltic Gas Interconnector	Germany, Denmark, Sweden	–	3	
Balticconnector	Finland and Estonia	–	2	5

Sources: EIA, media reports, company web-sitesUnits: billions of cubic metres per year.
Notes:
1) The Interconnector has a lower capacity (20 bcm) in the UK to Belgium direction, however what is relevant for the future is the recently increased capacity in the Belgium to UK direction, given the UK's fast-changing natural gas balance.
2) Started operation in December 2006 and at full capacity would account for 15 % of total UK consumption at 2006 levels.
3) This project was dormant, then revived in 2007 but is still at the evaluation stage. Potentially it may turn out to be either a one-way pipeline for Danish (and potentially Norwegian from Skanled) gas to Poland, or an interconnector, working in both directions. In the latter case Baltic Pipe would also enable Denmark to import Russian gas through Poland.
4) Skanled will probably be given the definitive go-ahead in 2009. If so it would be operational from late 2012. Capacity will depend on whether Baltic Pipe goes ahead.
5) Feasibility study completed, environmental impact assessment yet to be made. If all goes to plan, the line would start operating in 2010. The primary objective is to offer Finland an alternative route for Russian gas (rather than relying only on the Finland Connector) and would thus bring Russian gas from Latvia through Estonia onto Finland. However the line could also operate in both directions, and should therefore be interpreted as an energy security / energy solidarity project between Latvia, Estonia and Finland. Although only Russian gas would transitthrough the line, it reduces the isolation of the countries concerned, thus reducing both the risk and the potential damage of possible Russian supply disruptions.

Table C8: North African gas export pipelines to Europe

Pipeline name	Origin	Destination	Current capacity	Planned capacity
GALSI[1)]	Algeria	Italy	–	9–10
Greenstream[2)]	Libya	Italy	8	11
Maghreb-Europe	Algeria	Morocco, Spain, Portugal	8.6	11.7
Medgaz[3)]	Algeria	Spain	–	8
Transmediterranean[4)]	Algeria	Italy and Slovenia	24	33.5
Total capacity[5)]			40.6	74.2

Sources: EIA, media reports, company web-sitesUnits: billions of cubic metres per year.
Notes:
1) Expected start of operation in 2008.
2) ENI reported in December 2006 that full capacity of 8 bcm would be reached "upon completion", and announced in October 2007 plans to expand capacity by 3 bcm per year following new extraction agreements.
3) Construction started in 2007 and start of operation is forecast for mid-2009.
4) This pipeline (also called the Enrico Mattei Pipeline) has been in operation since the 1980s and underwent an expansion in the early 1990s. A third expansion to 33.5 bcm per year is under consideration.
5) An analysis of North African supply capacities would require an assessment of LNG facilities.

Bank Austria Aserbaidschan Bosnien-Herzegowina Bulgarien Deutschland Estland Italien Kasachstan Kirgistan Kroatien Lettland Litauen Polen Rumänien Russland Serbien Slowakei Slowenien Tadschikistan Tschechische Republik Türkei Ukraine Ungarn Creditanstalt