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Energy Infrastructure Priorities



DIRECTORATE-GENERAL FOR INTERNAL POLICIES

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Energy Infrastructure Priorities



DIRECTORATE GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY
INDUSTRY, RESEARCH AND ENERGY

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BRIEFING PAPER

Abstract

Energy infrastructure priorities are made on the basis of long-term energy models with underlying assumptions influencing the model results. This briefing paper analyses long-term assumptions up to 2050. It recommends that energy savings targets, CO₂ reduction targets and third country interconnections for renewable electricity import are used as underlying assumptions for a longer term Impact Assessment of infrastructure priorities. Furthermore, it is recommended to set intermediate targets for 2030 and 2040.

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LIST OF ABBREVIATIONS

AC	Alternating Current
CCS	Carbon Capture and Storage
CO₂	Carbon Dioxide
DC	Direct Current
HVDC	High-Voltage Direct Current
IEA	International Energy Agency
RES	Renewable Energy Sources

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EXECUTIVE SUMMARY

Background and aim

Based on the European Commission Communication on "Energy infrastructure priorities for 2020 and beyond - A Blueprint for an integrated European energy network" [European Commission, 2010] and the accompanying Impact Assessment [European Commission, 2010b], this briefing paper is devoted to answering the following two questions:

1. *How should the underlying assumptions of the Commission's impact assessment be modified or amended if the 2020 infrastructure targets are developed with a view of the situation in 2050 as opposed to 2030 as in the current impact assessment (e.g. reduction of 80-95% greenhouse gas emissions, high share of renewables, being the most energy efficient economy, reaching the 2020 energy efficiency target, including economically viable and proven technologies, etc.)?*
2. *The PRIMES projections developed under the Energy Infrastructure Communication are limited to 2020 / 2030. When developing a roadmap for 2050, would it be recommended to set intermediate targets for 2030 and 2040?*

Underlying assumptions

Lead and implementation times for energy infrastructures are in the order of a decade or more. Infrastructure investment planning thus needs to be supported by long-term scenarios. Despite uncertainties in energy demand in the longer term it is expected to be beneficial to take decisions today on the basis of longer term scenarios.

It is recommended that the longer term Impact Assessment should be based on the following **additional assumptions**: Achievement of the European 20% **energy savings target** by 2020, commitment to achieving the **long-term CO₂ reduction target** of 80-95% by 2050, **interconnections with North Africa** for solar and wind power import.

It will be necessary to have a **2050 outlook** taking into account expected achievements and additional technical development needs particularly in terms of energy storage.

Natural gas demand and **natural gas infrastructure** requirements critically depend on the technical and economic viability of **carbon capture and storage** (CCS). Assuming the two binding targets of 20% CO₂ reduction by 2020 and of 20% renewable energies by 2020 to be achieved, the use of CCS technologies in electricity production in 2030 is very low according to the Impact Assessment.

Long-term targets

Energy price modelling is based in **fossil resources availability**. The Impact Assessment is based on an optimistic resources availability scenario which is certainly not undisputed in the scientific community. Evidencing the more pessimistic scenarios is the fact that future **energy price forecasts** have increased significantly in recent years – forecasts for 2030 have more than tripled since 2003, and the then worst case scenario has today become the base case scenario.

It is therefore recommended to also carry out **PRIMES scenario model runs** based on pessimistic assessments of **all fossil energy resources** in order to understand system sensitivities and economic risks. The analysis of PRIMES scenario model runs should be updated regularly to evaluate the achievement gaps towards the long-term and the intermediate targets.

Because **uncertainties of energy projections** increase with increasing time horizon and notwithstanding the absolute need to developing longer term targets it will be useful to also develop intermediate targets both for **planning and control purposes**.

It is recommended to set **intermediate targets for 2030 and 2040** when developing a roadmap for 2050 in order to allow for intermediate checks and corrective action upon non-achievement of intermediate targets.

