Metastudy Analysis on 2050 Energy Scenarios

Policy Briefing

SEFEP working paper 2012-5

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July 2012

smart energy for europe platform

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SEFEP

SEFEP, the Smart Energy for Europe Platform, is an independent, non-profit organisation founded by the European Climate Foundation and the Stiftung Mercator. Based in Berlin, SEFEP offers a platform to stimulate cooperation and synergies among all European actors who aim to build a fully de-carbonised, predominantly renewable power sector.

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Executive summary

The EU has a major role to play in Europe's transition from a fossil fuels-based energy sector to a decarbonised one. The need for an "Energy Roadmap 2050" triggered a multitude of studies that were conducted between 2009 and 2011, which again contained a multitude of decarbonisation scenarios, which achieve the EU's long-term emission mitigation target of reducing greenhouse gas emissions by at least 80% until 2050 (relative to 1990 emissions). Naturally, each study uses different assumptions, approaches and methodologies. This variety of important analysis is difficult to compare and utilize for specific and timely policy decisions. Thus the Smart Energy for Europe Platform (SEFEP) has commissioned a comparative study of relevant energy scenario studies for Europe. The findings of this comparative study are summarized here briefly.

The comparison between the scenarios demonstrates several similarities and reveales a few important differences. The following mitigation strategies play a key role in all of the scenarios and can thus be regarded as "robust" strategies in the decarbonisation process:

- Significantly speeding up energy end-use efficiency improvements
  The future growth in electricity demand will have to be limited in order to be able to achieve large emission reductions in the power sector. End-use efficiency needs to improve considerably faster than in the past. This strongly suggests that additional policy initiatives are required.

- Ensuring high growth dynamics of renewables until 2020 and beyond
  While many EU Member States have successfully increased the share of renewable energy sources in electricity generation in recent years, the analysis has shown that for the EU as a whole an acceleration of recent trends is required to be able to follow a plausible long-term decarbonisation pathway.

- Preventing or at least limiting the construction of CO_2 intensive power plants
  All of the decarbonisation scenarios analysed suggest that climate change mitigation leaves no room for many additional high-emitting power plants that do not use CCS technology. However, the current (July 2012) CO_2 price of well below 10 €/t CO_2 is too low to sufficiently disincentive the use and construction of such plants.

- Ensuring sufficient flexibility of the power system to deal with growing share of renewables
  The increasing share of renewable energy sources, especially of wind and solar energy will require the use of multiple options to increase flexibility within the power system. The grid will need modifications and complementary power plants will have to be sufficiently flexible in the years to come. In the longer term additional storage capacity will be required.

The main area of disagreement between the various decarbonisation scenarios analysed is the respective role of nuclear power and CCS technology in any future European power sector. Uncertainty about these technologies is driven by questions about their costs, their social acceptance but also about their compatibility within a future electricity system dominated by fluctuating renewable energy sources.

1. The metastudy on EU electricity system scenarios

The EU has a major role to play in Europe's transition from a fossil fuels-based energy sector to a decarbonized one. The need for an "Energy Roadmap 2050" triggered a multitude of studies that were conducted between 2009 and 2011, which again contained a multitude of decarbonisation scenarios, which achieve the EU's long-term emission mitigation target of reducing greenhouse gas emissions by at least 80% until 2050 (relative to 1990 emissions). Naturally, each study uses different assumptions, approaches and methodologies. This variety of important analysis is difficult to compare and utilize for specific and timely policy decisions. Thus the Smart Energy for Europe Platform (SEFEP) has commissioned a comparative study of relevant energy scenario studies for Europe. The project's consortium consists of experts from Öko-Institut and Wuppertal Institute.

While each of the analysed decarbonisation scenarios[1] provides insights into the design of the power sector in the future, none assesses quantitatively the respective role that each of the causal factors - such as the exploitation of wind energy, electrification of road transport, etc. - plays in driving or reducing CO_2-emissions.

