Quantifying the impacts of a 30% GHG target on energy security for the EU

Is there a case for the EU to move beyond 20% GHG emissions reduction by 2020?

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**IS THERE A CASE FOR THE EU MOVING BEYOND 20% GHG EMISSIONS REDUCTION TARGET BY 2020?**

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# Table of contents

1 Introduction .............................................................................................................................................. 3  
2 Methods .................................................................................................................................................. 4  
3 Security of primary energy supply: vulnerability indicators ............................................................. 10  
4 Security of primary energy supply: outcome indicators .................................................................... 17  
5 Security of the electricity grid .............................................................................................................. 20  
6 Conclusions ........................................................................................................................................... 22  
7 Reference sources ................................................................................................................................. 24  
8 Appendix ............................................................................................................................................... 25
1 Introduction

Climate change and energy security are closely related. In the EU, almost 80% of greenhouse gases come from the use of energy (EEA 2010). Moving towards a 30% GHG reductions target will alter the structure of energy consumption in the European Union and this will have implications on the security of its energy supply.

This section looks at the impacts of a new GHG target on energy use in the EU and at the Member State level. To compare across scenarios, we will use a set of quantitative indicators that will provide a benchmark for energy security impacts under business-as-usual and a 20 and 30% scenario.

1.1 The concept of energy security

Security of supply has traditionally been an issue of import dependence, both in terms of the quantities of energy imported but also the source of imports. While, in and of itself, trade in energy is not an issue, trade increases exposure to external risks. In 2007, the EU imported approximately 83% of its oil and 60% of its natural gas and a large majority came from states with high levels of geopolitical risk (European Commission 2010). Russia, Libya, Saudi Arabia and Iran are large suppliers of energy to the EU. High on policy-makers agendas are the risks that emanate from the politically unstable Middle East and Russia.

While import dependency is at the forefront of energy security concerns, the concept of energy security is now more broadly defined to include factors beyond direct geopolitical risks. This includes welfare factors like affordability and access to energy. Recent EU legislation has also emphasized the importance of securing minimum standards for the performance of energy infrastructure like gas transmission networks (European Commission 2009).

Taking into account the wide variety of interpretations there are of energy security, this report will evaluate a set of quantitative indicators to understand the impacts of moving to a 30% GHG reductions target. The indicators will show an overview of the energy security implications and allow us to compare across policy scenarios.
2 Methods

Assessments on energy security to date have been widely left at the hands of qualitative expert judgment. Quantitative indicators, while still imperfect, can be used to present a comprehensive, structured framework that allows for comparison across scenarios. Several indicators were selected that looked at energy security from a systemic perspective, focusing on how a 30% GHG target would change the structure of the energy system.

In order to perform a quantitative assessment, energy security needs to be defined explicitly. We defined energy insecurity as the loss of welfare resulting from a change in the price and/or the physical availability of energy. The risk of energy insecurity can be measured by looking at the vulnerabilities in the energy system and determining how they would alter outcomes (Greenleaf & Harmsen, 2009). These outcomes can include, for example, a physical disruption in the delivery of natural gas. Outcomes always carry a welfare impact (cost).

We grouped indicators into two types which can be defined as follows:

**Vulnerability-based indicators** measure inputs that can be considered a proxy for the potential risk and/or magnitude of an energy security impact should it actually occur. An example is ‘import dependency’ which can indicate the vulnerability of the energy system to an interruption of supply.

**Outcome-based indicators** measure the actual welfare impact of energy insecurity. These will be assessed using scenarios to understand how welfare would change should an energy security event take place. An example of an outcome indicator is the cost of a power outage.

To sum up, vulnerability indicators measure the risk or vulnerability to an adverse outcome and outcome indicators measure actual welfare impacts. Using these two types of indicators, we analysed the implications of a 30% GHG target on energy security. Energy security impacts were grouped into those affecting the security of primary energy supply and those affecting infrastructure, most notably in the electricity system. For security of primary energy supply, the following indicators are used:

**Vulnerability-based indicators**
- Energy intensity of economy
- Changes in fuel mix
- Country dependency on imports
- Resource concentration/market power of suppliers

The outcome-based indicators measure the actual welfare impact of energy insecurity. These are assessed using scenarios or historical data from an energy security event. In our case, we used scenarios for fuel prices. We will see how the following might be impacted:
Outcome-based indicators

- Energy costs to the transport sector
- National energy costs related to GDP

Another type of energy security impact would come from the effects of climate policy on infrastructure. Changing targets for renewable energy and energy efficiency will alter the behaviour of actors that own and operate energy infrastructure. This will change the risk profile of the energy system.

