Climate Strategies

# The EU's 2030 Climate and Energy Framework and Energy Security


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# EXECUTIVE SUMMARY

**The renewed attention of the EU to the issue of energy security is well warranted**

Europe remains highly dependent on imported fossil fuels. In 2013, the EU's dependency rate on coal was 45%, 88% for oil, and 66% for gas. This high dependency on imported fossil fuels increases the EU's exposure to global energy price risks. It makes the EU vulnerable to supply disruptions from monopolistic energy providers such as Russia. And it drains significant sums of money away from the EU economy every year (the EU's energy imports accounted for about 3.3% of EU GDP in 2012).

In this story, however, natural gas has a special importance. In the short-term, natural gas security is threatened by current geopolitical tensions with Russia over Ukraine. Significant supply cuts took place in 2006 and 2009. This risk is all the more alarming because a lack of strategic infrastructure still leaves a some Member States unacceptably vulnerable to a supply disruption, particularly in Central and Eastern Europe.

Natural gas can play an important role in the transition to clean energy, both for balancing renewables and with the progressive integration of biogas into existing gas supply infrastructure. Reliable supplies of natural gas will therefore be essential for the low-carbon transition of the EU's energy sector. Tackling the EU's climate challenge therefore also requires a clear strategy on natural gas security.

There are several security issues that any serious European natural gas strategy must address. It must reduce the risks of supply disruption for vulnerable Member States; it must improve price transparency and Member State bargaining power with monopoly suppliers such as Gazprom; it must improve price convergence across the EU and it must reduce energy costs for consumers. This set of objectives implies that the solution cannot be a one-size fits all approach.

Indeed, our study argues that there is no magic bullet to improving the security of supplies of natural gas, be it shale gas, LNG, internal market infrastructure, greater demand side efficiency or fuel substitution by renewables, etc. A comprehensive strategy of mutually reinforcing elements is essential. This strategy must encompass immediate short-term priorities as well as setting longer term goals. It must also give equal weight to both supply side (e.g. renewables, gas infrastructure, and new sources like shale or LNG) and demand side (e.g. consumption efficiency) options.

On the supply side, the EU must move urgently to support the completion of the short-list of infrastructure projects of common interest which the Commission has already identified. Since not all projects can be completed immediately, it makes sense to further focus policy and financial support on an even smaller priorty list of infrastructure projects, which fill critical gaps in the EU's current disruption response system.

In the medium-to-longer term, a clear quantitative goal for internal market completion should be set (e.g. greater spot price convergence ex-transport costs throughout Europe). This should build on the infrastructure created via the completion of both the short and medium term PCI projects. Greater transparency in pricing and coordination with respect to contracting with Gazprom could also be enabled by greater oversight powers for the Commission of new contracts as well as the setting of a longer term goal of developing a liquid Central and Eastern European gas trading hub.

However, demand side action is also essential to address the limitations of supply side options. Our analysis shows that while supply side measures can help to reduce the price risks of supply disruptions and improve price convergence, they do little to reduce the negative economic impacts EU imports of natural gas, nor to reduce average costs for consumers. Moreover, lower overall gas demand means that new sources of supply go further as a share of total consumption, thus reinforcing supply side options. The two are therefore complements, not substitutes.

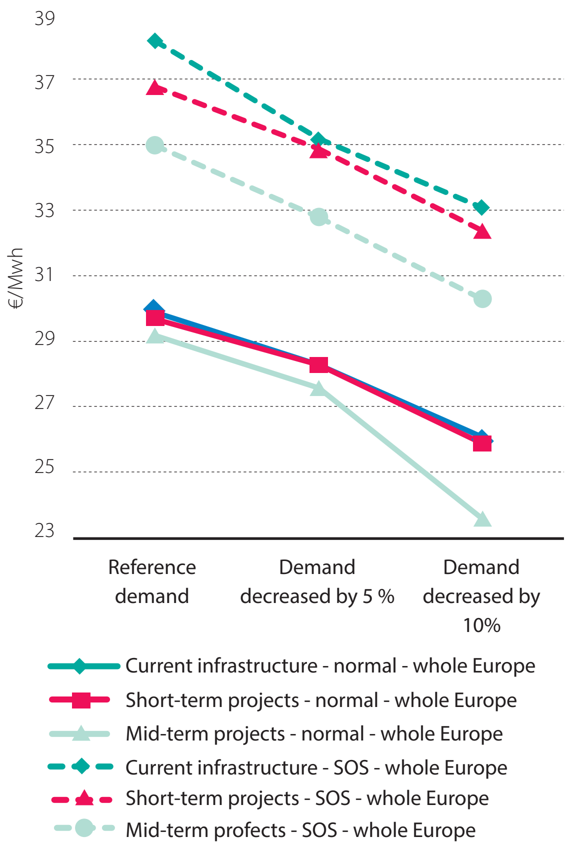
The potential dividends to reducing EU natural gas demand are big. Ambitious goals for energy efficiency and renewables under the 2030 Framework could lead to a -28% reduction of net gas imports (e.g. under the EE/RES30 scenario modelled by the Commission), and a -22% reduction of total energy imports compared to 2010. For gas, this roughly corresponds to current gas imports from Russia, or 7% of the EU's total energy import bill. In terms of new supply side investments, the savings are roughly equivalent to building 19 medium to large LNG regasification terminals.

The economic benefits of such measures are large. Our modelling analysis found that even a 10% reduction in annual natural gas demand (58bcm/yr) by 2030 could lead to a roughly equivalent 13% decline in average prices across the EU27, with the potential to reduce average prices further if combined with both short and mid-term infrastructure projects (see Figure A). Cost savings would be greater still, as both prices and quantities purchased would be reduced.

Once again, reducing European natural gas consumption is not the be-all-and-end all of natural gas supply security. As Figure A shows, our modelling suggests that while lower consumption significantly lowers prices in "normal" times, it is not adequate to prevent large peaks in prices in a Russian supply disruption scenario. Internal market completion therefore remains an essential pillar. This underlines the need for a comprehensive approach to energy security in 2030 Energy and Climate Framework.

Furthermore, less gas consumption in the power sector is not necessarily desirable as an energy security strategy: our study finds that the relatively easy substitutability of energy sources in the power sector suggests that greater decarbonisation need not necessarily imply greater vulnerability to natural gas supply disruption under a strong power sector decarbonisation scenario. Moreover, as gas would be increasingly used as a balancing fuel, its value would largely be as a flexibility option rather than to provide of large quantities of baseload power. The overall volumes of gas required as a balancing fuel in the electricity sector appear manageable.

**Figure A. Yearly average gas price with reduced gas demand (€/Mwh) for the EU27 as whole in reference and supply disruption (SOS) scenario with different infrastructure projects completed**

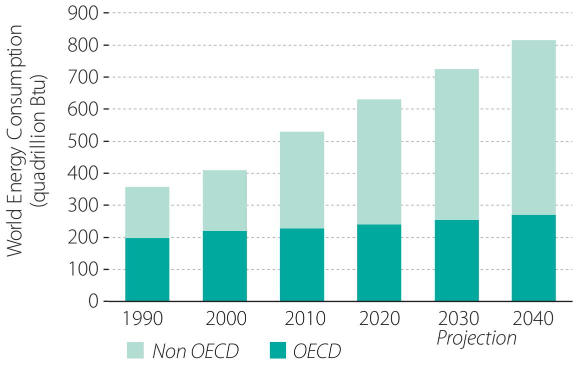



Source: REKK, Climate Strategies

## 1. Introduction

The EU is confronted with a rapidly changing global energy landscape. Between 2010 and 2030, the world economy is expected to roughly double in size[1]. This will place significant stress on resources and prices and it will have important consequences for European energy markets. Between 2010 and 2040, non-OECD energy consumption is projected to rise by approximately 80% (Figure 1). At the same time, global greenhouse gas (GHG) emissions will continue to rise, indeed at an accelerated rate over the past decade.[2]

**Figure 1. World energy consumption in OECD and non-OECD (1990-2040)**




Data: US EIA IEO 2013.

The EU is exposed to these trends in a number of ways. The EU is highly dependent on imported fossil fuels. In 2013, the EU's dependency rate on coal was 45%, 88% for oil, and 66% for gas.[3] Energy imports accounted for about 3.3% of EU GDP in 2012 and 2.8% in 2013. A significant share of this took place with Russia, i.e. about 1.3% of EU GDP in 2013. Moreover, by 2030, EU energy dependence is projected to increase to 73% for gas and 90% for oil.[4]

Energy consumption of different energy sources is not equally divided between sectors. For oil products, transport took 54% of total consumption in 2012, followed by non-energy uses (chemical feed stocks) and the household and tertiary sectors. For gas, households took 43% of total consumption, followed by the power sector at 24%, and industry 21%. For coal, the power sector took the lion's share, followed by coking plants, and industry.[5]

The EU's energy security faces different challenges for each of these main fossil fuel types. However, natural gas currently represents the most immediate threat in terms of supply disruptions. At one level, this threat stems from the EU's (and particularly central and eastern Europe's) strong dependence on a single supplier, i.e. Russia, which has demonstrated its willingness to use its control of supplies as a political tool. Combined with the fact that natural gas markets are globally more segmented, and the fact that important sectors using natural gas (households) have few short-term substitution options in the event of a supply disruption, natural gas there represents the most significant risk of supply disruption to Europe.

At another level, however, natural gas is also important to Europe as a long-term strategic fuel for the low-carbon energy transition. The flexibility of natural gas in the power sector as a complement to intermittent renewable power sources and as a lower carbon substitute for coal means that it is likely to be an important fuel for the transition, in the medium and longer term. While alternative sources of gas are potentially available at the margin in the longer term, such as power-to-gas technology, biogas, and shale gas, each of these options will take time to develop, is subject to uncertainties and is to technical and economic limitations on their potential scale. Power to gas for example is limited by the extent of surplus power production.

For these reasons this paper focuses primarily on natural gas. However, it should be noted that activities on the demand side to reduce gas consumption (discussed below) could help to make these alternatives go further as substitutes for foreign gas than they otherwise would if demand were greater. However, the issue of energy security encompasses the whole of the EU energy sector and not just one fuel or sector. No energy security strategy would be complete without looking at the transport sector given the role of oil in the EU's energy trade balance and consumer expenditure. Coal represents a strategic risk to European security via its impact on global climate change and the ensuing economic and political risks associated with overreliance on coal-fired technology.

1. HSBC, 2011
2. IPCC, WGIII, SPM.
3. Enerdata data.
4. EU Energy, transport and GHG emissions trends to 2050
5. Enerdata energy balance for Europe.

The objective of this paper is to examine this nexus between climate and energy security. Specifically, it provides a survey of key issues and options for fully exploiting synergies between energy security and climate agendas, particularly with respect to natural gas, for the reasons explained above. The role of coal is also examined in section 4. This section shows how the possible tensions between climate and energy security agendas can be managed.

We thus present original data analysis and original EU gas market modelling results to explore the key principles that must guide a robust European energy security strategy. The numbers strongly argue that Europe needs a comprehensive strategy, covering both supply side and demand side measures. Measures on the supply side, such as LNG infrastructure, and infrastructure improvements to improve the functioning of the internal market, are important. However, these measures would be significantly reinforced and made more effective if complemented by demand side measures. A co-benefit of these demand side measures is that they also help to reduce the EU's CO2 emissions. Note that this paper does not aim to give an exhaustive analysis of all demand-side potentials. The objective is rather to highlight the need for a comprehensive approach.

Section 2 thus begins by presenting key security challenges facing the EU in terms of natural gas security. It also assesses the extent to which supply-side oriented policies can contribute to improved resilience in the event of supply disruptions. Section 3 presents evidence of the potential for demand side policies to improve European gas security – it focuses on two prominent examples: energy efficiency and greater use of renewables as a gas substitute. Section 4 analyses the tensions between climate and natural gas security agendas. Section 5 concludes.

## 2. Assuring security in the natural gas sector: the role of supply side measures

An analysis of Europe's energy security strategy on natural gas must begin with an evaluation of the nature of the risks and strategic vulnerabilities to be addressed. The following section therefore presents original data and modeling analysis using the European Gas Market Model (EGMM) developed by REKK[6]. This analysis will then serve as the basis for the following discussion on supply and demand side security measures.

### 2.1. Assessing European vulnerabilities to natural gas supply disruptions from Russia

While the EU as a whole would face higher prices in the event of natural gas supply disruptions, there are a number of EU Member states that are particularly exposed to such risks. This is true for a number of Central and Eastern European Member states – such as the Baltic States and Finland, Poland, Bulgaria and Romania – which, despite significant improvements since 2009, are highly dependent on imported Russian gas and have insufficient alternative supply possibilities in the event of a loss of their largest supplier (a so-called "N-1 incident") (Table 1).

**Table 1. Key indicators for exposure to gas supply risks**

| | Share of natural gas in total primary energy consumption (%) | Share of Russian imports in natural gas consumption (%) | N-1 incident | Remaining physical import capacity as% of total physical import capacity (%) | storage capacity (total maximum/ national consumption) (%) |
|---|---|---|---|---|---|
| EE | 10 | 100 | loss of import capacity via Russia | 49 | 0 |
| LV | 28 | 100 | loss of import capacity via Russia | 28 | 154 |
| LT | 37 | 100 | loss of import capacity via Belarus | 15 | 0 |
| PL | 14 | 54 | loss of import capacity via Belarus | 28 | 14 |
| CZ | 16 | 89 | loss of import capacity via Germany | 62 | 40 |
| HU | 36 | 80 | loss of import capacity via Ukraine | 0 | 60 |
| SK | 26 | 91 | loss of import capacity via Ukraine | 79 | 57 |
| SI | 10 | 42 | loss if import capacity via Austria | 21 | 0 |
| BG | 13 | 83 | loss of import capacity via Romania | 0 | 19 |
| RO | 31 | 18 | loss of import capacity via Ukraine | 0 | 23 |

Source: authors' analysis based data from on Enerdata, Eurostat, Gas Infrastructure Europe Infrastructure map and storage data

The figures in do not give a comprehensive picture. For example, Poland is an important transit country of Russian gas onward to Germany, which may be seen as reducing vulnerability. Latvia has significant storage capacity which supplies the whole Baltic region, including Russia in winter. This creates interdependencies. **However, generally speaking a number of Eastern European countries are highly dependent on Russian gas, and still have insufficient alternative physical supply routes, despite recent improvements.**

However, given spill-over effects between member states, the degree of vulnerability as well as the gaps in the EU's internal gas market is perhaps best highlighted by a market modeling analysis of the EU's internal gas market outcomes in the event of a Russian supply disruption. This is presented below. Specifically, we quantified the impacts of two different gas supply disruption scenarios on wholesale gas prices in Europe using the European Gas Market Model (EGMM) developed by the Regional Centre for Energy Policy Research (REKK). Outcomes of both security of supply scenario

6. For a detailed description of the regional EGMM see Annexes to this report.

simulations are compared to a reference case based on market conditions at end of 2013. The model includes key characteristics of the market, including demand and supply characteristics, contractual constraints as well as infrastructure topology and capacity constraints[7].