1. Discussion of underlying assumptions

The briefing paper is divided into two sections. Based on the European Commission Communication on "Energy infrastructure priorities for 2020 and beyond - A Blueprint for an integrated European energy network" [European Commission, 2010] and the accompanying Impact Assessment [European Commission, 2010b], this first section is devoted to answering the following question:

How should the underlying assumptions of the Commission's impact assessment be modified or amended if the 2020 infrastructure targets are developed with a view of the situation in 2050 as opposed to 2030 as in the current impact assessment (e.g. reduction of 80-95% greenhouse gas emissions, high share of renewables, being the most energy efficient economy, reaching the 2020 energy efficiency target, including economically viable and proven technologies, etc.)?

KEY FINDINGS

- Lead and implementation times for energy infrastructures are in the order of a decade or more. Infrastructure investment planning thus needs to be supported by long-term scenarios. Despite uncertainties in energy demand in the longer term it is expected to be beneficial to take decisions today on the basis of longer term scenarios.
- It will be necessary to have a 2050 outlook taking into account expected achievements and additional technical development needs particularly in terms of energy storage.
- It is recommended that the longer term Impact Assessment should be based on the following additional assumptions: achievement of the European 20% energy savings target by 2020, commitment to achieving the long-term CO₂ reduction target of 80-95% by 2050, interconnections with North Africa for solar and wind power import.
- Natural gas demand and natural gas infrastructure requirements critically depend on the technical and economic viability of carbon capture and storage (CCS). Assuming the two binding targets of 20% CO₂ reduction by 2020 and of 20% renewable energies by 2020 to be achieved, the share of CCS technologies use in electricity production in 2030 is very low according to the Impact Assessment.

1.1. Infrastructure lifetimes and forecasting uncertainties

Energy infrastructures are long-lived assets. Indeed the Impact Assessment notes that many electricity transmission grids were built in the 1950's and 1960's and near the end of their lifetime. [European Commission, 2010b] Thus, in order to avoid stranded infrastructure investments, long-term development assessments need to be the basis for investment decisions.

In fact the Impact Assessment [European Commission, 2010b] explicitly acknowledges the need to align the infrastructure development to the long-term targets:

"[...] the European Council has set as an EU objective an 80-95% reduction in greenhouse gas emissions by 2050 compared to 1990 levels [...]. Infrastructure development and planning of today has to ensure that investments made in the next two decades are compatible with the long-term vision." [European Commission, 2010b]

On the other hand the Impact Assessment observes with respect to the assessment of investment needs for electricity and gas infrastructure:

"It should be noted that a forecasting exercise with a time horizon of up to two decades can only give indicative results, given the uncertainties surrounding future supply, demand and price developments." [European Commission, 2010b]

The present analysis of the underlying assumptions of the Impact Assessment requires balancing the conflicting tendencies of increasing modeling uncertainties with increasing time horizons on the one hand and the need for longer term vision for infrastructure planning on the other hand.

1.2. Underlying assumptions of the Impact Assessment

The analysis of the underlying assumptions focuses on issues foreseeable already today that will become relevant after 2030 and may change the results of the Impact Assessment. In doing so, fundamental aspects such as time frames for infrastructure build-up, the transition from past monopolies to the current market-based approach and the differentiation of five drivers for infrastructure build-up are discussed in order to put these issues into perspective. In addition, energy savings targets, also in the short term until 2020, are discussed as they are highly relevant and have the potential to change the results of the Impact Assessment significantly.