Indicators for vulnerabilities and outcomes for energy security risks stemming from infrastructure impacts were examined. These were as follows:

Vulnerability-based indicators

- Capacity factor

Outcome-based indicators

- Costs of an outage

2.1 Modelling approach

Projections for energy demand and supply were needed to assess the energy security indicators. The scenarios compared were: business-as-usual, -20% GHG and -30% GHG reductions. This was done using a model developed by Ecofys to analyse impacts of different quantitative targets on EU Member States (Höhne et al. 2008). The model is a bottom-up model of the five largest energy consuming sectors: power generation, residential, services & agriculture, transport and industry for the 27 EU Member States. The model has the capability to make projections at the EU and Member State level for energy demand. It uses current trends based on the PRIMES 2009 projections and applies policy scenarios to arrive at GHG, renewable energy or energy efficiency targets.

There are three general mitigation approaches in energy-consuming sectors: renewable energy, carbon capture and storage (CCS) and reductions in fossil energy demand. As the model focuses on the implementation of the RE and the energy efficiency (EE) targets, CCS is not included as an option. The high uncertainty that exists with the immature CCS technology and the long time frames for the construction of CCS infrastructure support our assumption that no significant CCS capacity will be built by 2020. Even if stringent reduction targets were enacted today, many technological, political and economic barriers remain (Haszeldine 2009). Instead, mitigation is achieved in the model by displacing fossil fuels with renewables and decreasing energy consumption through higher energy efficiency targets.

2.1.1 Business-as-usual

The business-as-usual scenario is based on the energy data from the PRIMES 2009 baseline published by DG Energy and maintained by the University of Athens (Capros et al. 2010), which is made consistent with GHG emission inventories of EU Member States and complemented by non-energy projections. The baseline of our model shows a GHG emissions decrease of 12% compared to 1990 by the year 2020 which is attributed in part to the effects of the economic recession. It is important to highlight that due to the
recession, the baseline has significantly shifted and GHG targets will now be much easier to reach, mostly by enforcing existing policies and measures\(^1\).

### 2.1.2 20% GHG reductions

The 20% GHG reductions scenario assumes that the renewable energy (RE) targets as mentioned in the Climate and Energy Package are achieved. Member states all meet their obligations under the renewable energy directive and the EU achieves the 20% RE target by 2020.

The effects of the RE target and the decreases in energy demand as a result of the economic recession mean that the 20% GHG target can be met with little additional effort. For the EU 27, an average decrease of 4% in energy demand over business-as-usual was enough to reach the -20% GHG target.

### 2.1.3 30% GHG reductions

The 30% scenario also assumes that the 20% RE target is reached by 2020. To decrease emissions by 30% from 1990, additional efforts in reducing energy demand are required. The model signals that a decrease of 15% in energy consumption over the model’s business-as-usual was necessary to reach the 30% target. The 15% reductions needed to arrive at the 30% target were split evenly among the member states and sectors, i.e. each sector has to reduce its energy consumption by 15%.

<table>
<thead>
<tr>
<th></th>
<th>BAU</th>
<th>-20% GHG</th>
<th>-30% GHG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GHG emissions compared to 1990</strong></td>
<td>-12%</td>
<td>-20%</td>
<td>-30%</td>
</tr>
<tr>
<td><strong>RE share</strong></td>
<td>14% of total energy use</td>
<td>20% of total energy use</td>
<td>20% of total energy use</td>
</tr>
<tr>
<td><strong>Decrease in energy demand over BAU</strong></td>
<td>0%</td>
<td>4%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 1 GHG emissions under different scenarios

### 2.2 Sectoral overview of impacts from 30% scenario

This section shows an overview of how five industry sectors were affected by changing to a 30% target in our model. The level of energy consumption and the composition of the fuel mix are shown in the figures below.

\(^1\) In the model, full compliance with the 20% RE target and a 4% improvement in energy efficiency were enough to reach the -20% GHG target.
In the energy industry, renewable electricity displaces generation from fossil sources. The share of RE expands to 25% of the total electricity supply in the -20% GHG scenario. RE targets have the greatest impact in the energy industry and most investments in RE are in renewable electricity. Under a 30% scenario, improved efficiency of power plants leads to decreases in total fuel consumption. At the same time, decreases in electricity demand from the residential, services and industrial sectors accentuate the decrease in fuel consumption for the energy sector.