The first scenario assumes a 100% supply cut from Russia for a month due to technical failure. The second scenario assumes a 30% reduction in supply for an entire year and is an intended reduction in supply. These scenarios compare closely to the 2006 and 2009 gas crises in central and eastern Europe (CEE), when deliveries through Belarus and Ukraine were reduced by 30% and 100%, respectively.[8] In case of a failure (the 100% one-month reduction scenario) we assume that Russia will compensate for lost supplies by shipments on alternatives pipelines up to available capacities.

In our first scenario we therefore investigated the price effect of a supply cut on all Russia-EU pipelines in January 2015. In this scenario demand is peaking in Europe. Injection into storage has been completed during the summer and fall, anticipating normal winter conditions to come. We do not assume that extra strategic storage injections occur - traders decide commercially on how much storage they use, expecting no supply security problems. In our second scenario we simulated an intended supply cut which means that either Russia is not willing to serve European consumers or Europe is not willing to accept natural gas deliveries from Russia. With reference to the intention of the European Council to define a policy package to reduce the EU's dependence on Russian gas supply[9], we assume a Western embargo scenario when the EU reduces its natural gas purchases from Russia by 30%. This means that only 70% of the Russian contracted quantity will be delivered to Europe on all Russia-EU pipelines for 12 months. In both security of supply scenarios we assume that Hungarian strategic storage stock is released.

7. For a detailed description of the regional EGMM see Annex.

8. For a detailed discussion on the lessons of the 2009 January gas crisis for CEE see Kaderjak (2011) *'The Lessons of the January 2009 Gas Crisis in Central and Eastern Europe'*, in: Vinois, J.A. (ed), *The Security of Energy Supply in the European Union*, pp. 193-219. Claeys and Casteels.

9. On their meeting on March 20-21, the leaders of EU member states concluded that, "The European Council is concerned about Europe's high energy dependency rates, especially on gas, and calls for intensifying efforts to reduce them, especially in the most dependent member states."

The price effect of these scenarios is presented in Table 2.

**Table 2. Wholesale price effect prompted by the two supply cut scenarios in the new EU member states and EU**

| | 100% supply cut in January | 30% supply cut for a whole year |
|---|---|---|
| | Change in January prices relative to reference (%) | Yearly average price change relative to reference (%) |
| FI | 481%** | 481%** |
| EE | 266% | 381% |
| LV | 255% | 390% |
| LT | 238% | 352% |
| PL | 92% | 40% |
| RO | 27%* | 40% |
| BG | 25%* | 38% |
| HU | 20%* | 68% |
| CZ | 16% | 11% |
| SK | 14% | 12% |
| SI | 10% | 10% |
| CR | 0% | 8% |
| **CEE member states+Finland** | **75%** | **86%** |
| EU27 | 22% | 18% |

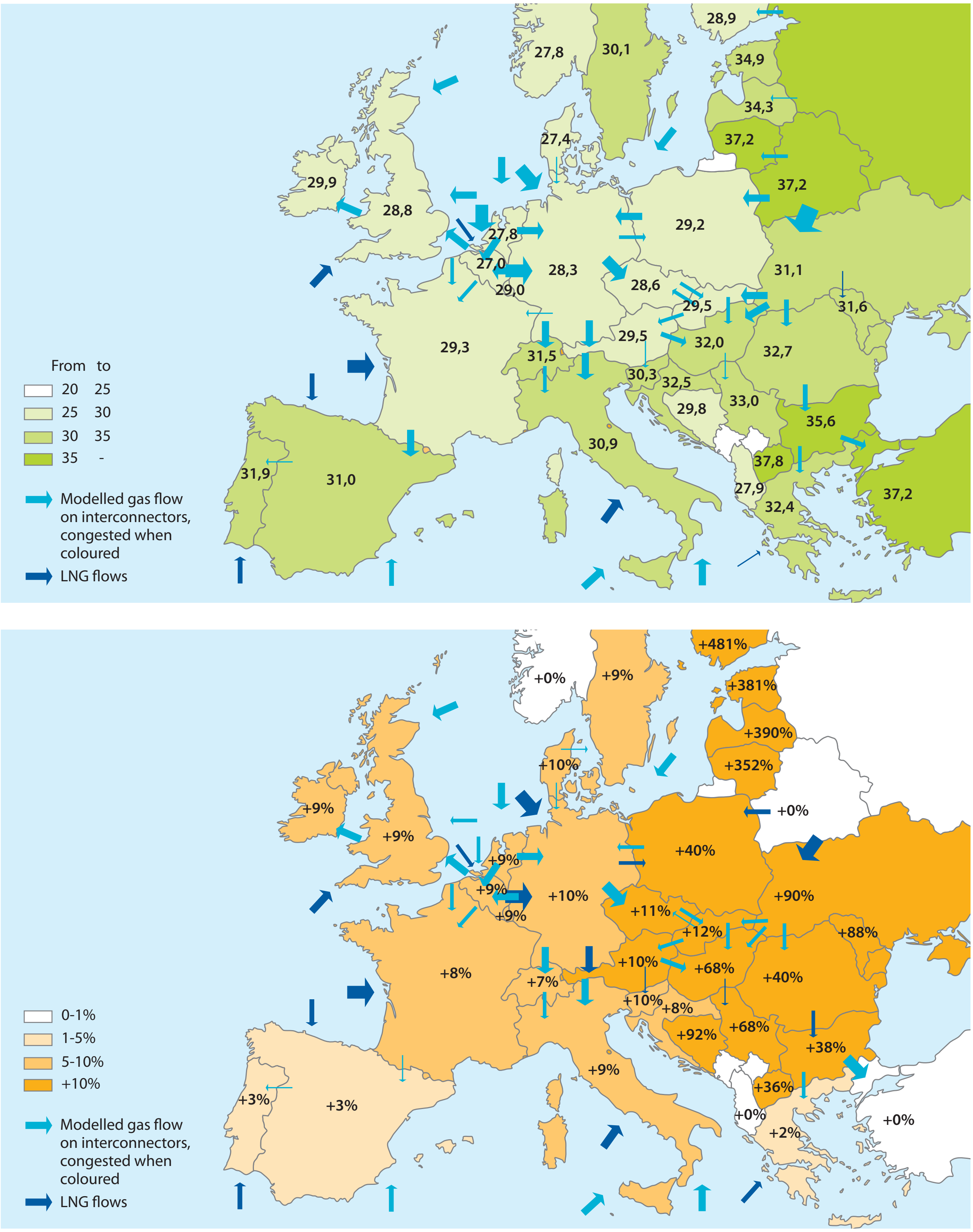
* Numbers assume release of the Hungarian strategic gas stock

** With a 481% price increase gas consumption in Finland is zero

Both supply cut scenarios result in a much sharper wholesale gas price increase in the new member states (75 and 86%) than in whole of the EU27 (22 and 18%). The most vulnerable countries are (not surprisingly) found to be the Baltic States and Finland because the only gas source for them is Russia (2-4, times higher prices in the 100% January scenario). This result reflects the fact that in this region there has been nothing invested into gas supply security infrastructure since 2009. In Poland January prices would almost double, but with the new LNG terminal coming online in January 2015, this increase would drop back to 65%. A security of supply incident would result in a price increase between 20-27% in Romania, Bulgaria and Hungary, due to the strategic storage stock in Hungary, which we assume to be released in a crisis situation. Romania and Bulgaria would also benefit from these sources. The same cut of Russian gas has a significantly smaller (below 20%) effect in Czech Republic, Slovakia and Slovenia because of their better connectivity to Europe. We also see that those regions that invested into security of supply driven infrastructure (PL LNG, Hungarian Strategic Storage, interconnectors (e.g. HU-HR, HU-RO, and reverse flow projects, like Yamal, CZ-SK) face significantly less risk than those which did not invest at all, highlighting the importance of key security infrastructure.

Good interconnectivity can however be a drawback in some cases for some countries: Hungarian prices for consumers would rise higher in a longer crisis, because high gas prices in the Balkans would pull up Hungarian prices, although suppliers to these countries would nevertheless benefit from the higher export price. With the SK-HU interconnector that is to come online by

Figure 2. Price increase in Europe due to a 30% supply cut for a whole year - reference case wholesale gas prices (€/MWh) in the left hand side and price increase (in percentage) due to the supply cut in the right hand side, representing a situation of year 2014**




**Note: 2014 infrastructure was used but with 2012 gas consumption data.

1 January 2015, this effect will spill over to Western Europe and better distribute the cost of the crisis through the convergence of prices (see below).

The price effect of our second (1 year long 30%) supply cut scenario in each country is presented in Figure 2.

**These results suggest that a significant number of Member states in central and Eastern Europe remain unacceptably vulnerable in the event of a natural gas supply disruption. There is therefore a strong case for additional measures to improve the EU's overall situation and reduce the vulnerabilities of these Member states.**

**As discussed in Section 4 below, providing this security is not only important for security of supply policy. It also crucial to creating confidence that gas can safely play the role of an important fuel during the low-carbon transition for Member states with currently low shares of natural gas in energy supply.**

## 2.2. Options to improve energy security in the gas sector

### 2.2.1. Liquefied Natural Gas

EU member states have been increasingly investing in LNG terminals, as a way to diversify supply sources and counteract declining domestic production. Between 2005 and 2013, the EU's LNG import capacity more than doubled from 68 bcm to 186 bcm. Signification shares of this took place in Spain (60.1), the UK (52.3), France (23.75 bcm in 2013) and Italy (14.71). Further, capacity under construction will increase EU LNG import capacity by 32 bcm by 2018.[10] Total nominal import capacity would reach about 218 bcm by 2018, which would equate to about 60% of projected EU net imports in 2020. Existing capacity utilization rates for the EU28 is 32.5%, i.e. quite low.[11]

LNG can be an effective option to increase security of supply via diversifying supply options. It can also introduce more competition into a given market. For instance, it is not coincidental that the Lithuanian utility Lietuvos Dujos was able to negotiate a 20% price decrease with Gazprom in 2014, with an LNG terminal expected to come online at the Lithuanian port of Klaipeda by the end of this year. Another LNG import terminal for Latvia is under discussion.

However, LNG on its own has a number of limitations and is unlikely to fully meet the EU's security requirements. Firstly, despite a prevalence of long-term contracting, LNG is a contestable global market, and marginal supplies will – with increasing free shipping capacities – tend go where prices (minus transport costs) are highest. Secondly, LNG prices are subject to a number of uncertainties: in particular, demand growth from Asia; the extent of new supply, in particular from the US; and global evolutions in the cost of LNG technology.[12] Together these two realities imply that a strategy that is too strongly dependant on LNG runs the risk of exposing the EU to greater degrees of LNG price risk.

Thirdly, and perhaps most importantly, Russian gas remains highly competitive compared to alternative sources of supply, such as LNG. Russia would therefore be able to pursue a pricing strategy that made large scale consumption of LNG unattractive, in order to retain European market share.[13] If LNG terminals would not be used, this will in turn discourage investors from financing (capital-intensive) terminals in the first place.

**In sum: LNG can be a very useful option for some EU Member states to diversify gas supplies and increase the contestability of their gas markets. This can have security and economic benefits for these countries. Strategically located LNG infrastructure can also play a key role in limiting the adverse impacts of a supply disruption. However, a large scale LNG strategy for the EU as a whole would not be a silver bullet for European gas security. A heavy-weighted strategy towards LNG would expose the EU to higher prices and international price risk. Moreover, Russia remains a highly competitive supplier and could probably pursue a pricing strategy to retain market share. Strategic LNG infrastructure therefore represents a useful tool to provide alternatives and greater contestability in EU gas markets, but not a panacea.**

### 2.2.2. The internal market, gas contracting and pricing, and the Tusk Proposal

The internal market is a key tool for improving energy security and competitiveness of energy supply. Since the 2009 Russo-Ukrainian gas crisis, significant efforts have been made to improve this situation, notably as a result of EU law.[14] Storage capacity has been increased by 22%. New gas interconnections have been added, with a capacity equivalent to 24% of EU consumption. The European Commission has pursued a robust internal market policy, pushing for more competition in EU gas markets, in particular in Eastern Europe.

However, as the modeling analysis presented in the preceding section showed, some Member states are still very isolated from alternative supply sources. Natural gas prices still vary significantly across different member states. More should therefore be done.

In this respect, the EU has announced a list of Projects of Common Interest (PCIs) within which it has established a list of 29 priority projects for the completion of the internal energy market. Our modeling analysis suggests that these projects offer the potential to significantly reinforce European natural gas security and to increase price convergence in the event of disruptions.

10. LNG import data from Gas Infrastructure Europe database.

11. Authors' calculation based on capacity and import data from Enerdata and Eurostat

12. The impacts of such factors can be seen in historical data: between 2010 and 2013, the share of LNG in EU gas imports fell by 5 percentage points as higher demand and prices drove global LNG to the Asia Pacific Region (Japanese LNG import prices increased from 9.06 USD/Mbtu to 16.17 USD/Mbtu in 2013).

13. See e.g. Rogers, 2012

14. REGULATION (EU) No 994/2010

Table 4 examines the expected overall effects of the key security of supply infrastructure projects shortlisted by the European Commission[15]. We modeled the same security of supply scenarios as before, however in this scenario the infrastructure is expanded with the natural gas projects included in the European Energy Security Strategy. First, we expanded our reference scenario with potential 'short-term' projects; then we also included the potential 'mid-term' projects. (The specific projects included in each category are listed in the Annex to this report.)