Thus, the project

1. Characterized and compared the power sectors' envisaged by the various scenarios,
2. Performed a comparative analysis to gain insights into the quantities of CO_2-emissions related to either CO_2-emission drivers or CO_2-emission reduction levers.

Based on the results of this analysis the project identified crucial implications for EU energy policy, which will be highlighted in section 0.

The project's results have been published in detail in two working papers, which can be downloaded here: www.sefep.eu/activities/publications-1/decarbonisation-scenarios-leading-to-the-eu-energy-roadmap-2050 and www.sefep.eu/activities/publications-1/analysis-of-the-eus-energy-roadmap-2050-scenarios.

This briefing paper provides policy makers with a snapshot of the main results and serves as a means to demonstrate that scenario studies can be further utilized to derive information that is usually implicit to them.

[1] See below for a list of the scenario studies analysed within this project.

2. Results of the scenario comparisons

This section provides a comparison of the EU power sector as described in the various scenarios across two areas of interest.

The first area of interest is **a comparison of the energy mixes of the scenarios**, i.e. of the energy sources used to generate electricity. This comparison helps to analyse the power supply as such. This type of information is usually explicitly documented in scenario studies. Here the focus will be on the year 2050.

The second area for interest is to **explore which factors actually drive or reduce CO_2-emissions in each scenario** from base year to 2050. This type of information is usually implicit to scenario studies but can be retrieved by utilising specific analytical means (decomposition analysis).

Eleven decarbonisation scenarios from four different studies have been analysed within this project:

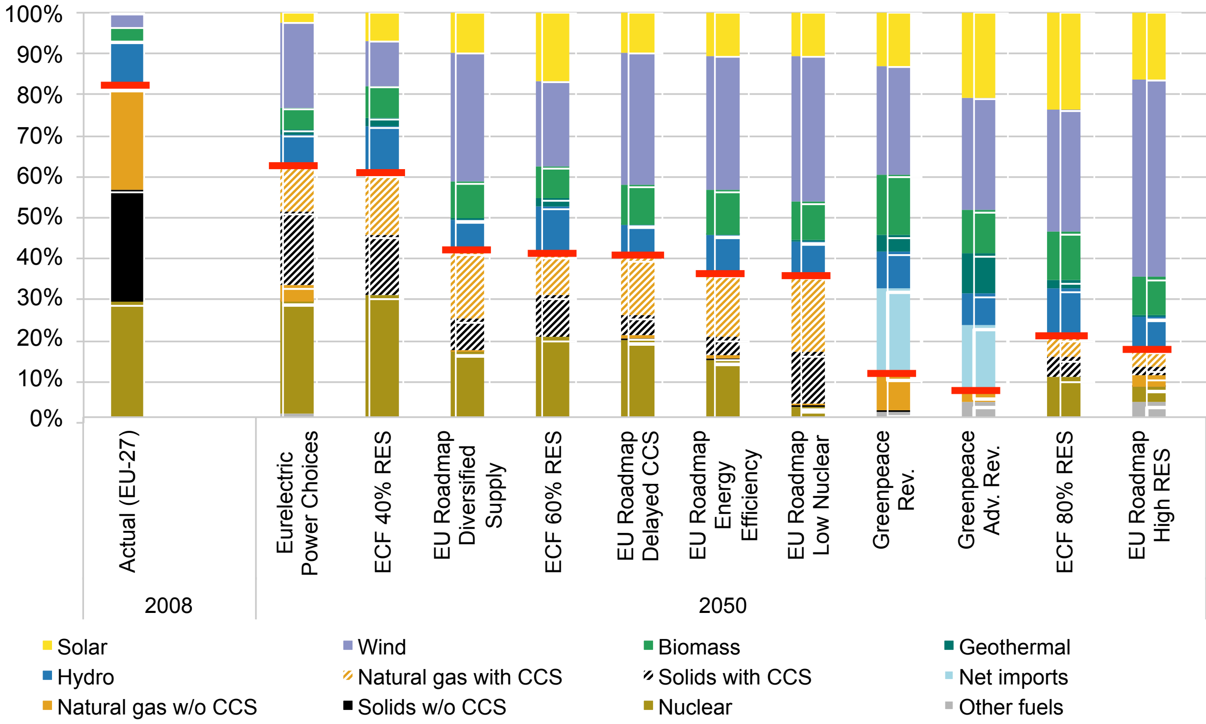
- (Greenpeace International & EREC, 2010): Revolution scenario, Advanced Revolution scenario
- (European Climate Foundation, 2010): ECF 40% RES scenario, ECF 60% RES scenario, ECF 80% RES scenario
- (eurelectric, 2009): Power Choices scenario
- (European Commission, 2011): Energy efficiency scenario, Diversified supply scenario, Delayed CCS scenario, High RES scenario, Low nuclear scenario