For the industry sector, renewables also expand, mainly through an increased use of biomass and waste in CHP and industrial boilers. The 30% scenario leads to decreases in total energy consumption due to higher energy efficiency targets.
For the residential sector, the RE target leads to increases in the use of biomass for residential heating. The 30% target leads to further decreases in energy consumption due to higher efficiency standards. In the services and agriculture sector, RE increases due to increased use of biomass and waste.

The transport sector has a much more limited ability to increase the share of renewables. In the 20% scenario, biofuel use increases only marginally and the level of total fuel consumption stays relatively the same. Under a 30% target, higher energy efficiency standards lead to reductions in oil consumption.
The split of energy sources among industry sectors in the 30% scenario affects the profile of energy demand and the energy mix.

- The energy sector sees a large increase in renewables due to the 20% RE target which is largely met through new renewable electricity capacity.
- Residential and transport sectors have very little reductions in energy demand under the 20% scenario. Due to EE measures, the 30% scenario has higher reductions. This contributes to energy security.
- The reduction of oil use in transport is very significant for energy security.

There is very small potential for RE to make a difference in transport.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Change in emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy industry</td>
<td>-36%</td>
</tr>
<tr>
<td>Industry</td>
<td>-26%</td>
</tr>
<tr>
<td>Transport</td>
<td>-15%</td>
</tr>
<tr>
<td>Households and services</td>
<td>-22%</td>
</tr>
</tbody>
</table>

The sector with the largest capacity to reduce emissions is energy industry followed by the industrial sectors. Energy industry could make large improvements in energy efficiency and has a high potential to incorporate the use of renewables. The energy industry also benefits from reductions in energy consumption in other sectors.
3 Security of primary energy supply: vulnerability indicators

Mitigation actions in the scenarios modelled lead to a decrease in the total amount of energy use or change the mix of the energy supply. This has impacts on energy security. This section will present several energy security indicators that measure the vulnerabilities in the energy system.

3.1 Energy demand

Mitigation actions to reach the 30% target will decrease energy consumption. This will happen either through technical means e.g. increasing the efficiency of combustion engines or through structural shifts in economic activity towards activities that are less energy-intensive.

In the modelled scenarios, the 20% GHG target could be met with a combination of measures. One is full compliance with the 20% RE target and second, through a decrease of 4% in energy consumption. Meeting the 30% target required more ambitious reductions in energy consumption to 15% below the post-recession BAU. The energy demand index (Figure 4) shows the changes in energy demand for the BAU, a 20% scenario and a 30% scenario for all Member States. This is indexed to energy consumption in 2005.

![Energy demand index in 2020](image)

The energy demand index shows how the vulnerabilities of different member states would change respective to 2005. From an energy security standpoint, decreasing energy consumption leads to improvements in security. Energy efficient countries are less vulnerable to swings in energy prices and the negative effects these have on economic activity.
3.2 Fuel mix

Diversification of the energy supply will hedge against supply disruptions that may arise due to a geopolitical event or a physical disruption. A physical disruption includes any accident, failure or stoppage (intentional or otherwise) that would disrupt the delivery of energy.

Fuels have different risk profiles which are affected by the concentration of suppliers in the market and their political stability (International Energy Agency 2007). Mitigation actions to reach the different targets will change the fuel mix, impacting energy security. These actions can include switching from solids to natural gas in electricity generation, switching fuels in transport and increasing the share of renewable energy sources.

In our modelled scenarios, there were two trends which contributed to changes in the fuel mix. One is an increase in renewables in the share of total energy supply due to the 20% RE target. The other is increasing energy efficiency in line with higher GHG targets. Figure 5 shows how the share of each fuel changes at the EU level for the 20 and 30% scenarios compared to business-as-usual for the year 2020.

![Figure 5](image)

**Figure 5**  
Change in fuel demand over BAU for EU 27 in 2020

### 3.2.1 20% scenario

The 20% target is reached mainly through an increased expansion in renewables. Solids (coal and lignite) and gas consumption decrease significantly due to the increased share of renewable electricity. The small improvements shown for oil are a result of marginal energy efficiency improvements and a limited growth in the use of biofuels. The move to a 30% target results in larger gains as more aggressive EE efforts are undertaken. One such effort would be increased fuel efficiency standards for automobiles which has a strong impact on oil consumption. Electric vehicles were not included in the model. However, a wide spread adoption would impact our results. Consumption of gas, solids and renewable electricity would rise in proportion to the increased demand in electricity for automobiles and oil consumption would decrease.