**Table 3. Infrastructure additions in the gas internal market since 2009, and proposed projects of common interest**

| | European Energy Program for Recovery | | Proposed projects of common interest |
|---|---|---|---|
| | Completed | In progress | |
| EU funding | 672 million | 578 million | 5.1 billion |
| extern funding | 824 million | 835 million | n.a. |
| Interconnections | 10 | 6 | 14 |
| Reverse flow | 13 | 1 | 4 |
| km built | 2575 | 5145 | 5030 |
| added capacity (bcm/y) | 114.9 | 61.1 | 93.2 |
| share of EU consumption (2012) | 23.8% | 12.7% | 19.3% |

Source: authors, based on data from DG Energy, European Commission.

**Table 4. Wholesale price effect prompted by the two supply cut scenarios in the new EU member states and EU in the presence of short-term and mid-term projects**

| | Normal scenario | | Security of supply scenarios | | | |
|---|---|---|---|---|---|---|
| | | | 100% supply cut in January | | 30% supply cut for a whole year | |
| | Average price in new member states (€/MWh) | Average price in EU27 (€/MWh) | Price change in January relative to reference in new member states (%) | Price change in January relative to reference in EU27 (%) | Price change relative to reference in new member states (%) | Price change relative to reference in EU27 (%) |
| Reference | 31.1 | 29.9 | 75% | 29% | 86% | 28% |
| Short-term projects included | 30.9 | 29.7 | 59% | 26% | 52% | 24% |
| Both short and mid-term projects included | 30.2 | 29.2 | 24% | 21% | 23% | 20% |

The effects are similar in the two scenarios. For example in the case of a 100% supply cut in January the price increase relative to the reference scenario decreases significantly in CEE member states: from 75% to 59% due to the short-term projects and to 24% due to the short- and medium-term projects. Considering the EU27, the price decrease effect of the new project is smaller. The overall price effects of the short-term projects in the case of a one year embargo (30% reduce in deliveries) can be seen in Figure 3.

Connecting the cheaper Western Europe with the more expensive Eastern and South-Eastern Europe redistributes the costs of the embargo among the European states more evenly, however still far from equal. The average price increase in Western Europe rises from 9% to 10-11% if short-term projects are included, but in exchange there is significant reduction in Hungary (from 68% down to 11% increase), Romania (40% to 13%), Bulgaria (38% to 7%) and Serbia (68% to 12%).

**These results suggest two important policy implications:**

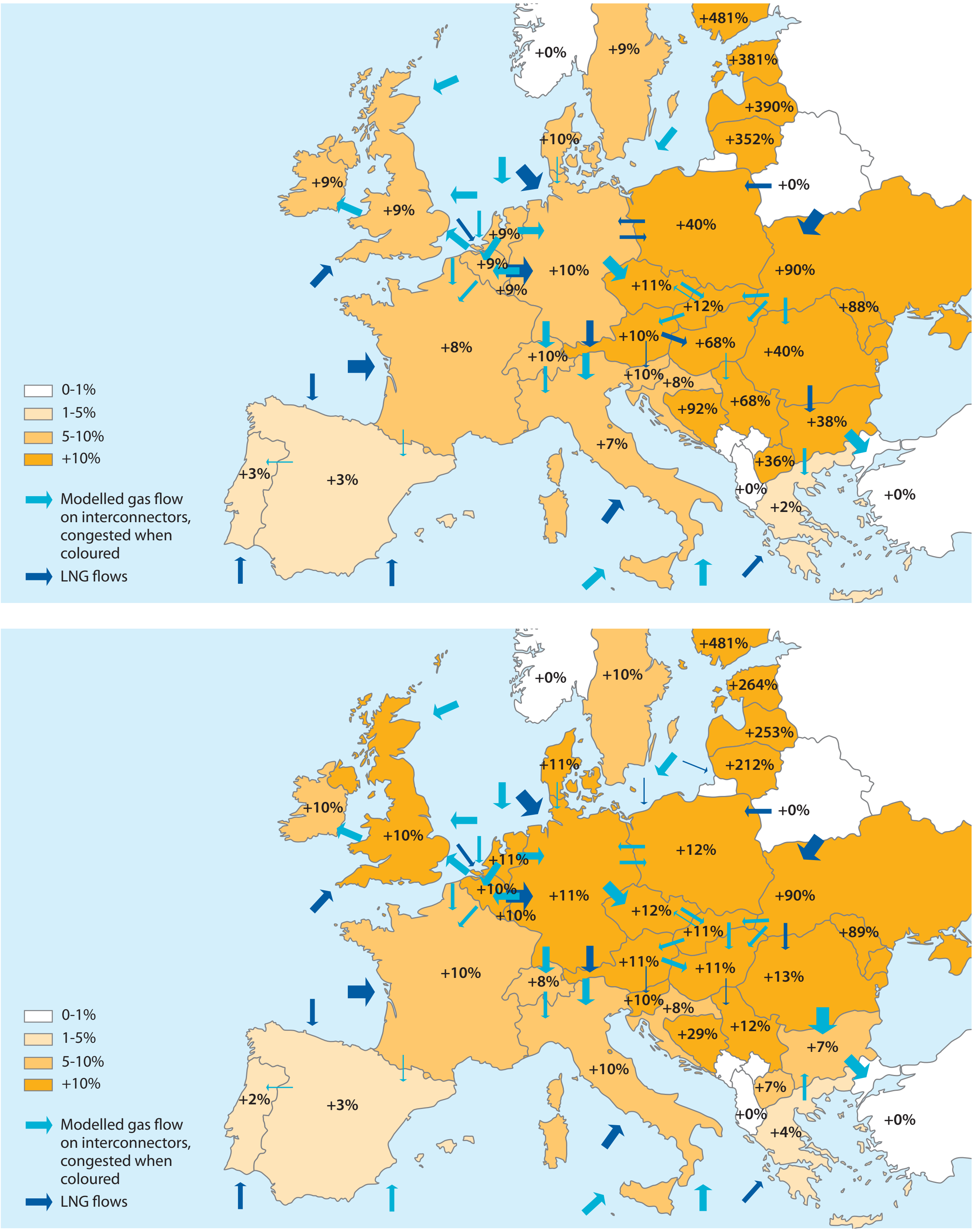
1. Natural gas projects of common interest offer the opportunity to significantly advance the internal market's resilience to external supply shocks both in the short and medium term. **In the short run, specific projects (i.e. a short list of projects among the commission's existing short-list) could be further prioritized by the EU2030 Framework to target those parts of the natural gas market and those Member states (such as the Baltics, Poland, and Southern Europe) that are the most exposed in the event of a disruption.**
2. Not surprisingly, greater interconnection of the internal gas market between East and Western Europe offer the physical pre-conditions for greater price convergence and exchanges between Member states. **While not sufficient, such developments could serve as a basis for the development of Central and Eastern European regional gas hub. This hub could in time, provided liquidity is sufficient and that there is a diversified source of ultimate supply, come to be used as a reference point for more transparent and competitive contracting with Gazprom**.

As noted above, there is considerable divergence of wholesale gas prices in Europe, with Eastern European countries paying particularly high prices. This is because Gazprom is able to exercise monopoly power in these uncontested markets. The Polish 6-point Plan for a European Energy Union, announced by Prime Minister Donald Tusk on 29th March, 2014, included as one of its recommendations that the European Union should improve its bargaining power with Russia's Gazprom and others by jointly negotiating contracts. However, full centralized contracting may be difficult to combine with the logic of the internal market.

In practice several alternatives for increasing transparency and improving price convergence exist. At one extreme, one could theoretically imagine a single European authority, charged with negotiating on behalf of Member states. At the other end of the spectrum, one could imagine simple legal requirements that Member states publish their contractual details to ensure transparency

15. Projects are listed in Annex 2 of the COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL European Energy Security Strategy {SWD(2014) 330 final}. We used the capacity data for modelling the New Member states projects as they were provided by the pomoters for the PCI selection process, published at: http://ec.europa.eu/energy/infrastructure/pci/pci_en.htm

**Figure 3. The price effect of short-term projects in SOS situation (left: reference, right: mid term projects included - representing our 2030 scenario)**



and potentially allow for soft co-ordination of contractual negotiations among EU Member states.

In the longer term, the proper provision of infrastructure and internal market policy will drive greater liquidity and diversity in EU gas markets. In this context, it is likely—indeed almost inevitable—that there will be a shift towards more gas-to-gas competition, i.e. hub-based pricing for natural gas in Europe.[16] This has already been occurring. As one way to give impetus and long-term direction to internal market integration in gas, **the EU could adopt a long-term objective such as convergence towards hub base pricing or convergence in whole-sale gas prices (corrected for transport costs) by e.g. 2030. This would go beyond current commitment to internal market completion by defining specific indicators. This would also be one way to address Polish concerns for assurances of greater policy drive for solidarity, while remaining coherent with a competitive internal market. It could be combined with priority funding for key PCIs which are necessary to provide part of the underlying infrastructure for liquid hubs. However, to be an effective reference price for contracting with Russia, a diversity of ultimate supply sources (and liquidity) would be necessary.**

But while strengthening the internal market is a necessary and important step, it too does not represent a magic bullet for European natural gas security. Developing a full range of projects required for internal market completion will take time. As domestic gas production declines, the EU would continue to depend more intensively on a limited number of foreign suppliers (including Russia). Finally, even with internal price convergence, the EU would still be subject to the uncertainties of global gas and LNG markets. **A functioning internal market can thus be a greater source of resilience to short-term supply shocks and greater price transparency, but it ultimately does not tackle the EU's longer term dependence of unstable foreign supplies.**

### 2.2.3. Domestic Production of Unconventional Gas

The preceding discussion raises the question of what role new, domestic sources of natural gas supply could play in the EU's gas security strategy. Production of domestic natural gas is projected to decline by about 40% by 2030.[17] However, significant shale gas reserves are believed to potentially exist in France, Poland, Germany and the UK. Due to a lack of exploration and associated data, there remain considerable uncertainties about the amount of economically recoverable shale gas resources in Europe:

A further modeling exercise is beyond the scope of this paper. However, the potential role of shale gas in meeting future European gas demand and the size of the associated uncertainties can be gleaned from Table 5, which provides a summary of existing studies:

The highest production scenarios see shale gas roughly compensating for declining domestic conventional production. In such scenarios, import dependencies remain at current levels, and prices are still largely determined by international import prices. In lower production scenarios, domestic shale production is not sufficient to compensate the decline in domestic conventional production.

Table 6 provides estimates of the cost of shale gas production in the EU, compared with other sources of supply. It can be seen that shale gas can be competitive with some sources, although only marginally so. Shale's competitiveness also depends significantly on external factors, such as the price of international LNG. Modeling studies suggest that the impact on EU prices will be limited. Significant shale production (20-60 bcm) is expected to lower EU gas prices in the order of 2-6%.[18]

**Table 5. European shale production scenarios[19]**

| Study | Cost assumption | Projected EU shale gas production in 2035 | Natural gas import dependence 2035 (63% in 2011) |
|---|---|---|---|
| JRC 2012 | 5-12 USD/ Mbtu | 1 to 2.1 tcm cumulatively in 2035 in the optimistic/ pessimistic scenarios | 57% in the high shale scenario<br>72% in the low shale scenario |
| IEA WEO NPS 2013 | Unclear | 20 bcm in 2035 | 81% |
| Pöyry and Cambridge Econometrics study for International Association of Oil and Gas Producers (2013) | 9 USD/Mbtu | 60 bcm in 2035 in the low scenario<br>150 bcm in 2035 in the high scenario | 80% in the low scenario<br>63% in the high scenario |
| BP WEO 2013 | Unclear | 37 bcm in 2035 | Ca. 75% |
| EIA 2013 | Unclear | 79 bcm in 2035. N.B. figures are for OECD Europe, not the EU. | 75%. N.B. figures are for OECD Europe not the EU |
| Joode et al (2012) | 7-10 USD/ Mbtu | Ca. 100 bcm in 2030 | 90% in the high demand scenario 78% in the low demand scenario |

**Table 6. Estimated costs of shale gas in comparison with other sources of natural gas supply for Europe**

| Estimated average price for shale gas in Europe | Estimated price for US LNG in Europe (Sabine Pass Liquefaction Project, with Henry Hub price of 6.50 $) | NBP (01.04. 2014) | TTF (01.04. 2014) | Russian Pipeline gas, German border (April 2014) | Price for LNG in Europe (July 2013) | Estimated Price for Yamal LNG |
|---|---|---|---|---|---|---|
| 9.90 | 9.90 | 8.926 | 8.857 | 10.79 | 10.14-14.2 | 8-9 |

Source: Gusev, A. 2014.

Note: Henry Hub is the main US gas spot trading market, NBP (National Balancing Hub) is the UK spot market, TTF is the Netherlands-based Continental European spot market

**To summarize: shale gas could provide a diversification option for Europe, and in particular for some Member states. However, its aggregate impacts on price and dependency appear likely to be relatively limited.**

16. Stern, J. 2014

17. IEA WEO 2013, pp. 109.

18. From Spencer *et al.*, 2014, Unconventional wisdom: an economic analysis of US shale gas and implications for the EU

19. Cambridge Econometrics (2013)

# 3. Assuring security in the natural gas sector: the role of demand side measures

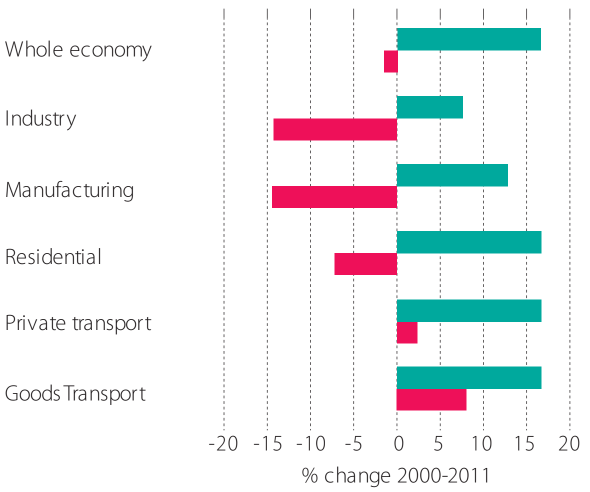
The preceding section highlighted the potentials of the main supply side measures (LNG, shale gas and internal market infrastructure) for assuring security in the EU's natural gas sector. It was shown that while each of these options offered potentially important elements of the solution, they also left important gaps in the EU's security strategy: e.g. increasing gas dependency over time due to declining domestic production (all options), exposure to international prices (LNG and internal market completion), significant uncertainties and time delays to deliver results (shale gas and internal market completion). This section therefore explores the potential contribution of demand side actions – notably on energy efficiency and renewables – to complement and reinforce the effectiveness of the above supply-side options.