The Impact Assessment is, among others, based on the **PRIMES model**, an equilibrium model calculating energy supply and demand. For the Impact Assessment, two PRIMES model scenarios are used: the PRIMES "**Baseline 2009** that takes into account the policies implemented in the Member States up to April 2009" and the "**Reference scenario**, which includes policies up to the end of 2009 and assumes the achievement of the legally binding targets on renewables and greenhouse gas reduction". [European Commission, 2010b]

1.2.1. Time frames for infrastructure build-up

Although "increasing fossil energy prices will lead to renewable energies becoming cost competitive to fossil electricity generation", [Ecofys, 2010] the buildup of infrastructures supporting renewables has lead times of 10 years and beyond, and it may be more cost effective to build up infrastructure early to save costs in the long run. [Fischedick, Samadi, 2010] also demonstrate that the buildup of renewable energies even if it is not cost effective in the short term may be the more cost effective long-term strategy as it avoids lock-in effects or getting into techno-economic dead ends. This reconfirms the need for long-term perspectives in energy planning in general.

A similar effect is mentioned in the Impact Assessment for Carbon Dioxide (CO₂) infrastructure, which is related to carbon capture and storage (CCS) concepts: "As the results of recent private sector analysis show, it is still more economical to oversize the pipelines initially and wait around 10 years until the spare capacity is fully utilised than to build pipelines fit for one emission point and one CO₂ sink."

This confirms that the assessment of infrastructure needs **long-term scenarios going beyond the one decade time horizon of infrastructure planning**. While scenario calculations go up to 2030, the Impact Assessment is limited to 2020.

The Impact Assessment analyses infrastructure investment needs compatible with the PRIMES Reference scenario in 2020 and in 2030 including an additional high renewables scenario. **Results provided however do not differentiate between these scenarios.**

1.2.2. Energy savings target

It is noteworthy that the **energy savings target of a 20% reduction** of primary energy consumption by 2020, compared to the Baseline development [Altmann et al., 2010], which so far is not a binding target, is **not assumed to be achieved in the Reference scenario**. [E3M, 2010]

As the target is generally agreed to relate to **primary energy**, the replacement of electricity produced in thermal power plants (coal, natural gas, oil and nuclear) by electricity produced through renewable energies such as wind power, hydro power or photovoltaics, directly reduces primary energy consumption. [ECF, 2010] Another relevant aspect is the fact that **carbon capture and storage (CCS) technologies clearly reduce the efficiency of fossil power plants**.¹ [Wuppertal Institute, 2010] As a result, whilst reducing greenhouse gas emissions of fossil power production, CCS increases the primary energy consumption and consequently CCS actually makes it more difficult to achieve the savings target.

1.2.3. Additional climate targets

It should be noted that the reference scenario does not include "a possible step-up of the emission reduction target to -30% by 2020 or additional transport policies beyond CO₂ and cars emissions regulation. They [the energy demands; the editor] should therefore rather be seen as upper limits for the expected energy demand." [European Commission, 2010]

It is obvious that strengthening the climate target from -20% to -30% by 2020 would create significant additional requirements for infrastructure development, and would thus change the results of the Impact Assessment considerably.

The EU objective of an 80-95% reduction in greenhouse gas emissions by 2050 compared to 1990 levels set by the European Council represents a fundamental long-term guideline to policy making. This ambitious goal at EU level and equivalent goals at national or global levels have been analysed by various scientific studies in order to develop pathways to their achievement. They all conclude that the goals can be achieved, but that this requires political action at all levels as early as possible. [ECF, 2010b], [ewi gws Prognos, 2010], [IEA, 2010], [EREC Greenpeace, 2010]

The long-term climate target of an 80%-95% CO₂ reduction by 2050 is of utmost importance for the usefulness of the modeling results. Assuming CO₂ to stabilize at 2020 levels or even grow again will certainly give different results than a scenario with further decreasing emissions. The present work in the Reference scenario **ensures -20% CO₂ emissions by 2020, but does not impose any requirements with respect to CO₂ emissions beyond that.**

¹ An overview provided in [Wuppertal Institute, 2010] shows that the energy efficiency penalty of CCS technologies estimated by various scientific studies varies between 4 and 18 percentage points.