### 3.2.2 30% scenario

In the 30% scenario, we see an even larger impact on solids and gas consumption. The main drivers are greater efforts in energy efficiency which directly contribute to a
decrease in the consumption of all fuels. Coal and lignite use decreases as energy efficiency gains at power plants are accentuated by reductions in electricity demand from the residential and industrial sectors.

The large decrease in oil consumption is due to energy efficiency improvements. This is an important benefit because oil use in transport presents among the highest energy security risks. In the calculations for the ‘Energy Security Index’, which are shown in a section below, oil has the highest risk out of all fuels. The index is composed of two main components. One is an indicator for market concentration and the other for political stability. Oil ranks badly in both. Therefore, decreasing oil consumption has strong energy security benefits.

**Implications**

- The RE target does little to reduce dependence on oil – mostly solids are replaced which are available domestically. Diversification is not achieved in the transport sector unless there is a large scale deployment of breakthrough technologies i.e. widespread-adoption of electric vehicles.
- EE targets are better for energy security regardless of how the EE target is reached. The EE target reduces the demand for all fossil-fuel sources.

**3.3 Import dependency**

One of the most frequently used metrics for energy security is the ‘dependency of a country on oil and gas imports’. However, in order to more accurately determine the level of energy security, additional information is required to differentiate between supply sources. Two large oil suppliers to the EU are Norway and Russia. Looking exclusively at import dependency would not capture the differences in geopolitical risk between these two trading partners. Trade in energy can even increase energy security as it can help secure supply should a natural disaster or other event bring a physical disruption to domestic supplies. Nonetheless, the import dependency metric is widely used and can act as a proxy for the potential exposure of a country to external and geopolitical disruptions.

We calculated import dependency by taking projections on domestic production and subtracting gross inland consumption per fuel. Supply projections are based on PRIMES 2009 baseline estimates in the year 2020.

Figure 6 shows projected import levels of oil & gas in the year 2020 under a BAU and a 30% GHG reduction scenario. This figure allows us to compare the level of imports to the importance that these resources play in gross inland consumption (GIC). When viewed in combination, variables on the chart’s axes (% of oil and gas in gross inland consumption and dependence on oil and gas imports) serve as proxies for determining the vulnerability of the energy system to supply disruptions. The four lines drawn provide a benchmark for risks to the physical availability of oil and gas. A country with a high level of imports and high share of oil & gas in GIC carries the highest risk. On the other end of the scale would be countries with either very little imports or a small share of oil & gas in GIC.
The countries of Malta and Cyprus sit in the top right of the chart. Without any indigenous energy resources other than solar power, they rely almost entirely on imported fuel for their energy supply. At the opposite end of the spectrum is Denmark which is a net exporter of oil and gas. Although Denmark utilizes oil and gas for about 58% of its primary energy supply, the country is self-sufficient in energy. It is important to note that self-sufficiency does not address all of the energy security risk faced by a country. Households and industries would still be exposed to price fluctuations in the international oil and gas markets.

In the two scenarios shown, movement across the x-axis indicates overall reductions in oil and gas consumption. Movement up the y-axis shows diversification of the primary energy supply, mainly through the use of renewables.

For the majority of countries, moving to a 30% target presents clear benefits in reducing import dependency and decreasing reliance on oil and gas. However, there are some countries which actually see their risk increase. Poland has a high reliance on solids for electricity generation. Meeting the 30% GHG target would imply decreasing the share of coal-fired power plants and increasing the share of natural gas generation. The majority of this fuel would need to be imported and this negatively affects the energy security of the country. As we mentioned before, import dependency is not necessarily negative, more important is the source of these imports. The negative impacts to Poland can be abated through strong EU legislation in favour of regional transmission networks which would connect Poland to a wider European market.

Figure 6 Import dependency risk (lines show equal risk, i.e. oil and gas consumption times dependence of imports)
3.3.1 Regional perspective for natural gas

The EU has increased its emphasis on regions for meeting security of supply standards. In this paper we focus on gas import dependency for two regions in the Gas Regional Initiative (GRI). The GRI is an initiative by the Council of European Energy Regulators (CEER) which acts as a stepping stone towards a single European gas market (CEER 2010). The demarcation of regions in the GRI has been suggested as a starting point for future regional regulation (European Commission 2009).