## 3.1. Energy efficiency

### 3.1.1. Looking back

Energy efficiency policy is not a new idea. Improving energy efficiency has positive impacts in reducing the EU energy trade deficit, in improving households' purchasing power and in industrial competitiveness. It can also have positive spillovers in terms of job creation. For these reasons, Member states and the EU have already placed emphasis on improving energy efficiency with new policies and measures.

**Figure 4. Real economic activity (blue) and energy demand (red)**




Source: IDDRI analysis, based on Enerdata data

NB: Whole economy economic activity = GDP and total primary energy consumption. Industry = industrial value added and industrial final energy consumption. Manufacturing = manufacturing value added and manufacturing final energy consumption. Residential = private consumption and total residential final energy demand. Private transport = private consumption and total energy consumption for passenger transport. Goods transport = industry value added and total consumption of transport of goods

The evidence suggests that the EU energy efficiency drive is beginning to make itself apparent in the data. Indeed, the EU has begun to successfully decouple economic growth and energy demand. Figure 4 demonstrates this at both the macro-economic and sectoral level. The only exception is goods transport.[20]

An example of the results of existing energy efficiency policies can be provided by looking at the household sector. Gas made up 34% of total final energy consumption in the household sector in 2013. The major use is space and water heating. Since 2000, energy efficiency in space heating has improved by 19.14% for the EU.[21] The improvement was particularly strong in Western Europe (22.3%) and Eastern Europe (21.7%). This improvement is equivalent to about 5.6% of household gas consumption or 17 bcm of natural gas (4.1% of EU imports). This is the equivalent in supply terms of the annual capacity of a large-sized LNG regasification terminal, but without the cost of construction, nor importing the gas.

The value of these cost-savings can be better understood and appreciated by looking at household energy expenses, and in particular comparing those in the EU with those in the United States. In the US, energy prices for households are generally 50% or more lower than in Europe—due notably to lower tax rates and prices (Table 7).

**Table 7. Household energy prices and per capita consumption in Europe and the US (2012)**

| | Gasoline (Euro05/l) | Natural gas (Euro cents 05/kWh) | Electricity (Euro cents05/ kWh) | Per capita electricity consumption (kWh) | Per capita oil consumption (t) |
|---|---|---|---|---|---|
| France | 1.39 | 5.79 | 12.11 | 6,973.69 | 1.11 |
| United Kingdom | 1.61 | 5.41 | 16.21 | 5,136.41 | 0.89 |
| United States | 0.68 | 2.41 | 8.13 | 12,158.98 | 2.30 |
| Germany | 1.46 | 6.23 | 23.37 | 6,495.78 | 1.30 |

Source: IDDRI based on Enerdata

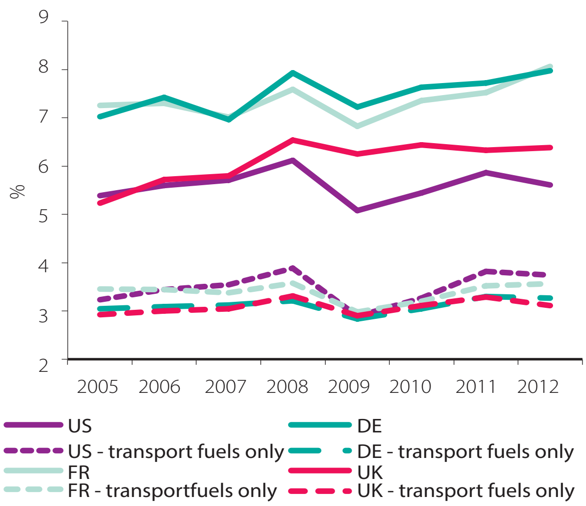
However, despite much lower energy prices, household energy expenditures as a share of total consumption expenditure in the US are broadly comparable with those in Europe (Figure 5), albeit slightly lower. Whereas European households tend to pay much more for electricity and gas due notably to higher tax rates and prices, in the US the higher volume of energy consumption compensates for much of the price difference[22].

20. The proxy for economic activity in the goods transport sector is industry value added; an imperfect proxy. Growing dispersion of value changes may be responsible for the increase in energy demand above the proxy taken for economic activity in this sector.

21. Odyssee database.

22. It should be noted that the US has higher average per capita income than the three EU countries highlighted here. Energy consumption as a share of income tends to decrease as incomes rise. Therefore, adjusted for income level, the difference in energy expenses between EU and the US would be smaller.

**Figure 5. Household energy expenditure as a share of total household consumption (2012)**



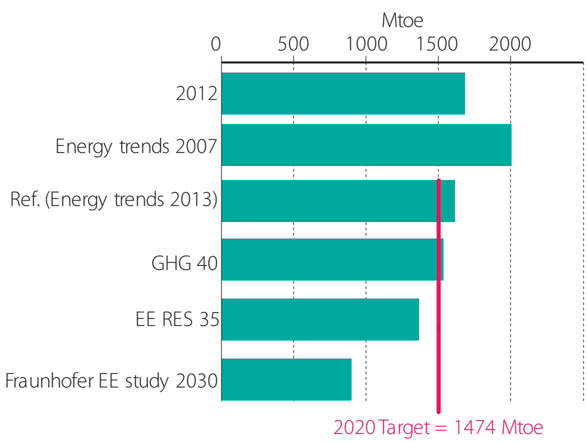

Source: Authors' analysis based on Insee (FR), BWE (DE), Office for National Statistics (UK), Bureau of Labor Statistics (US).

### 3.1.2. Looking forward

Despite this progress, Europe still has enormous potential for going further with its energy efficiency performance. Figure 6 compares primary energy consumption in 2030 across a range of scenarios:

- The European Commission's 2007 reference scenario (pre-crisis and pre-Energy Efficiency Directive);
- The European Commission's 2013 reference scenario;
- The 40% GHG reduction scenario from the Commission's Impact Assessment for the 2030 Climate and Energy Framework
- The 40% GHG scenario plus extra efforts on energy efficiency and renewable energy.
- The Fraunhofer study of cost-efficient energy efficiency potential in the EU under an ambitious policy scenario.

**Figure 6. Primary energy consumption for the EU27 in 2030 in different scenarios**




Source: Authors based on EC, 2014 and Fraunhofer, 2009.

It can be seen that the 40% GHG target alone would not achieve the EU's 2020 efficiency target (1 474 Mtoe primary energy) even in 2030. More ambitious scenarios for energy efficiency would lead to a -28% reduction of net gas imports (under the EE/RES30 scenario), and a -22% of total energy imports (compared to 2010). **For gas, this roughly corresponds to current gas imports from Russia. Put another way, the savings are equivalent (in terms of new gas investments) to building 19 medium to large (15 bcm) LNG regasification terminals. Annual savings would be about 7% of the EU's current energy import bill.**

Moreover, evidence suggests that the Enhanced Energy Efficiency scenario of the Impact Assessment is not unachievable. Indeed, other studies suggest that the EU could go further while being cost effective. For instance, a joint Fraunhofer-Wuppertal-ISIS-Vienna Technical University study (2009) has undertaken one of the most detailed assessments on energy efficiency in Europe. (Details of the study's scope, methodology and key assumptions are provided in the Annex.) It suggests that European energy consumption could be reduced more dramatically than is suggested by the Commission's 'top-down' impact assessment modelling, even if several of main conservative assumptions on energy prices, discount rates and demand growth are shared between both models. According to the Fraunhofer study, in 2030 the EU has the potential to achieve a 33% (405Mtoe) reduction in energy use by 2030 even if only economical options are exploited. Moreover, the EU has the technical potential to achieve 44% end-use energy savings potential for 2030 if it did not focus on cost-effectiveness alone. Under the latter scenario, households and industry would receive net benefits in terms of energy cost reductions of €240 billion annually by 2030, while net employment would be increased by 400,000 jobs by 2020.

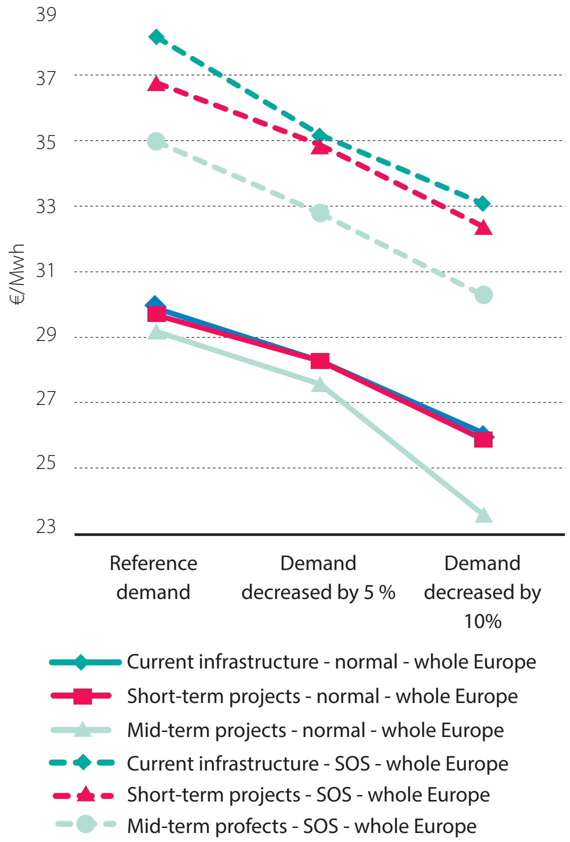
However, a pure focus on exploiting options which are cost-effective obviously excludes potentially important criteria for evaluating the benefits of energy efficiency projects, such as benefits to (vulnerable) consumers from lower energy prices. To illustrate this point, we modeled the effect that stronger energy efficiency efforts in the gas sector alone would be likely bring to consumers in terms of lower prices. We tested our results assuming 5% and 10% total gas demand reduction to the 2012 consumption data in our reference scenario[23]. We found that energy efficiency measures alone have a significant price reduction impact in the reference scenario: prices would decrease by 1.6 -3.8 €/MWh[24] on EU average—for the new member states this reduction is

23. 5% gas demand reduction equals about 29 bcm reduction in total EU consumption, 10% is about 58 bcm. The EU communication on Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy COM(2014) 520 final p.11 says: „With 25% energy savings, the 2030 framework would already deliver substantial improvements in the Union's energy dependency, representing a €9 billion saving per annum in fossil fuel imports (2% less) and a ***13% reduction in gas imports (ca. 44 billion cubic metres)*** compared to current trends and policies. However it does not say anything on how gas imports and gas comsumption relate to each other so it cannot be compared directly.

24. It is about 5-13% reduction to the 2012 yearly average EU price. For NMS it is 4-11%.

slightly lower. A 10% gas demand reduction combined with the mid-term infrastructure package, would even result in a 6.3€/MWh reduction of the average EU gas price. This represents a significant benefit to European natural gas consumers.

**Figure 7. Yearly average price with reduced gas demand (€/Mwh) for the EU as whole in reference and supply disruption scenario with different infrastructure projects completed**



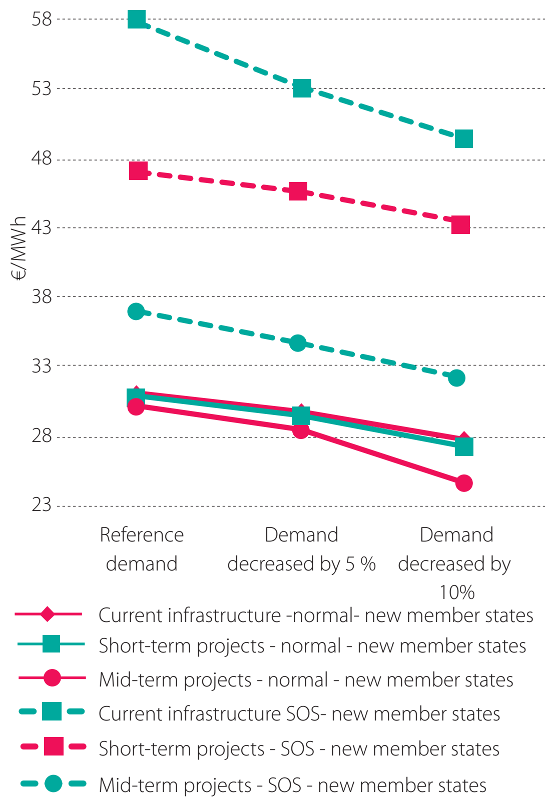

Source: REKK

Moreover, greater energy efficiency can help to complement (although not replace) strategic infrastructure projects to limit price increases resilience in the event of supply disruption. As can be seen in Figure 7, in the gas supply cut scenarios defined above, prices do not rise as high as they otherwise would have done without the demand reduction. However, it is clear that in both scenarios better interconnectivity through short-term projects reduces the difference between old and new member states by more than the demand reduction does (NMS), and mid-term project reduce the difference even more.

Figure 7 and Figure 8 suggest the following conclusions:

- Energy efficiency does contribute to security of supply goal of CEE member states through the reduction of gas import dependency: under normal conditions, a 10% reduction in demand would result in around a 10% price reduction even without any gas infrastructure investment.
- Implementing all the mid-term investment projects without energy efficiency driven gas consumption reduction would result in higher normal average gas prices (30.2 €/MWh) than investing into 5% gas demand reduction (29.5€/MWh)
- However in an SOS situation gas demand reduction alone does not per se solve all the problems of a gas supply disruption: even a 10% gas demand reduction would not bring as much in terms of average price reduction as implementing the key short-term priority energy investment projects.