2.1. Electricity mix at a glance

For reference, the actual 2008 electricity generation mix is also shown.

Figure 1 visualises the shares in net electricity generation by source in various scenarios in **2050,** information that is usually **explicitly documented** in decarbonisation studies. Each bar corresponds to the electricity mix in a given scenario, composed of the various energy carriers. For reference, the actual 2008 electricity generation mix is also shown.

Figure 1 **Shares in net electricity generation by source (including imports) in various scenarios in 2050 for the EU-27 (plus Norway & Switzerland for ECF scenarios) and actual shares in 2008**



Sources: Own figure based on scenario data in European Climate Foundation, 2010; European Commission, 2011; Greenpeace International & EREC, 2010; eurelectric, 2009 and Eurostat for historical data.

Note: Horizontal red lines indicate share of non-renewable electricity generation.

Several key messages can be derived from this figure:

- <u>Similarities across scenarios:</u>
  Renewable energy sources play a major role across all scenarios in delivering electricity in 2050. Among renewable energy sources, wind power plays the dominant role in all the scenarios analysed and fluctuating renewable energies provide the major share of electricity from renewable sources. Electricity generation from fossil fuel sources will decline significantly by 2050. In all scenarios, except for eurelectric's Power Choices scenario and ECF's 40% RES scenario, renewable energy sources combined contribute more to electricity supply in 2050 than fossil fuels and nuclear power combined.

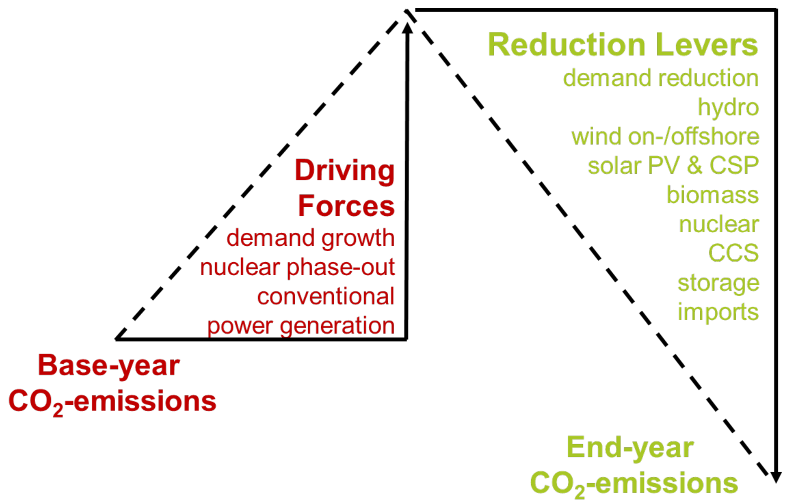
- Differences across scenarios:
  The role of CCS varies across the scenarios. The same is true for the role nuclear power. While ten of eleven decarbonisation scenarios analysed envisages a declining role of nuclear power compared to 2008, one scenario (Power Choices) in 2050 documents a (marginally) larger share of electricity from nuclear power than in 2008. Imports of electricity play a role in only two scenarios. All other scenarios envisage no major net imports of electricity.