The GRI regions represent areas of integrated gas markets and transmission networks. Assuming that gas can easily flow from one Member State to another within the region, we can consider import dependency at the regional level.

Using the 30% Equal Effort Scenario presented above, we grouped Member States into their GRI regions and analysed reliance on imported gas. The level of gas consumption, the amount of production and the level of imports were aggregated for all countries in the region. A region was modelled to act like one market and gas could flow seamlessly between Member States in the region. Thus, import reliance could be assessed at a regional level.

Currently, the North-West Region is less reliant on imports due to the gas fields in the Netherlands, the UK and Denmark. The South-South East region has several Member States with domestic gas production. However, this is on a much smaller scale. Consider that the largest gas producer in the region is Germany but its total yearly level of production is about 1/5th of that in the Netherlands. Thus the South-South East region is significantly more import-dependent under all scenarios.

Reliance on imports decreases under both the 20% and 30% target. Under the 20% scenario, imports mainly decrease due to the expansion of renewables in electricity generation. In the 30% scenario, the decrease is due to higher energy efficiency standards. The use of renewables is assumed to stay constant for the 20% and 30% scenarios and in line with the 20% RE target.

The North-West region sees larger reductions in gas imports under the 30% target relative to the countries in the South South-East region. This is due to the high share of coal and lignite in primary energy supply in Poland, Bulgaria and the Czech Republic. Higher GHG targets would entail shifts from coal to gas for electricity generation.
Although, electricity consumption decreases significantly in these countries due to EE measures, fuel shifting in power generation moderates this impact on natural gas demand.

Improving energy efficiency in the electricity and heating sectors and increasing interconnections, storage and transmission capacity between regions is a clear way to improve the security of natural gas supply.

3.4 Energy Security Index

There are risks that stem from the profile of energy suppliers which are not evident from assessing the fuel mix and imports alone. The Energy Security Index (ESI) provides a method for such an assessment. It was developed and used by the IEA to quantify the energy security impacts of climate policy (International Energy Agency 2007).

There are two components in the index; one is resource concentration and the other is political stability. Resource concentration is measured by a method based on the Herfindhal-Hirschman Index (HHI) used in competition law. It is calculated by taking the share of each supplier in the market, squaring it and obtaining the sum. The index value ranges from 0 for a perfectly competitive market to 10000 for a pure monopoly ($100^2$). Additional detail on the methodology is provided in the Appendix.

The other component of the Energy Security Index is political stability of supplier countries. This is quantified using the World Bank governance indicators of Political Stability, Absence of Violence and Regulatory Quality to build a political stability index (PSI). The index is normalized across all countries and given a range from 1 to 3, where the higher value indicates higher risk. The PSI serves as a modifier for the resource concentration score and altogether forms the Energy Security Index. The highest score that could be obtained if the market was a complete monopoly and the supplier was extremely unstable politically would be 10000 * 3 or 30000.

A composite index for the entire fuel supply of a country is calculated by taking the ESI score for each fuel type and multiplying it by the share of each fuel in the Total Primary Energy Supply and taking the sum.
The results for the EU and selected member states are shown in Figure 3. The line shows the index under a BAU, a 20% GHG reductions scenario and both 30% scenarios. The index changes as a direct result of decreased energy demand with higher GHG targets. It also changes as a result of switching from more risky to less risky fuels and vice versa. For example, oil has a score of 9369 and gas 4934. At the same time, switching from coal to gas would increase the score. Coal has a score of 2979.

Going from the 20% target to a 30% GHG target slightly increases the ESI score for the European Union. The main reason is the substitution of natural gas for coal in electricity generation, where the supply of gas is less secure than the supply of coal. Figure 3 shows the ESI score for the EU 27, Sweden and Poland. The two countries were chosen because they provide a good example of how their domestic energy profile interplays with the different EU targets. Sweden has a high percentage of energy supply from renewables and nuclear which do not carry energy security risks under this index. Because of this, Sweden has the lowest score in the EU. Moving to a 30% target further decreases its risk because consumption of fossil fuels decreases. Poland, which currently has a high reliance on coal, is negatively affected by the substitution of coal for gas.

Figure 3 Energy Security Index for the EU and selected member states.
4 Security of primary energy supply: outcome indicators

The energy security outcome indicators show the welfare impacts of the different GHG targets. This was done with scenarios for energy prices to see how different Member States and sectors would be affected by a 20 and 30% target.