**Figure 8. Yearly average price with reduced gas demand (€/Mwh) for CEE Member states only in reference and supply disruption scenario with different infrastructure projects completed**




Source: REKK

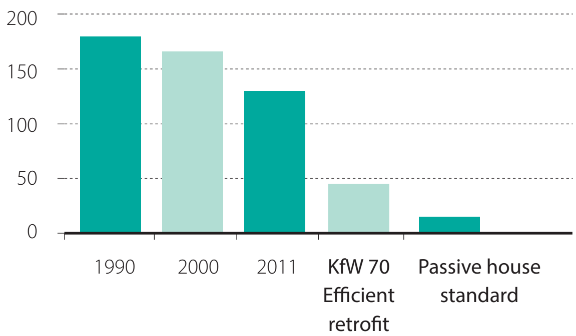
**These results underscore the fact that an intelligent European gas security strategy must be comprehensive and must not pull all its eggs in one basket. Energy efficiency provides significant price and cost reductions for consumers in both normal and supply disruption scenarios. While greater interconnectivity and supply side infrastructure projects play a key role in reducing volatility of prices between normal and supply disruption scenarios and reducing vulnerabilities in key regions. Ambitious supply and demand side measures are valuable complements and must both be included in any security of supply strategy.**

### 3.1.3. Focus on the buildings sector

Since the bulk of cost-effective energy efficiency potentials exist in the buildings sector, energy efficiency policies have a particular role to play in reinforcing Europe's natural gas security in particular.

Buildings represent 40% of final energy consumption and 36% of GHG emissions in Europe. In absolute figures, the gas consumption of European buildings has increased by 50% since 1990, whereas the share of gas has increased its share from 23% to 33% between 1990 and 2012, compensating the decline of heating oil and coal.
Since 1990, space heating requirements per m² have been significantly lowered across Europe due to efficiency gains (-28%). However, the current average of European buildings (scaled to EU average climate) is still substantially (3 to 4 times) higher than the level that can be achieve through deep retrofitting, and about 10 times the space heating needs of the passive house standard.

**Figure 9. Average space heating requirement (kwh/m²) in Europe compared to efficient standards**




Source: IDDRI analysis

Clearly, there is tremendous potential from buildings retrofits, although the administrative and financial challenge posed by implementing significant programs should be acknowledged. According to Ecofys (2014), a deep retrofit strategy for all European buildings could reduce the sectoral consumption of natural gas by 40% (-600 TWh) until 2030, a volume corresponding to 1.5 times current imports from Russia. Overall, final energy consumption of buildings would be 30% lower in 2030 and 65% lower in 2050 compared to 2012.

### 3.1.4. Conclusions and policy implications

A range of scenarios suggest that Europe's energy security could be significantly enhanced by a stronger focus on ambitious energy efficiency policies. Indeed, some of Europe's large economies have already set their own domestic targets to improve energy efficiency substantially by 2050. For example, Germany, France and the UK have outlined ambitious objectives to decrease energy demand by up to 50% by 2050.[25]

However, **specific vulnerabilities for a number of Central and Eastern European Member states and the reality that gas price rises and insecurity can spill over between Member states in the event of supply disruptions, imply that there is a need to Europeanize ambitious energy efficiency goals throughout the EU. It is in all Member states interest to ensure that ambitious targets are set and that there is sound implementation in all Member states.**
**There is therefore a need for a European governance mechanism for establishing ambitious quantifiable goals, tracking progress and facilitating and ensuring sound implementation throughout the Union. This should ideally take the form of national targets.** Targets are valuable because they can provide a clear focal point for setting and benchmarking domestic policy. They also can be valuable for coordinating the various actors who are required to coordinate for treating complex sectors such as building retrofits.
**However, if legally binding targets are not possible, then a second-best solution would require (as a minimum) an ambitious energy efficiency performance benchmark at EU level, against which Member states performance would be regularly reviewed.**

## 3.2. Domestic low-carbon energy supply

Another option for reducing the demand for natural gas while also exploiting synergies with climate change goals is to pursue low-carbon energy supplies. As with energy efficiency, domestic low-carbon energy can help to reinforce supply side gas security measures by reducing the residual demand for foreign gas. Once again, these potentials are quite large.

### 3.2.1. Looking back

Between 2000 and 2012, the production of low-carbon energy increased significantly. All of this increase came from renewables (+69%) as nuclear production fell 6%. Total production of renewables almost doubled, from 103 Mtoe to 204 Mtoe in 2013 (Table 2).

**Table 8. Growth in renewables production 2000-13**

| Mtoe | Hydro | Wind | Solar elec. | Solar heat | Geothermal elect. | Geothermal heat | Total biomass | Total |
|---|---|---|---|---|---|---|---|---|
| 2000 | 33.28 | 1.91 | 0.01 | 0.42 | 0.41 | 0.59 | 66.01 | 102.63 |
| 2013 | 34.84 | 19.8 | 7.12 | 1.81 | 0.50 | 1.24 | 138.65 | 203.94 |
| % Change | 5 | 934 | 70053 | 330 | 21 | 112 | 110 | 99 |

Source: Authors based on Enerdata

25. **Germany's *Energy Concept*** includes an objective to reduce primary energy consumption by 20% by 2020 and 50% by 2050, compared with 2008 levels. This overall objective is broken down into several sectoral targets. In June 2014 the French government issued a framing law on the national energy transition strategy. If adopted in its current version, this law would also enact a binding objective to reduce final energy consumption by 50% until 2050 (base 2012), making energy efficiency the main tool to achieve decarbonization. It includes other sectoral or fuel specific targets. In the **United Kingdom,** decarbonization scenarios set out by the Department for Energy and Climate Change in 2011 project a reduction in final energy demand per capita of -31% to -54% in 2050 compared to 2007. The UK also committed itself to achieving an 18% reduction in final energy consumption until 2020 (-20% in primary energy demand).

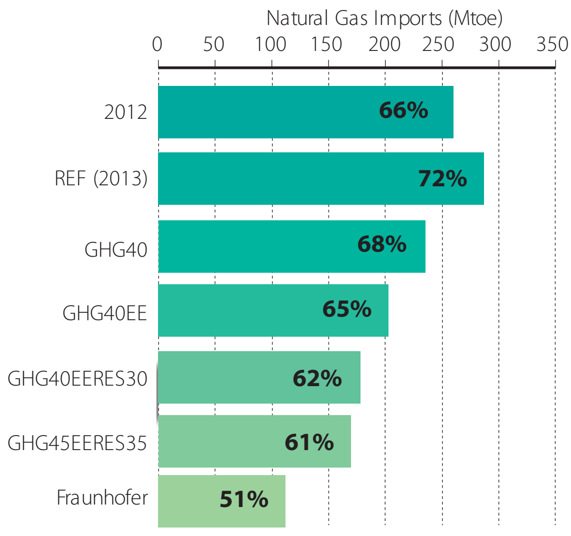
The increase of renewable energy in the energy mix has led to diversification of sources of supply and avoided the consumption of a large amount of fossil fuels. For example, in a hypothetical scenario, if renewables had remained at the same level of energy production as in 2004, the EU28 would have consumed in 2012 approximately 30 bcm of additional gas (7% of EU natural gas consumption, and the equivalent of the annual capacity of two large LNG regasification plants). With the same methodology, we estimate that the RES development in Eastern Europe avoided the consumption of 3 bcm of additional gas and 9 megatonnes of coal equivalent (mtce) of coal.

Clearly, this is only a simplified hypothetical scenario. Nonetheless, it can give a sense of the scale of substitution that has taken place in a relatively short period of time (8 years).

### 3.2.2. Looking forward

The EU also has an important capacity to generate further substitution between renewables and natural gas going forward. For example, Figure 10 highlights the different level of EU gas imports under different scenarios for the 2030 Climate and Energy Framework modeled by the European Commission. The import dependency rate (included above each column in the graph) decreases slower than the absolute level of imports, because of the simultaneous decline of domestic production. The figure nonetheless highlights, on the basis of the Commission's modeling, a significant incremental role for stronger renewables measures considered under the 2030 Climate and Energy Framework impact assessment to lowering gas import demand.

**Figure 10. Gas imports in 2030 for the EU 28 for different scenarios (Mtoe and rate of dependency)**




Source: Authors based on European Commission and Fraunhofer analysis

The values indicate gas imports, calculated as gross consumption – domestic supply. Domestic gas production figures for 2030 are based on the 2013 Reference Scenario (Energy trends 2050) with a total domestic production of 110 Mtoe in 2030 (against 156 Mtoe in 2010).

For example, an incremental change in renewable energy source (RES) targets from the GHG40EE scenario (which equated to about 26.5% business as usual renewable share in 2030, to a 30% RES target for 2030 under the GHG40EERES30 scenario, leads to a decline of 25 million toe of gas imports or 30.1 bcm of avoided natural gas imports in 2030. This is equivalent to the annual capacity of building 2 large LNG regasification terminals, or around 6.5% of EU natural gas consumption in 2013. Increasing the RES target to 35% and the GHG target to 45% would deliver additional natural gas savings of 10 bcm in 2030 – equivalent to another medium sized LNG regasification terminal or another 2.2% of total EU gas demand in 2013. Thus, while the Commission's analysis found that the GHG40 target was the most cost-effective pathway in its modeling; its results suggest that there would be significant additional natural gas security benefits to adopting more ambitious renewable targets.

Recent work by the IEA has also concluded similarly:

- Implementing the 40% GHG target in comparison to the New Policies Scenario (which does not include the 40% GHG target) reduces natural gas imports by 28 bcm (7%) and oil imports by 0.5 mb/d (7%).
- Implementing great efforts on renewables reduces natural gas imports by 33 bcm in 2030.

### 3.2.3. Focus on renewable heating and cooling

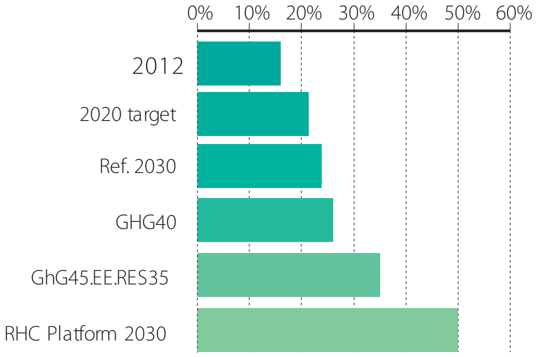
While such analysis is useful for indicating orders of magnitude and possible scenarios, it is also possible that renewable energy could provide greater substitution of natural gas demand if it were targeted to specific gas consuming sectors. Indeed, while much focus is on renewable development in the power sector, there are significant renewable potentials in the heating and cooling sector where RES can be a direct substitute for natural gas.

Currently, 50% of final energy consumption in Europe is used for the generation of heat for domestic and industrial purposes. In the residential sector, which accounts for 43% of Europe's natural gas consumption, heat (including space and water heating) accounted for 86% of final energy consumption (Enerdata, n.d.). Only 16% of total heat demand is covered by renewable sources (2012). Thus, along with energy efficiency, the deployment of efficient renewable heating and cooling technologies can play a key role in reducing Europe's energy dependence and cutting GHG emissions.

However, the Commission's reference scenario of the 2030 impact assessment (cited above) indicates a RES share for H&C of 24% in 2030, representing a very small increase over the 2020 level of 21,3%.[26] Moreover, decarbonization scenarios in the 2030 IA indicate a range for RES H&C between 26 and 35%, roughly in line with the overall share of RES in gross final consumption. More ambitious scenarios, such as the roadmap developed by the Renewable Heating & Cooling Platform (2011) indicate a share of more than 50% of renewable energy in H&C could potentially be achieved by 2030.

26. Calculation based on the National Renewable Energy Action Plans, EREC (2012).

**Figure 11. Renewables share in total heating and cooling demand in Europe**




Source: Authors based on European Commission 2014 and RHC 2011.

### 3.2.4. Conclusions and policy implications

**The evidence suggests that Europe's energy security could be significantly enhanced by a stronger push on low-carbon and particularly renewable energy sources, particularly for the heating and cooling sector.** As with energy efficiency, supply side measures to increase natural gas supply security, would be reinforced and made more effective if complemented with demand side measures such as renewable and low-carbon demand substitution.

**While Commission modeling suggests that renewable targets are not the most cost-effective route to achieving 2030 GHG targets, the analysis shows that they nevertheless offer significant additional benefits in terms of broader EU energy security objectives. Stronger targets than the currently proposed 27% - which is extremely close to business as usual – should therefore be adopted.** In any event, significantly higher renewable shares will need to be developed within the coming decades if the EU's 2050 decarbonisation goals are to be met.

Looking back at existing policies shows that Member State targets have been an effective framework for delivering rapid growth in renewable energy shares in a short period of time. Indeed most Member states, and the EU as a whole, are expected to meet its 2020 target of 20% RES share of energy consumption. Targets are valuable because they can provide a clear focal point for setting and benchmarking domestic policy. They also can be helpful for coordinating diffuse actors, such as grid planning and operation, investors, regulators, etc. **A possible second-best solution could involve an ambitious RES performance benchmark at EU level, against which Member states' performance would be regularly reviewed.**

## 4. Managing tensions between climate and gas security goals

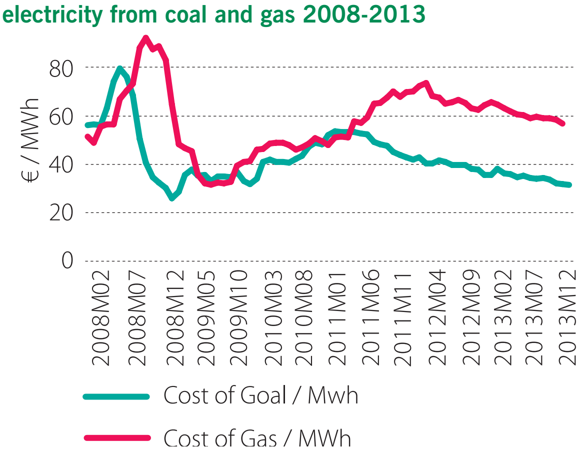
The preceding analysis highlighted a number of important synergies between climate and gas security goals. A number of possible tensions also exist. This section addresses two such tensions, namely: the tension between reducing gas demand for the EU while depending upon gas as a transition fuel for the power market; the tension between reducing gas consumption, while also aiming to reduce coal consumption. Section 4.1 addresses the former issue. The latter is addressed in sub-sections 4.2 and 4.3 with a focus on the example of the Polish coal sector and the tensions in that market.