2.2. Decomposition analysis at a glance

Utilising decomposition techniques (documented in www.sefep.eu/activities/publications-1/decarbonisation-scenarios-leading-to-the-eu-energy-roadmap-2050), it is possible to retrieve information that **is implicit** to each of the scenarios, namely to determine whether individual causal factors contributed to these CO_2-emission reductions (reduction lever) and if so to what extent.

Figure 2 demonstrates the basic idea of the decomposition analysis: As there are several causal factors which would increase CO_2-emissions if viewed separately (*CO_2-emission driving forces*), other factors need to overcompensate for these additional CO_2-emissions (*CO_2-emission reduction levers*) if overall CO2 emissions are to be reduced. Therefore the total CO_2-emission reductions that need to be delivered (*gross emission reductions*) to arrive at the end-year CO_2-emissions need to be larger than the difference of CO_2 emissions between base-year and the end-year (*net emission reductions*).

Figure 2 **Schema of systematic base for decomposition analysis**



Source: Own figure.

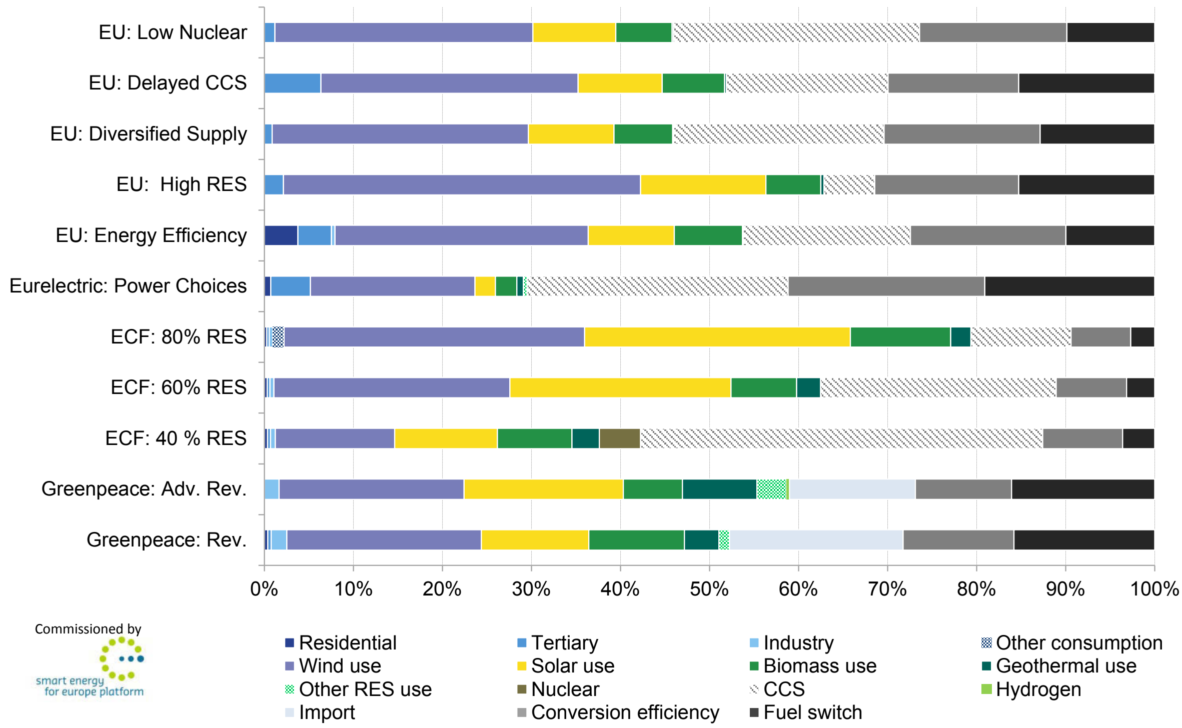
The causal factors considered in the decomposition analysis are of different nature but have the common characteristic that their utilisation either causes CO_2-emissions or reduces them. Considered in the analysis were factors addressing the consumption side, the fuel mix and the efficiency of the fossil power plants:

- Consumption on sectorial level: tertiary, industry, residential, transport, exports
- General fuel-mix: fossil fuel-based power generation, solar PV/CSP, wind on/offshore, hydro, biomass, imports, hydrogen, CCS

- Fossil fuel mix and efficiency of fossil power plants: fossil fuel emission intensity (indicator for fuel switch), fossil fuel input intensity (indicator for fossil power plant efficiency)

Figure 3 provides insights into the CO_2-emission reduction levers: Demonstrated are the shares of each of the factor regarding CO_2-emission **reductions** for the year 2050 compared to each scenario's base year.

Figure 3 Shares of CO_2-emission reduction levers on gross emission reductions delivered in 2050 compared to each scenario's base year



Source: Own figure, results from decomposition analysis.

Key messages from the decomposition analysis summarised in Figure 3 are the following:

- Similarities:
  Renewable energy sources are a key reduction lever in delivering CO_2-emission reductions across all scenarios. Fossil fuel switch (emission factor) and conversion efficiency (fossil power plant efficiency) contribute to CO_2-emission reductions, albeit to varying degrees. The same holds for most of the demand sectors (except the transport sector): They contribute to CO_2-emission reductions, but only to a minor degree.

- Differences*:*
  CCS technology plays a varying role across the scenarios in contributing to CO_2 emission reductions. Net imports help to achieve CO_2 emission reductions in two scenarios.

3. Main findings and implications for EU energy policy

Eleven decarbonisation scenarios (as well as five reference scenarios) from four different studies of the EU energy system have been analysed within this project. Very different institutions like the EU Commission, the industry association eurelectric and the environmental NGO Greenpeace have commissioned these studies and different scientific institutes have been involved.

Because of this and because of the range of different scenarios described in three of the four studies (especially in the EU's Roadmap 2050 study which developed five different decarbonisation scenarios) we believe that the scenarios' results as a whole can be regarded as a plausible range of the possible future development of the EU's electricity system under the assumption that the EU will fulfil its greenhouse gas emission reduction targets.

It follows that specific characteristics of the power sector's developments which are identical or similar among all the scenarios analysed can be regarded as robust characteristics which are – at least from today's perspective – necessary to achieve a low-CO_2 power sector by the year 2050.

In the following we summarise these robust corridors in a first step and then discuss the implications that can be drawn for EU energy policy.

3.1. Robust characteristics of a low-CO_2 power sector

- Significant energy efficiency improvements are required
  The importance of end-use efficiency is not immediately apparent from the results presented in Figure 3 as the methodology used identifies emission reductions from end-use sectors only if electricity demand is reduced compared to the base year. However, the four scenario studies analysed make it clear that their decarbonisation pathways can only be realised if electricity demand in the non-transport sectors is significantly reduced compared to a business-as-usual development.[2] Thus considerable improvements in the efficient use of electricity are urgently required. The following table stresses this point by comparing the EU economy's past change in electricity intensity (electricity demand/GDP) with the future changes assumed in the four scenario studies analysed. In all scenarios electricity intensity between 2010 and 2050 is reduced much faster than it has been reduced in the past two decades.

[2] All studies expect a significant increase in electric vehicles within the next decades in their decarbonisation scenarios and therefore all these scenarios foresee a considerable increase in electricity demand in the transport sector.

Table 1 Historical and modelled change in electricity intensity in the scenarios of four studies

	Historical	EU Commission	Greenpeace & EREC	eurelectric	ECF
1990-2010	-0.3%				
2010-2050		-1.1% to -1.4%	-0.5% and -1.0%	-0.7%	-0.9%

Sources: Own representation based on European Climate Foundation, 2010; European Commission, 2011; Greenpeace International & EREC, 2010; eurelectric, 2009.