4.1 Energy costs in the transport sector

We first consider the case of oil in the transport sector. We estimated that reductions in energy demand in the order of 15% would be needed to reach the 30% GHG target. Energy security in the transport sector would benefit strongly from this trend. We projected oil demand in the transport sector by Member State under a 30% GHG target. In 2020, oil demand in the transport sector dropped by 49 Mtoe per annum for the EU 27 compared to the 20% scenario and 59.5 Mtoe compared to business-as-usual. To see the welfare implications of going to a 30% target, we ran several scenarios for oil prices in 2020 to see the additional savings that a higher target would bring.

Oil prices were modelled as scenarios based on several benchmark values. The outliers were the high and low prices of 2008, the year with highest volatility in recent history. The high price in 2008 was US$ 145/bbl and the low price was US$30.28/bbl. Our median price was US$ 108 per barrel, the projection by the US EIA for 2020 (Energy Information Administration 2010). As a margin of error we used one standard deviation from the median price. The standard deviation is equal to the observed average annual volatility of the oil price in the years 1970-1996 which is ± 20.6% (Pindyck 1999).

<table>
<thead>
<tr>
<th>US$/Barrel 2008</th>
<th>EIA</th>
<th>-1STD DEV</th>
<th>+1STD DEV</th>
<th>High 2008</th>
<th>Low 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>108</td>
<td>86</td>
<td>131</td>
<td>145</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 4 shows annual savings in billions for the EU transport sector in the year 2020. The graph depicts the additional savings of going from the 20% target to a 30% GHG target. The dotted line represents the range between the outliers in the price of oil. The box represents most-likely values. The red line shows the median. The median savings in oil costs for the transport sector of going to a 30% target were €28.5 billion per year and most-likely values were between €23 and €34.5 billion.

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1 euro = 1.3 USD
At the Member State level, large oil consumers stand to gain from energy savings in transport. France, Germany, Italy, Spain and the UK have median savings of between €3 and €4.7 billion per year (Figure 5). These figures do not represent the avoided costs for private drivers. These numbers show the costs before energy taxes. In Europe, petrol and diesel are taxed at a high rate so there would be additional savings for individual drivers.

Figure 4 Savings in oil costs in transport sector for EU 27 in 2020

Figure 5 Savings in oil costs in transport for member states in 2020, difference between the 20% and the 30% target
4.2 Fossil energy costs related to GDP

The last outcome indicator is ‘energy costs in relation to GDP’. Estimates for GDP are based on the 2009 PRIMES projections for the year 2020. Coal, gas and oil prices are also based on PRIMES which provides high and low fuel price scenarios. Renewable energy is not included in our calculations due to the uncertainties in estimating costs for future RE technologies. Nuclear electricity prices were also not considered. Figure 6 shows the total fossil fuel costs compared to GDP.

Figure 6 EU 27 fossil energy costs as a share of GDP
5 Security of the electricity grid

5.1 Vulnerability indicator: capacity factor

The electricity sector will be one of the main sectors affected by higher GHG targets. Regardless of the emissions target, the electricity sector will have to meet mandates on renewable energy and energy efficiency. This will have an impact on both the scale and the type of electricity capacity investments. The degree of which is difficult to assess because there are many dynamic factors which could contribute and change the structure of the electricity system. Due to the difficulties and confidentiality issues in obtaining projections for capacity investments under various climate policy scenarios, it is most appropriate to evaluate this indicator qualitatively.

One consideration is that the large-scale introduction of intermittent generation will change the shape of wholesale electricity prices with more frequent periods of low prices (Greenleaf and Harmsen 2009). This will impact on the behaviour of investors, and the economics of power plants. This uncertainty regarding future changes to electricity prices has the potential to decrease return on investments and lower new investments in generating capacity. This effect could have the impact of decreasing capacity margins which would negatively impact energy security and increase the risk of an outage. The level by which this would risk would increase between the 20 and 30% scenarios is hard to judge.