### 4.1. Gas security vs. gas as a power market transition fuel

As noted in the introduction, natural gas is likely to be an important transition fuel for power sector sector decarbonisation. In the short run, significant abatement can be achieved by substituting coal-fired power production with natural gas, and at relatively low-carbon prices compared to other abatement options (around ~45€/tCO2)[27]. In the medium and longer term, technological breakthroughs on storage and improved power market designs notwithstanding, natural gas could also take on an important role in balancing demand fluctuations in the power grid. Natural gas remains a prime candidate fuel given its flexibility and low capital cost of new plant compared to other options. Does decarbonisation therefore conflict with improving EU natural gas security?

In practice, there are a number of reasons why the contradiction between power sector decarbonisation and natural gas security objectives are more theoretical than real. Firstly, unlike alternative uses of natural gas, the power sector is able to quickly substitute natural gas with alternative fuel sources when gas prices become too high. Indeed, such switching from gas to coal has occurred in large amounts in recent years, due to the divergence of coal and gas prices (see Figure 12 and Figure 13). Thus to the extent that the power sectors using natural gas fuel retain alternative sources of back-up generation capacity, greater use of natural gas in the power sector need not pose a systemic risk in the same way as sectors with fewer substitution possibilities.

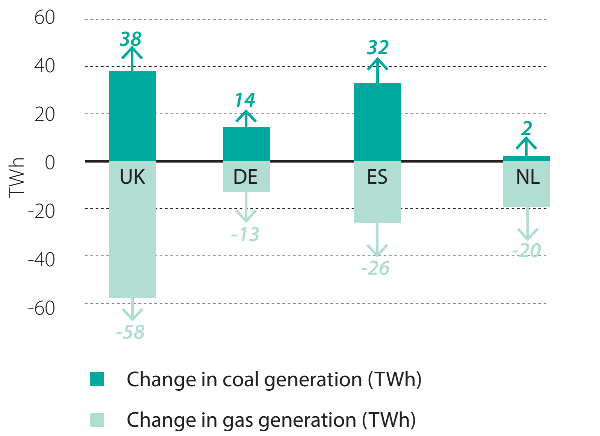
**Figure 12. Short-run marginal production cost of electricity from coal and gas 2008-2013**




Source: Authors' calculation based on IMF Commodity Price data.

27. Author's calculations.

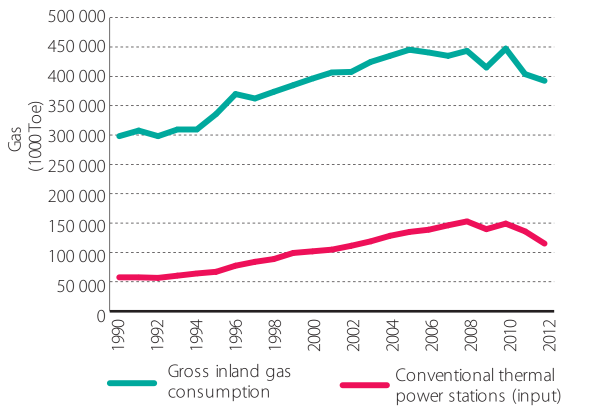
**Figure 13. Change in electricity generation from gas and coal between 2010 and 2012 (TWh)**




Source: IDDRI based on data from DECC, AGEB, RTE, Red eléctrica, CBS

Secondly, it is worth noting that electricity consumption is important but still a relatively minor source of natural gas consumption compared to other sectors. Power presently accounts for around one quarter of gross EU domestic natural gas consumption (Figure 14). As noted above, this could be further reduced by increasing the share of renewable and low-carbon power supply.

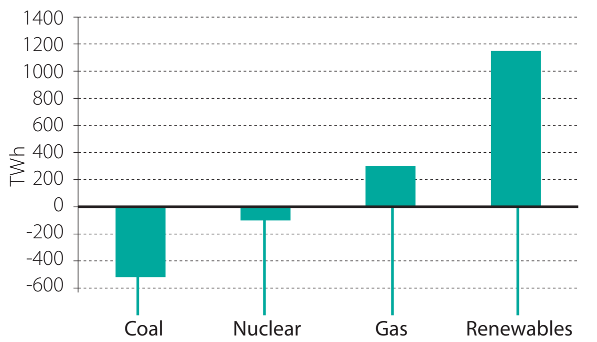
**Figure 14. EU natural gas consumption by thermal power stations *vs*. total domestic consumption**




Data: Authors' calculations based on Eurostat data.

Moreover, using gas as a balancing fuel would not necessarily imply large quantities of natural gas use. Rather, it would require that available capacities exist to provide balancing and flexibility services during critical hours, such as when renewables are ramping down but demand has not yet fallen away for the evening. This is reflected in the estimates below (sourced from the IEA 2012 World Energy Outlook) which forecast that if EU policies would continue to boost renewables such that they accounted for 44% of EU power generation in 2035, natural gas consumption in the power sector would rise, but by relatively small amounts, even despite a declining role for coal and nuclear (see Figure 15).

**Figure 15. Changes in power generation by fuel source for the EU in 2035 with higher RES shares**




Source: Authors, based on data from IEA WEO 2012.

**In sum: Natural gas' role in the power sector and as a transition fuel is unlikely to be so large as to undermine a robust gas security policy combining both demand and supply side elements. Moreover, the power sector's greater capacity for switching in the event supply disruptions make the power sector a less systemically risky source of demand for natural gas. As additional generation options are likely to remain available for some time, this problem is often more apparent than real in the medium term.**

## 4.2. What role for coal as an energy security fuel?

### A tension between coal and other non-gas energy sources?

One of the proposals made by Polish Prime Minister Donald Tusk's 6-point plan[28] for a European 'Energy Union'[29]—was that Europe should more intensively exploit all of its domestic energy resources, including coal and lignite. Global coal prices have also become significantly cheaper than natural gas as a primary fuel in recent years (see Figure 13), coal is traded in relatively secure global markets, and some EU member states, most obviously Poland, possess significant domestic reserves of coal and lignite and retain non-negligible numbers of relatively high wage jobs in the sector.

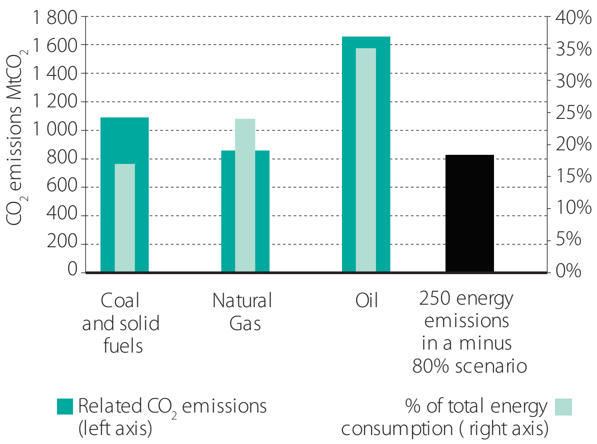
However, fuller use of European coal as a gas substitute would make meeting the EU's medium and longer term emissions mitigation goals impossible (barring unexpectedly rapid developments in the area of carbon capture and storage technology). The Tusk proposal nevertheless raises the question of what the appropriate role of coal should be in Europe's energy strategy. How should tensions between climate and energy security objectives be managed – particularly in Member states such as Poland, which, for historical reasons, are heavily invested in coal? First and foremost, it is helpful to consider the arithmetic

28. http://www.euractiv.com/sections/energy/poland-calls-eu-energy-union-301303

29. https://www.premier.gov.pl/en/news/news/donald-tusk-on-the-polish-project-of-the-european-energy-union.html

of decarbonisation. As Figure 16 shows, coal and related fuels such as lignite already account for approximately 30% of Europe's energy-related CO2 emissions, despite accounting for only 17% of its total primary energy consumption. Moreover, in an 80% decarbonisation scenario for the energy sector as a whole, present emissions from all major fuel types would all individually need to be reduced below current levels. Given the challenges related to rapid substitution of oil in the transport sector, this implies a greater role for reductions of natural gas and coal in the short to medium term. If however, natural gas were to be substituted with greater coal use, this would effectively place the burden of short to medium term decarbonisation on the transport sector, while lifting coal emissions alone significantly above the global energy sector's -80% 2050 energy emissions target. For these reasons, greater coal use is inconsistent with medium and longer term decarbonisation of the European energy sector.

**Figure 16. Energy-related $CO_2$ emissions by fuel type *vs.* an 80% reduction scenario in 2050**




Data: Enerdata, US EIA. Note: Data are for 2011.

The arithmetic of coal emissions therefore implies that an energy security strategy consistent with a climate security strategy will require a continual diversification of energy sources away from coal in both the medium and long-term.

However, for Member states which, for historical and geological reasons, are today heavily invested in coal, the requirement of a shift away from coal, as well as hesitancy to significantly increase dependency on natural gas, poses a number of challenges. The nature of these challenges can be appreciated by a consideration of the challenges facing Europe's biggest coal producer – Poland.

**Economic and investment challenges:** For Member states with an unusually high share of coal and lignite in their power generation mix, such as Poland (83% in 2013) or even the Czech Republic (47% in 2013)[30], the desire to Phase out coal without investing heavily in natural gas presents a challenge in terms of electricity costs. Specifically, the power prices required to support new low-carbon generation (whether nuclear or renewables or even CCS) are likely to represent a step-change from current price levels (see Table 9).

**Table 9. Estimated levelised cost of low-carbon energy sources in Poland (2011 data)**

| | Minimum price | Zakres wartości | Średnia - przegląd literatury | Mapa Drogowa 2050 | McKINSEY |
|---|---|---|---|---|---|
| geothermal | 35,14 | 85,11 | 64,75 | 107,70 | 69,90 |
| wind | 29,67 | 90,33 | 68,16 | 120,00 | 107,60 |
| biomass | 33,78 | 85,36 | 71,38 | 105,00 | 105,29 |
| offshore wind | 60,12 | 188,08 | 126,35 | 192,94 | 135,30 |
| PV | 87,45 | 384,69 | 227,18 | 310,00 | 369,45 |

Source: IBS

Moreover, coal intensive Member states such are likely to have coal-fired power in their generation mix for longer than other Member states, given the time needed for transition. In some cases, this may imply that carbon price-pass through to power consumers will occur to a greater extent and for a longer transition period in these power markets than in other Member states.

At the same time, it should be noted that the above-mentioned investment and power market challenges do not only flow from climate policy considerations. For instance, in the Polish case, an aging power generation structure in need of reinvestment and modernization, the revised European directive on industrial pollutants, and a general need to diversify its power mix to improve system stability, are, together with climate policy risks, expected to gradually push Poland in the direction of diversification away from coal-fired generation in the medium term. Thus an IBS (2011) found that the average expected role for coal in 2030 across different scenarios analysed for Poland was at the level of 45% (13% wind, 12% biomass, 12% nuclear, 9% gas). **Given the structural investment challenges facing the Polish power sector, European climate policy may actually help create some of the incentives, such as carbon prices, needed to support investments in a more diversified generation portfolio.**

**Employment and social adjustment challenges**: For Member states with historically large coal production operations, there is also the issue of employment and social impacts of the phasing out of coal. In Poland, for example, the three major enterprises in the Polish coal sector currently directly employ 106 000 workers at 24 mines (see Box 1). Employees in coal mining sector have on average significantly lower qualifications compared to other sectors, which weakens their chances to find other jobs outside the sector.

Once again, a realistic business as usual scenario is likely to decrease employment and the number of mines operated in countries like Poland independently of climate policy. The evidence strongly suggests that this phenomenon is structural rather than cyclical.

30. Enerdata n.d.

**Box 1. Understanding trends in the Polish coal industry**

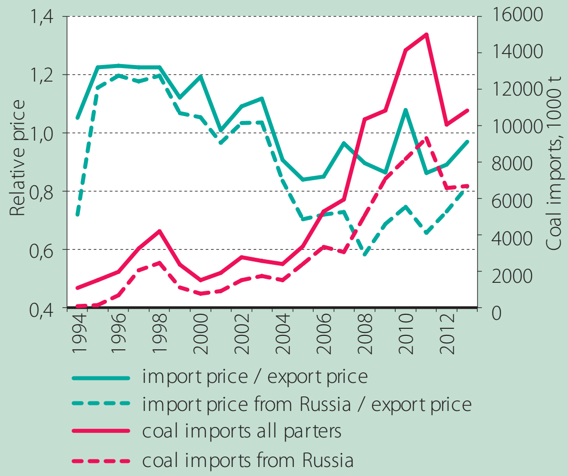
Polish coal, while traditionally significant, is facing declining competitiveness compared to foreign coal. Since 1989, the Polish coal (and lignite) mining sector went through a deep restructuring process that limited the number of active mines from 70 to 24 and reduced employment from ca. 415k to 110k. Production of coal fell from 176 mln t in 1989 to 68 mln t in 2013 (PIG, 2014). In 2011, the coal mining sector contributed 1.6% of Polish GDP. The share of coal in total Polish exports is 0.7% (2011). Poland is the biggest coal exporter in the EU and it contributes 0.82% to global coal exports. It has also a leading position in global coke trade (25% of world exports)[1].

Nevertheless the current situation of the sector is still difficult and appears likely to worsen in coming years. In 2013, the sector as a whole suffered a loss of PLN 273.5m, lowered its production by 4% and investment expenditure by 13%. The biggest mining company, Kompania Węglowa, which owns a half of all active mines in Poland and employs over 50% of miners working in Poland suffered losses in 2013 estimated at around 700 mln PLN (Piszczatowska, 2014).

The costs of exploration remain rigid and also the structure of costs remains unfavourable (salaries in a highly unionized sector with unusually high wages constitute around 50% of costs) and accounting liquidity is very limited (Piszczatowska, 2014). The sector has also already experienced significant downsizing since 1989. High prices of Polish coal resulted in an increase of imports of cheaper coal (mainly from Russia, whose share in coal imports to Poland is over 60%) and, in consequence, making competitive pressure on Polish producers (see Figure 17).

CCS development remains elusive in Poland. Implementation of the CCS Directive by Poland in 2013 was limited to the development projects aiming at verification of the technology in terms of efficiency in reduction of $CO_2$ emission as well as its impact on health and environment. The decision about widening the scope of the legislation to commercial use of CCS in Poland was planned to be taken in 2024. Yet two attempts to engage in development projects of CCS in Poland were abandoned after preliminary assessments. The first one was planned for the lignite-fired unit of Bełchatów power plant. The second project was to be implemented by Gupa Azoty S.A. in its new gas-fired installation in Kędzierzyn. Although the EU-funds (NER300) were to cover a half of costs and preferential bank loans were promised for missing capital, both companies calculated that the cost of CCS would be profitable only with $CO_2$ emission permits at the level of 60€/t$CO_2$. Currently there is in Poland only one consortium working on the CCS-technology—Tauron S.A. and the Institute for Chemical Processing of Coal yet the project is rather small scale.