- The growth dynamics of renewables need to be accelerated
  By 2050 renewable energy sources combined become the most important source in electricity generation in all eleven decarbonisation scenarios analysed. In nine of those scenarios renewables reach a share of at least 60% and up to 98% in net electricity generation by the middle of the century. Already by 2020 the share of renewables reaches 33 to 43% in all of the scenarios, roughly 2 to 2.5 times the share of 2009 (17%). By 2030 this share increases to between 48 and 69% in all but one decarbonisation scenario. As the share of renewables has only increased by 3 percentage points between 2000 and 2009, a significant acceleration of the growth dynamics of renewable energy is required in order to realise the pathways described in the decarbonisation scenarios.

- Electricity supply will rely to an ever larger share on fluctuating energy sources
  Of all renewable energy sources wind is by far the most important one for the decarbonisation of the electricity system. Robust growth in wind power is expected already in the near-term as the technology, especially onshore wind, is relatively mature and among the most economically attractive low carbon electricity generation options. This also means that a large share of future electricity generation in Europe will be from fluctuating renewable energy sources (especially wind and solar PV).

- The CO_2-intensity of the remaining fossil fuels in electricity generation needs to be reduced
  As Figure 1 indicates, conventional (non-CCS) coal and lignite power plants are completely or nearly completely phased out in all of the decarbonisation scenarios. Coal and lignite are only used (to a limited extent) in those scenarios, which assume that CCS power plants will be technologically and economically viable within the coming decades. By 2050 natural gas clearly dominates among all fossil fuels in power generation.

3.2. Implications for EU energy policy

- Significantly speeding up efficiency improvements in electricity use
  The analysis has shown that the future growth in electricity demand will have to be limited in order to be able to achieve large emission reductions in the power sector. End-use efficiency needs to improve considerably faster than in the past. This strongly suggests that additional policy initiatives are required. EU framework regulation could motivate and support EU Member States in enacting appropriate policies to improve efficiency.

- Accelerating growth dynamics of renewables until and beyond 2020
  While there has been success in recent years in many EU Member States in increasing the share of renewable energy sources in electricity generation, the analysis has shown that a plausible long-term decarbonisation pathway requires the use of renewable energy sources within the EU to continue to grow dynamically not only until 2020 but also beyond. For this it is of primary importance to increase investors' confidence. Therefore it would be beneficial for the EU to agree on renewable energy targets for each Member State for the post-2020 period - and do so sooner rather than later. The energy scenarios analysed could be an indication for the target that could be aimed for in the electricity sector: By 2030 most decarbonisation scenarios achieve a share of renewables in net electricity generation of about 50 to 60%.

- Preventing or at least limiting the construction of new CO_2-intensive power plants
  The current (July 2012) CO_2 price of below 10 €/t CO_2 is too low to sufficiently disincentive the use and construction of new high-emitting power plants. Swift modifications to the EU ETS are needed in order to increase the price level. The EU and its Member States should also contemplate using regulatory policy to limit the number of new CO_2 intensive power plants to be built, as any such new plants are likely to lock a significant level of emissions for decades to come. This could be achieved by setting emission standards for new fossil power plants reflecting today's best available technology (e.g. 400 g/CO_2 per kWh).

- Ensuring sufficient flexibility of the power system to deal with growing share of renewables
  The increasing share of renewable energy sources, especially of wind and solar energy will require the use of multiple options to increase flexibility within the power system. The grid will need modifications and complementary power plants will have to be sufficiently flexible in the years to come. In the longer term additional storage capacity will be required. It would be highly beneficial if new infrastructure planning were coordinated on the EU level in order to facilitate the construction of new grid infrastructure and storage capacity and to reduce overall costs.

- Limiting reliance on mitigation options with high uncertainty
  It is more difficult to draw conclusions about those mitigation options whose roles vary considerably from scenario to scenario. The various uncertainties associated with the mitigation options nuclear power (e.g. costs and public acceptance) and CCS (e.g. storage capacity and public acceptance) suggest that for the time being both options should not play key roles in any robust decarbonisation strategy.

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