The International Energy Agency estimates in the next 20 years, Europe will need to invest 2 trillion euro in new capacity and transmission networks (IEA 2008). This is the business-as-usual scenario. Given that new GHG targets will change the mix of generation required in 2020 and beyond, a significant amount of additional investment will be needed compared to business-as-usual (e.g. where existing assets can be run as standard to end of life). The scale of the investments required combined with a post-crisis financial landscape may complicate financing for projects, in particular for renewable energy as it is more capital intensive compared to other technologies. The largest component of the levelised cost of generating renewable electricity is its large sunk costs and the discount rate. This makes renewable investments more risky and sensitive to financing constraints. On the other hand, because there are no fuel inputs, the operating costs are relatively low.

We have seen that reaching the 30% target would require large improvements in energy efficiency. In our modelled scenarios, the average efficiency of the European generating portfolio would need to improve by 3%. Reaching this target would require the decommissioning of plants before end-of-life and switching to other technologies, particularly natural gas. Investments in new gas plants would depend on developments in the natural gas market and the volatility of the price. Large uncertainties in the natural gas market would have a negative impact on capacity margins.

A key factor that affects investments in electricity capacity is policy uncertainty. The EU ETS brings new risk to electricity investments by introducing a large variable cost
component in the cost of CO₂ permits. This is in addition to the risk utilities already face with fuel and electricity price volatility. Uncertainty over the demand and supply of allowances is expressed through the price of EUAs. In 2006, the price of EUAs crashed due to the EU prematurely releasing demand data. Changing to a 30% target will impact the levels of EUAs available in the market. The 30% target can act to support the market with guarantees that the market will be short in the long term.

5.2 Outcome indicator: cost of an outage

A possible outcome based indicator for the security of the electricity supply would be the costs of an outage. Interruption of the power supply has an economic cost for business and consumers. The scope of this project did not allow the quantitative evaluation of this indicator. It is hard to judge to date, how more stringent GHG reductions would affect this indicator.
6 Conclusions

There are two general trends that will drive the transformation of the EU energy system in response to climate policy. One is the movement towards renewable energy and the other is increased energy efficiency. The renewable energy target component of the climate and energy package does little to reduce dependence of the EU on foreign oil – mostly solids are replaced which are available domestically. Fuel diversification is not achieved in the transport sector unless there is a big breakthrough in low carbon technology development and deployment i.e. widespread-adoption of electric vehicles. The energy efficiency targets are better drivers of energy security regardless of how the target is reached. The energy efficiency target reduces the demand for all fossil-fuel sources. Table 3 provides an overview of the impacts of climate policy on energy security for EU 27 for the indicators evaluated in this report.

More ambitious GHG emission reductions generally increase the security of primary energy supply. They lead to decreases in energy demand, diversify the fuel mix and require fewer imports. The energy security index shows an indifferent trend, since it values the switch from the relatively secure fuel coal to the relatively less secure fuel of gas as an increase of risk.

The security of electricity supply may be affected negatively by emissions reduction measures if not countered by additional measures. Due to the intermittent nature and specific technical challenges of wind and solar, the flexibility of the grid has to be enhanced. Due to the faster change, the investment in new capacity has to be ensured.

In short, we show that more ambitious GHG emission reductions generally increase the security of primary energy. The potentially increased risk of the electricity supply has to be countered with measures to support the electricity system.
Table 3 Summary of impacts of climate policy on energy security for EU 27