**Figure 17. Polish relative coal prices and imports of coal 1994-2013.**




Source: Authors based on Comtrade data

1. Comtrade

As Box 1 explains, Poland (and indeed Europe as a whole) now imports a significant share of their coal consumption due to the uncompetitiveness of domestic reserves. Nevertheless, as coal and lignite mining is strongly interlinked with electricity sector (for example, virtually all lignite is burnt in plants located next to the mines), an acceleration of the phase out of coal-fired power would reinforce the unprofitable situation of the sector.

**Political and equity challenges:** Finally, the phase out of coal-fired power in coal-intensive Member states with concurrent limitations on the willingness to use natural gas as a substitute fuel source creates political and equity challenges. It implies a loss of profitability for incumbent conventional power market and coal-sector companies, not to mention a political economy challenge in a context where no significant market rival to coal-fired power currently exists.

Legitimate equity issues are also raised by the fact that coal-intensive Member states are coal-intensive largely by virtue of historical and geological accident, rather than by conscious choice.

## 4.3. Conclusions and implications for energy policy

The preceding discussion underscores a number of important points for reconciling climate and energy security policy agendas in the 2030 Energy and Climate Package. Firstly, the use of natural gas as a transition fuel in the power sector need not weaken broader efforts to reduce the EU's natural gas dependency. Greater use of low-carbon and renewable power sources would not undermine the achievement EU's natural gas security objectives advocated elsewhere in this report.

Secondly, the simple arithmetic of decarbonisation shows that Europe will not significantly reduce its foreign energy costs by greater reliance on coal. Greater use of unabated coal as a substitute for natural would mean abandoning targets for decarbonisation of the European energy sector by mid-century.
Thirdly, coal intensive Member states must face up to a difficult transition regardless of climate policy. The only way for Member states heavily invested in coal is to extract themselves from a more costly and drawn out transition is to diversify their energy sources. The European 2030 Framework should acknowledge the more difficult challenges facing policy makers in coal-intensive Member states owing to historical contingency. This could be done by

- Providing needs-based supports (such as dedicated ETS auction revenues and allocations) for the power sector modernisation and decarbonisation.
- Including an explicit strategy for Member states to control power costs for consumers for whom coal will remain a marginal generation fuel for longer due to their high share of coal-fired generation.
- Supporting greater European prioritisation of natural gas security projects in vulnerable Member states for whom phasing out coal implies an increase in natural gas usage.

At the same time, coal-intensive Member states should recognise that the EU as a whole is heavily politically invested in an ambitious climate and energy policy. Coal-intensive Member states such as Poland could therefore attempt to pursue an opportunity for synergies between European and domestic policies: e.g. reinforcing European CO2 pricing ultimately reduces the need for domestic subsidies of new generation investments by their governments, because it increases power prices and thus the return to lower carbon producers who may seek to enter the market.

## 5. Conclusions and policy recommendations

europe's energy security strategy must address risks of short-term disruptions of supply, reducing the high cost of imported fuels, exposure to price shocks and systemic price increases, as well as systemic challenges such as decarbonization and the low or declining competitiveness of domestic fossil fuel energy sources.
Combining these agendas requires a comprehensive approach with a mix of both short-term tactical and longer term strategic goals. The effectiveness of the strategy is maximized by pursuing both supply side measures (such as LNG, internal market completion, shale in certain Member states, and newer options such as power-to-gas and biogas) and demand side measures (such as energy efficiency and low-carbon and renewables) in tandem. Doing so can provide a strong, mutually reinforcing effect on European energy security. Reducing the demand for gas lowers the 'denominator' that must be supplied by the 'numerator' of different supply options.
On the supply side, our modeling analysis strongly suggests that the internal market is a key tool for increasing resilience to supply disruptions, particularly for regions currently isolated or with particular vulnerabilities based on present infrastructure. Decisions could be taken as part of the Package regarding the funding of short-and mid-term infrastructure priority projects in the most vulnerable Member states. This could perhaps help to reassure these Member states in accepting more ambitious emissions targets as gas security, a key fuel for the low-carbon transition, will be reinforced.
In addition, a long-term goal could be set to ensure sufficient integration in the internal market, e.g. progressive convergence (allowing for transport costs) of wholesale prices in EU countries, building upon this and future infrastructure. This could complement an integration objective in electricity.
However, it is equally true that there is no silver bullet to European gas supply security. Strategic LNG projects and alternative supply sources can help to introduce alternatives and competition into isolated markets and limit the impact of supply disruptions. But it will likely remain a relatively expensive option, and subject to global uncertainties. Shale gas might contribute to supply in some countries, but the volume and price effects are as yet highly uncertain. In addition, shale will take time to ramp up. By themselves, neither of these solves the issue of gas import dependency. Proposals for greater use of domestic resources of more carbon-intensive fuels, such as coal, are not realistic given the declining competitiveness of domestic hard coal and the global EU emissions budget.
That is why supply side measures must be complemented by ambitious demand side options. While supply side measures on improving the internal market can help to reduce price volatility and variability across the EU in the event of a supply shock, energy efficiency dominates infrastructure projects as a means of reducing the cost to consumers and national economies of natural gas imports. Our modeling suggests that even a 10% reduction in EU gas demand is associated with a roughly 10% decline in average prices in the EU. Going further, simply by adopting enhanced energy efficiency policy settings and a 30% RES target in 2030, the EU could save the natural gas consumption equivalent of total current gas imports from Russia. This is roughly equivalent to building 19 LNG regasification terminals.
To make this happen, the 2030 Energy and Climate Package could contain an energy efficiency goal at EU level, which would act as a benchmark for stronger sectoral regulations and member state actions in sectors not regulated by EU instruments (buildings, etc). Improving energy efficiency also requires appropriate pricing of energy by Member states via the stance of fiscal policy.
Scaling up domestic low-carbon energy supply is another crucial measure to improve long-term energy security, even if it needs to be done in a cost effective manner and consistent with Member states' different starting points and decarbonization strategies. We show that, according to the European Commission's modeling, a slight change in ambition relative to business as usual could help the

EU to save an additional 10% of projected natural gas consumption in 2030. To make this happen, an EU renewables goal could act as a benchmark for ambitious national decarbonization plans, potentially with binding, nationally-proposed elements, under the proposed governance mechanism.

The transition is more than 'more efficiency, more low-carbon energy'. It is also new ways of producing and consuming goods and services. Greater substitutability between energy vectors is an important part of the transition (electricity in transport, biogas or artificial methane – methanation – in the existing gas infrastructure). Such evolutions are subject to technology uncertainties and coordination challenges, but could give significant benefits in terms of energy security and resilience. There is a need for greater efforts on R&D on such technologies and 'system changes'. Robust and policy consistent energy pricing for fossil fuels and carbon intensive energies will also be necessary to provide an economic basis for these developments. Reporting on the policy consistency of energy pricing could therefore be a key element contained in reporting on national energy plans under the new EU energy governance mechanism.

Finally, the European 2030 Framework presents should acknowledge the more difficult challenges facing policy makers in coal-intensive Member states owing to historical contingency. This could be done by

- Providing needs-based supports (such as dedicated ETS auction revenues and allocations) for the power sector modernisation and decarbonisation.
- Developing an explicit strategy for Member states to control power costs for consumers for whom coal will remain a marginal generation fuel for longer due to their high share of coal-fired generation.
- Supporting greater European prioritisation of natural gas security projects in vulnerable Member states for whom phasing out coal implies an increase in natural gas usage.

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## Annexes

### Definition of PCI projects included in the modeling analysis

**Projects of the short-term priority package:**
LNG: Poland and Lithuania
Storage: upgrade in Bulgaria
Interconnectors: bidirectional SK-HU and GR-BG, bidirectional RS-BG
Reverse flow projects: RO-HU, HR-HU,

**Projects of the mid-term priority package:**
LNG: Croatia, Estonia, Greece
Interconnectors: bidirectional PL-LT, bidirectional FR-ES, bidirectional PL-SK, bidirectional: PL-CZ, bidirectional EE-FI, upgrade LV-LT, TAP, TANAP, IAP

### Detailed description of the Regional Energy Community Center's (REKK) 'European Gas Market Model'

**Overview**
REKK's European Gas Market Model has been developed to simulate the operation of an international wholesale natural gas market in whole Europe. Figure 18 shows the geographical scope of the model. Country codes denote the countries for which we have explicitly included the demand and supply side of the local market, as well as gas storages. Large external markets, such as Russia, Turkey, Libya, Algeria and LNG exporters are represented by exogenously assumed market prices, long-term supply contracts and physical connections to Europe.
Given the input data, the model calculates a dynamic competitive market equilibrium for 35 European countries, and returns the market clearing prices, along with the production, consumption and trading quantities, storage utilization decisions and long-term contract deliveries.
Model calculations refer to 12 consecutive months, with a default setting of April-to-March.[31] Dynamic connections between months are introduced by the operation of gas storages ("you can only withdraw what you have injected previously") and TOP constraints (minimum and maximum deliveries are calculated over the entire 12-month period, enabling contractual "make-up").
The European Gas Market Model consists of the following building blocks: (1) local demand; (2) local supply; (3) gas storages; (4) external markets and supply sources; (5) cross-border pipeline connections; (6) long-term take-or-pay (TOP) contracts; and (7) spot trading. We will describe each of them in detail below.

31. The start of the modeling year can be set to any other month.

**Figure 18. The geographical scope of the European Gas Market Model**


**Local demand**
Local *consumption* refers to the amount of gas consumed in each of the local markets in each month of the modeling year. It is, therefore, a quantity measure.[32] Local *demand*, on the other hand, is a functional relationship between the local market price and local consumption, similarly specified for each month of the modeling year.
Local demand functions are downward sloping, meaning that higher prices decrease the amount of gas that consumers want to use in a given period. For simplicity, we use a linear functional form, the consequence of which is that every time the market price increases by 0.1 €/MWh, local monthly consumption is reduced by equal quantities (as opposed to equal percentages, for example).
The linearity and price responsiveness of local demand ensures that market clearing prices will always exist in the model. Regardless of how little supply there is in a local market, there will be a high enough price so that the quantity demanded will fall back to the level of quantity supplied, achieving market equilibrium.

**Local supply**
Local *production* is a similar quantity measure as local consumption, so the corresponding counterpart to local demand is local *supply*. Local supply shows the relationship between the local market price and the amount of gas that local producers are willing to pump into the system at that price.
In the model, each supply unit (company, field, or even well) has either a constant, or a linearly increasing marginal cost of production (measured in €/MWh). Supply units operate between minimum and maximum production constraints in each month, and an overall yearly maximum capacity.[33]

32. All quantities are measured in energy units within the model.

33. Minimum production levels can be set to zero. If minimum levels are set too high, a market clearing equilibrium may require negative prices, but this practically never happens with realistic input data.

Any number of supply units can be defined for each month and each local market. As a result, local supply will be represented by an increasing, stepwise linear function for which the number, size, and slope of steps can be chosen freely.

**Gas storages**

Gas storages are capable of storing natural gas from one period to another, arbitraging away large market price differences across periods. Their effect on the system's supply-demand balance can be positive or negative, depending on whether gas is withdrawn from, or injected into, the storage. Each local market can contain any number of storage units (companies or fields).

Storage units have a constant marginal cost of injection and (separately) of withdrawal. In each month, there are upper limits on total injections and total withdrawals. There is no specific working gas fee, but the model contains a real interest rate for discounting the periods, which automatically ensures that foregone interest costs on working gas inventories are taken into account.

There are three additional constraints on storage operation: (1) working gas capacity; (2) starting inventory level; and (3) year-end inventory level. Injections and withdrawals must be such during the year that working gas capacity is never exceeded, intra-year inventory levels never drop below zero, and year-end inventory levels are met.

**External markets and supply sources**

Prices for external markets and supply sources are set exogenously (i.e. as input data) for each month, and they are assumed not to be influenced by any supply-demand development in the local markets. In case of LNG the price is derived from the forecasted Japanese spot gas price, taking into account the cost of transportation to any possible LNG import terminal. As a consequence, the price levels set for outside markets are important determinants of their trading direction with Europe. When prices are set relatively low, European countries are more likely to import from the outside markets, and vice versa.

**Cross-border pipeline**

Any two markets (local or outside) can be connected by any number of pipelines or LNG routes, which allow the transportation of natural gas from one market to the other. Connections between geographically non-neighboring countries are also possible, which corresponds to the presence of dedicated transit routes.

Cross-border linkages are directional, but physical reverse flow can easily be allowed for by adding a parallel connection that "points" into the other direction. Each linkage has a minimum and a maximum monthly transmission capacity, as well as a proportional transmission fee.

Virtual reverse flow ("backhaul") on unidirectional pipelines or LNG routes can also be allowed, or forbidden, separately for each connection and each month. The rationale for virtual reverse flow is the possibility to trade "against" the delivery of long-term take-or-pay contracts, by exploiting the fact that reducing a pre-arranged gas flow in the physical direction is the same commercial transaction as selling gas in the reverse direction.

Additional upper constraints can be placed on the sum of physical flows (or spot trading activity) of selected connections. This option is used, for example, to limit imports through LNG terminals, without specifying the source of the LNG shipment.

**LNG infrastructure**

LNG infrastructure in the model consist of LNG liquefaction plants of exporting countries, LNG regasification plants of importing countries and the "virtual pipelines" connecting them. "Virtual pipelines" are needed to define for each possible transport route a specific transport price. LNG terminals capacity is aggregated for each country, which differs from the pipeline setup, where capacity constraints are set for all individual pipeline. LNG capacity constraints are set as a limit for the set of "virtual pipelines" pointing from all exporting countries to a given importing country, and as a limit on the set of pipelines pointing from all importing countries to a given exporting country.

**Long-term take-or-pay (TOP) contracts**

A take-or-pay contract is an agreement between an outside supply source and a local market concerning the delivery of natural gas into the latter. The structure of a TOP contract is the following.