<table>
<thead>
<tr>
<th>Security of primary energy supply</th>
<th>Vulnerability-based</th>
<th>Outcome-based</th>
<th>Security of electricity grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy demand</td>
<td>Positive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand</td>
<td>-4% from BAU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversity of fuel supply</td>
<td>Positive</td>
<td>Oil Demand -1%</td>
<td></td>
</tr>
<tr>
<td>Diversity of fuel supply</td>
<td>-13% from BAU</td>
<td>Gas -13% from BAU</td>
<td></td>
</tr>
<tr>
<td>Diversity of fuel supply</td>
<td>-20% from BAU</td>
<td>Coal -20% from BAU</td>
<td></td>
</tr>
<tr>
<td>Diversity of fuel supply</td>
<td></td>
<td>Oil Demand -12%</td>
<td></td>
</tr>
<tr>
<td>Diversity of fuel supply</td>
<td></td>
<td>Gas -27% from BAU</td>
<td></td>
</tr>
<tr>
<td>Diversity of fuel supply</td>
<td></td>
<td>Coal -34% from BAU</td>
<td></td>
</tr>
<tr>
<td>Resource concentration/market</td>
<td>Mixed</td>
<td>-4% Reduction in ESI from BAU</td>
<td></td>
</tr>
<tr>
<td>concentration/market power of</td>
<td></td>
<td>-2% Reduction in ESI from BAU. Increase of 2% from 20% scenario</td>
<td></td>
</tr>
<tr>
<td>suppliers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependency on gas &amp; oil imports</td>
<td>Positive</td>
<td>-2.6% from BAU</td>
<td></td>
</tr>
<tr>
<td>Dependency on gas &amp; oil imports</td>
<td>-3.4% from BAU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil costs in transport</td>
<td>Positive</td>
<td>-0.4% over BAU</td>
<td></td>
</tr>
<tr>
<td>Oil costs in transport</td>
<td>----</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil costs in transport</td>
<td></td>
<td>€28.5 billion in savings from 20% scenario</td>
<td></td>
</tr>
<tr>
<td>Oil costs in transport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fossil energy costs related to</td>
<td>Positive</td>
<td>-0.4% over BAU</td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td></td>
<td>-0.9% over BAU</td>
<td></td>
</tr>
<tr>
<td>Fossil energy costs related to</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insufficient capacity margin</td>
<td>Negative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insufficient capacity margin</td>
<td>Not quantified</td>
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<td></td>
</tr>
<tr>
<td>Cost of an outage</td>
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<tr>
<td>Cost of an outage</td>
<td>Not quantified</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Median value, 1 US$ = € 1.30
4 Median value w/PRIMES 2009 energy price assumptions
7 Reference sources


EEA. 2010. Tracking progress towards Kyoto and 2020 targets in Europe. Europe.


8 Appendix

8.1 Methodology - energy security index

The market power of energy suppliers can be quantified using an index derived from competition law. The US Federal Trade commission uses the Herfindhal-Hirschman Index (HHI) as a method to measure market concentration. It is calculated by summing the squares of the individual market shares of all participants. The IEA and Ecofys used an indicator based on the HHI called Energy Security Market Concentration (ESMC) in a study of the impacts of climate policy on energy security (Lefevre 2007, Greenleaf et al. 2009). It uses the HHI as a basis to look at the market concentration of different supplier countries so that:

\[ ESMC = \sum S_i^2 \]

Where \( S_i \) is the share of each supplier \( i \) in the market of fuel \( f \) defined by its net export potential. \( S_i \) varies from 0 to 100 percent. A perfectly competitive market would have a score of 0 and a monopoly, a score of 10 000.

8.1.1 Political stability

An aspect that has to be considered is that not all supplier countries are the same. The political stability of supplier countries will affect energy security risks. This can be taken into account using the World Bank governance indicators. The World Bank has maintained a set of indicators since the 1990’s which give governance scores to countries. The IEA used Political Stability, Absence of Violence and Regulatory Quality to build a composite political stability index with a range of 1 to 3, where the higher score indicates a higher degree of risk (International Energy Agency 2007). Scores for political stability were complied by Ecofys in 2009. The scores of supplier countries ranged from 1.3 for Norway to 2.4 for Nigeria. These index scores were also used for this assessment.

Political stability scores can be used as a multiplier for ESMC; where, the highest score that could be obtained if the entire market was supplied by one country and the country was extremely unstable politically would by 3 times 10 000, so 30 000.

Now that we have a method to measure the risk from market concentration and political stability, we have to assess how individual countries are exposed to this risk. This will depend on the role that each fuel plays in a country’s economy where the higher the share of a fuel in primary energy supply, the higher the risk.

8.2 ESI

A composite score for the Energy Security Index (ESI) can be obtained by multiplying the ESMC adjusted for political stability times the share of each fuel in the total primary energy supply and summing this score for all fuels. This will provide one number that allows us to compare across scenarios.
\[
ESI_{\text{price}} = \sum_f ESMC_{\text{pol-f}} \times \frac{C_f}{TPES}
\]

Where \(\frac{C_f}{TPES}\) is the share of each fuel in energy supply and \(ESMC_{\text{pol-f}}\) is the energy Security Market Concentration in the international market for fuel \(f\) (International Energy Agency 2007).

There are some assumptions inherent in these calculations that should be considered. One is that this indicator does not take into account the country’s own share in the fuel market. For example, Denmark is a net energy exporter and this indicator would not take this fact into consideration. However, we can consider the fuel market to be international and fungible so a supply disruption in one part of the world will have consequences for energy prices. Although Denmark could turn to domestic sources should a supply disruption occur, Danish consumers would bear the consequences of increased energy prices, even if Denmark is a net energy exporter.