Each contract has monthly and yearly minimum and maximum quantities, a delivery price, and a monthly proportional TOP-violation penalty. Maximum quantities (monthly or yearly) cannot be breached, and neither can the yearly minimum quantity. Deliveries can be reduced below the monthly minimum, in which case the monthly proportional TOP-violation penalty must be paid for the gas that was not delivered.

Any number of TOP-contracts can be in force between any two source and destination markets. Monthly TOP-limits, prices, and penalties can be changed from one month to the next. Contract prices can be given exogenously, indexed to internal market prices, or set to a combination of the two options.

The delivery routes (the set of pipelines from source to destination) must be specified as input data for each contract. It is possible to divide the delivered quantities among several parallel routes in pre-determined proportions, and routes can also be changed from one month to the next.

**Spot trading**

The final building block, spot trade, serves to arbitrage price differences across markets that are connected with a pipeline or an LNG route. Typically, if the price on the source-side of the connection exceeds the price on the destination-side by more than the proportional transmission fee, then spot trading will occur towards the high-priced market. Spot trading continues until either (1) the price difference drops to the level of the transmission fee, or (2) the physical capacity of the connection is reached.

Physical flows on pipelines and LNG routes equal the sum of long-term deliveries and spot trading. When virtual reverse flow is allowed, spot trading can become "negative" (backhaul), meaning that transactions go against the predominant contractual flow. Of course, backhaul can never exceed the contractual flow of the connection.

**Equilibrium**
The European Gas Market Model algorithm reads the input data and searches for the simultaneous supply-demand equilibrium (including storage stock changes and net imports) of all local markets in all months, respecting all the constraints detailed above.

In short, the equilibrium state (the "result") of the model can be described by a simple no-arbitrage condition across space and time.[34] However, it is instructive to spell out this condition in terms of the behavior of market participants: consumers, producers and traders.[35]

Local consumers decide about gas utilization based on the market price. This decision is governed entirely by the local demand functions we introduced earlier.

Local producers decide about their gas production level in the following way: if market prices in their country of operation are higher than unit production costs, then they produce gas at full capacity. If prices fall below costs, then production is cut back to the minimum level (possibly zero). Finally, if prices and costs are exactly equal, then producers choose some amount between the minimum and maximum levels, which is actually determined in a way to match the local demand for gas in that month.

Traders in the model are the ones performing the most complex optimization procedures. First, they decide about long-term contract deliveries in each month, based on contractual constraints (prices, TOP quantities, penalties) and local supply-demand conditions.

Second, traders also utilize storages to arbitrage price differences across months. For example, if market prices in January are relatively high, then they withdraw gas from storage in January and inject it back in a later month in such a way as to maximize the difference between the selling and the buying price. As long as there is available withdrawal, injection and working gas capacity, as well as price differences between months exceeding the sum of injection costs, withdrawal costs, and the foregone interest, the arbitrage opportunity will be present and traders will exploit it.[36],[37]

34. There is one, rather subtle, type of arbitrage which is treated as an externality, and hence not eliminated in the model. We assume that whenever long-term TOP contracts are (fully or partially) linked to an internal market price (such as the spot price in the Netherlands), the actors influencing that spot price have no regard to the effect of their behavior on the pricing of the TOP contract. In particular, reference market prices are not distorted downwards in order to cut the cost of long-term gas supplies from outside countries.

35. We leave out storage operators, since injection and withdrawal fees are set exogenously, and stock changes are determined by traders.

36. Traders also have to make sure that storages are filled up to their pre-specified closing level at the end of the year, since we do not allow for year-to-year stock changes in the model.

37. A similar intertemporal arbitrage can also be performed in markets without available storage capacity, as long as there are direct or indirect cross-border links to countries with gas storage capability. In this sense, flexibility services are truly international in the simulation.

Finally, traders also perform spot transactions, based on prices in each local and outside market and the available cross-border transmission capacities to and from those markets, including countries such as Russia, Turkey, Libya, Algeria or LNG markets, which are not explicitly included in the supply-demand equalization.

**Table 1. Summary of modelling input parameters and data sources**

| Category | Data Unit | Source |
|---|---|---|
| Consumption | Annual Quantity Monthly distribution (% of annual quantity) | Energy Community data, Eurostat, ENTSO-G |
| Production | Minimum and maximum production | Energy Community data, ENTSO-G |
| Pipeline infrastructures | Daily maximum flow | GIE, ENTSO-G, Energy Community data |
| Storage infrastructures | Injection, withdrawal, working gas capacity | GSE |
| LNG infrastructures | Capacity | GLE, GIIGNL |
| TOP contracts | Yearly minimum maximum quantity Seasonal minimum and maximum quantity | Gazprom, National Regulators Annual reports, Platts, Cedigaz |

## 7.3. Assumptions and methodology underlying the Renewable Heating and Cooling Platform analysis of EU 2030 RHC potentials

Figures cited in this report in Section 3.2.3 come from the European Technology Platform on Renewable Heating and Cooling (RHC)'s 2011 study entitled "2020-2030-2050: Common Vision for the Renewable Heating and Cooling sector in Europe". These figures are based on estimates of physical supply potentials calculated by RHC. Several of the key assumptions underlying these calculations are taken from this publication and are reproduced below.

**Coverage of the analysis**
- The demand for high temperature ("high" meaning above 250 °C) heat is not analysed nor included in these calculations. They therefore ignore the needs of high-temperature industrial heat users, which make up 30% of the heat market.
- The analysis does not consider renewable electricity as an option for heating and cooling purposes as this is beyond the scope of the RHC-Platform.
- Each RES for heating can only be used to deliver heat up to a certain temperature, affecting the applications that they can be used for. Shallow geothermal is best suited for temperatures up to 50 °C, solar thermal up

to about 100 °C (with the exception of concentrating solar, which can reach very high temperatures). Deep geothermal heat can supply temperatures in the range of 50-150 °C depending on local conditions, and biomass can supply heat at any temperature below the combustion temperature of the feedstock.

**Base line demand and enhanced demand scenarios in 2030**

The "Business as usual Scenario" (BAU) is based on the following assumptions:

- Moderate reduction of the heating demand compared with 2006 (on average: -5% by 2020, -10% by 2030 and -20% by 2050).
- Policy support: RE obligations only for new residential buildings; subsidies for existing residential, service and commercial buildings as well as for industrial applications (subsidies: 10 - 30% of the system cost) or constantly moderate rising energy prices of fossil energy.
- Medium R&D rate and therefore solutions for high energy density heat stores and new collector materials; sufficient and cost competitive solutions for solar thermal cooling by the year 2020.
- Medium growth rate of RHC installed capacity (10-15% per annum until 2020).

The "Full Research, Development and Policy Scenario" (RDP), upon which the estimates reported in Section 3.2.3 of this report, is based on the following assumptions:

Significant reduction of the heat demand compared with 2006 (depending on the country but on average: -10% by 2020, -20% by 2030 and -30% by 2050).

- Full policy support: RE obligations for all new and existing residential, service and commercial buildings as well as for low-temperature industrial applications or high energy prices of fossil energy.
- High R&D rate delivers solutions for cost efficient high energy density heat stores and new collector materials; sufficient and cost competitive solutions for solar thermal cooling available by 2020.
- High growth rate of RH&C installed capacity (approx. 25% per annum until 2020).

**Disaggregation of headline results:**

The vast majority of potential growth in renewable heat demand is met by biomass, followed by solar thermal. Approximately 180-190Mtoe of heat is provided by biomass, 60-70Mtoe by solar thermal, with the remaining 30Mtoe met by equal shares of aero/hydro HP, geothermal HP and geothermal deep.

Assuming a 9% reduction in overall final energy demand due to energy efficiency measures by 2020 (compared to 2006), in the most ambitious scenario (RDP) solar thermal could provide up to 6,3% of the 20% target for renewable energy in the EU. Considering the European energy mix in 2005 (reference year of the "RES Directive"), solar thermal systems will contribute for a share equivalent to 12% of the total new renewable energy capacity installed by 2020 to meet the EU targets". Post-2020, the RDP scenario shows contributions of solar thermal to total European low-temperature heat demand of 3.6% in 2020, 15% in 2030 and 47% in 2050.

The RHC-Platform expects biomass use to more than double by 2020 and to reach around 370 Mtoe of primary energy in 2050 (Figure 12), mostly to meet heat demand. Aquatic biomass has the potential to make a large contribution of this supply in any regions of Europe. By 2030 biomass for heat could be used to meet 182Mtoe of heat demand.

## Assumptions and methodology underlying the Fraunhofer analysis of EU 2030 Energy Efficiency potentials

Figures cited in this report in Section 3.1.2. come from a Joint study lead by the Frauenhofer ISI institite in 2009. Several of the key assumptions underlying these calculations are taken from this publication and are reproduced below.

**Aims and scope of the analysis**[38]

- "To estimate in a harmonised manner (technical and economic) energy savings potentials for each EU27 Member State, as well as for Croatia and for other countries of the European Economic Area EEA (Norway, Iceland and Liechtenstein)."
- "To develop a tool to assess national NEEAPs and to ascertain if they sufficiently take into account the existing energy savings potential within a country, and to identify the sectors where the national savings targets established under the ESD Directive can be met most cost effectively.

**Methodology of the analysis**

"The project and the central part of the evaluation of energy efficiency and energy savings potentials at the demand side is based on the bottom-up ***MURE simulation tool***. MURE (Mesures d'Utilisation Rationnelle de l'Énergie, www.mure2.com) has a rich technological structure for each of the four demand sectors (residential, transport, industry and services) in order to describe the impact of energy efficient technologies. The structure described in a technological manner in MURE comprises modules for:

- Residential Sector Buildings
- Residential Electric Appliances
- Transport Sector
- Industrial Sector: Processes
- Industrial Sector: Electric Cross-cutting Technologies (pumps, ventilators, compressed air…)
- Service Sector Buildings
- Service Sector Electric Appliances
- IT Appliances (all sectors)
- Demand-side CHP (all sectors)"

The study "also determined the potentials for decentral renewables such as solar thermal collectors and decentral

38. Text quoted directly from pp.1-8 of the report

PV". It "used the **Green-X model** run by TU Vienna in co-operation with Fraunhofer ISI" for this purpose.

The main focus of the work was on the final demand sectors.

Biofuels used for the transport sector where not taken into account although they may potentially reduce greenhouse gas emissions.

The approach "developed a flexible and user-friendly database which:

(i) gathers the data inputs (scenario data and technology data) for communication with the MURE simulation model and

(ii) allows for a suitable presentation and structuring of the main model inputs and results concerning the analysis of energy saving potentials for external communication purposes. This database was developed based on the current input/output structures of the MURE demand simulation model".

The approach "developed an interface that allows feeding data to the two input databases and the output database."

"... Concerning the technology database behind the potentials this relies mainly on updated information in the MURE simulation tool, on further national sources and on the Odyssee database, supported by additional information from auxiliary sectoral models such as the residential model run by the Wuppertal Institute or an industrial model run by Fraunhofer ISI."

"Concerning the scenario inputs the study made use of the official projections and statistical data available at both the EU and the national levels although adaptations needed to be considered. However, they limited these adaptations to data not available in the PRIMES model used for the official EU projections in order to remain compatible with the PRIMES approach, despite the fact that one or the other figure in the official projections could give rise to substantial debate (such as for example the future development of transport mobility which, in their view, appears largely overestimated). The Odyssee database was used as an essential tool to calibrate future scenario data as well as social drivers such as increased comfort factors, general rebound effects etc."[39]

**Reference scenario**

"In order to ensure compatibility with official DG TrEn projections, it was decided to rely for this exercise on the choices of drivers of the baseline scenario calculated with the PRIMES model. From these projections drivers such as the number buildings, energy prices, the development of value added of industry etc was chosen in order to be consistent with these projections. However, the future development of unit consumptions, intensities etc. was allowed to evolve according to the knowledge implemented in the MURE model."[40]

**Policy Scenario's considered:**

The Fraunhofer *et al.* study considered 5 different scenarios which differ by "policy intensity":

(i) "Autonomous Progress Scenario APS (which comprises autonomous progress and earlier policies such as the labelling Directives for electric appliances but excluding the success of important recent EU policies which [at the time of the study were] not yet fully implemented such as the EU Performance Directive for Buildings and the $CO_2$ standards for cars and light duty commercial vehicles).

(ii) "A variant of the Autonomous Progress Scenario which includes the success of these recent policies (APS+RP).

(iii) "Low Policy Intensity Scenario LPI (which implies continued high barriers to energy efficiency, a low policy effort to overcome the barriers and high discount rates for investments in energy efficiency).

(iv) "High Policy Intensity Scenario HPI (which implies removing barriers to energy efficiency, a high policy effort to overcome the barriers and low discount rates for investments, options are economic on a life cycle basis).

(v) "Technical Scenario (includes also more expensive but still fairly realistic options; no exotic technologies)"[41].

Energy prices, consumption growth and discount rates in the autonomous progress scenarios are set in line with the PRIMES analysis of the Commission carried out in 2008. These are generally conservative estimates. For instance, oil prices in 2030 are assumed to be at just 62USD2005/barrel of oil equivalent, gas prices in 2030 are 47.6USD2005/barrel of oil equivalent, and coal prices remain at 14.9USD2005/boe in 2030. Social discount rates are usually high (at 15% or more in the baseline scenarios but lower (5-10%) in the enhanced policy scenarios.

***Energy efficiency potentials***

"In 2020 the LPI potentials may reach 158 Mtoe for the EU27 (15% compared to APS); in 2030 244 Mtoe (22% compared to APS) are achievable in economic terms.

"In 2020 the HPI potentials may reach 248 Mtoe for the EU27 (22% compared to APS); in 2030 405 Mtoe (33% compared to APS) are achievable in economic terms.

"In 2020 the Technical Potentials may reach 336 Mtoe for the EU27 (29% compared to APS); in 2030 565 Mtoe (44% compared to APS) are achievable."[42]

39. Ibid, p.5

40. Ibid p.6

41. Ibid, p.8

42. Ibid, P.9

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Climate Strategies is a leading independent, international research organisation based in the UK. Through our network of global experts, we assist governments and industrial stakeholders around the world in developing climate change and energy policies. We are a not-for-profit organisation with all our activities funded through a broad spectrum of governments, businesses and foundations.

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