1.2.4. Five drivers for infrastructure expansion

There are essentially five drivers for infrastructure extension as described in the Impact Assessment:

1. **Climate objectives:** build-up of renewable power technologies, such as off-shore wind in the northern seas, or solar power in southern Europe and North Africa, requiring additional electricity transport infrastructure.
2. **Security of supply:** developing access to multiple and additional sources, notably natural gas sources outside the European Union, allowing for interoperability and coordinated planning of contingencies under disrupted conditions “resulting from natural hazards and human-made malicious threats” [European Commission, 2010b]
3. **Market integration:** trans-national interconnections developing the national grids into an integrated European grid
4. **Smart grids:** infrastructure investments induced by smart grid elements such as smart meters. The third energy package defines: “Where roll-out of smart meters is assessed positively, at least 80% of consumers shall be equipped with intelligent metering systems by 2020.” [European Union, 2009]
5. **Evolution of energy generation mix:** changes in the type and geographic location of power plants require extensions and modifications of the grid.

The Impact Assessment estimates infrastructure investment needs separately for electricity, natural gas and CO₂ infrastructure.

Table 1: Drivers for infrastructure extension

	Electricity	Natural gas	CO ₂	Oil
(1) Climate objectives	+	(indirect)	+	
(2) Security of supply	+	+		+
(3) Market integration	+	+		
(4) Smart Grids	+			
(5) Generation mix	+	+	+	

Source: Own analysis based on [European Commission, 2010b]

Electricity infrastructure expansion is driven by all five drivers, while natural gas infrastructure expansion is mainly driven by security of supply (2 in Table 1 above) and market integration (3). Climate objectives are an indirect driver for natural gas infrastructure for its role in electricity production, notably as back-up for fluctuating renewable energies. CO₂ infrastructure establishment is driven by climate objectives (1).

1.2.5. Infrastructure build-up from past monopolies to a market-based approach

Infrastructure build-up in the individual European member states has taken place under monopoly situations and government control. In these situations, priorities, financial risk assessments, financing options etc. were evaluated differently than in today’s regulated

market approach to infrastructure operation and extension with established unbundling of TSOs. [Altmann et al., 2010] It should be noted, however, that **the TSOs of 18 out of the 27 EU Member States are government controlled through an equity stake above 50%** and in addition, in two Member States, some TSOs are controlled by various public entities at national and regional levels, or by national governments of other Member States.²

1.2.6. Technological development

PRIMES uses several sources of techno-economic input data of energy technologies. The PRIMES update 2007 specifies: "Information on technical-economic characteristics of existing and future energy supply technologies was taken from the TechPol database developed within a series of DG Research projects, of which the most recent one is Cascade-Mints. Regarding thermal power technologies, the data have also been cross-checked with data from the Zero-Emission Technology Platform and the database of VGB." [E3M, 2008]

It is beyond the scope of the present paper to analyze this large number of detailed input assumptions. However, it needs to be pointed out that **a potential bias in these input assumptions may influence the results obtained by the model.**

1.2.7. Carbon capture and storage

The Impact Assessment comes to the following conclusion with respect to CCS technologies:

"The development and marketability of CCS technologies – and hence the need for a CO₂ transportation network – are highly dependent on the CO₂ prices. This is shown in the PRIMES reference scenario (lower CO₂ prices due to lower demand for emission permits due to higher share of RES and more energy efficiency in the system) where the share of CCS use in power generation is only 1.4% in 2030 corresponding to 37.6 Mt of captured CO₂. The PRIMES baseline with higher carbon prices allows for more CCS development reaching 8.7% of power generation in 2030." [European Commission, 2010b]

This demonstrates that the commercial viability of CCS technologies critically depends on the underlying assumptions made for the energy modeling. There is a factor of six between the two resulting CCS deployment figures by 2030! In other words, **assuming the two binding targets of 20% CO₂ reduction by 2020 and of 20% renewable energies by 2020 to be achieved, the share of CCS technologies use in electricity production in 2030 is very low at 1.4% only.** Additionally assuming the energy savings target to be achieved (see section 1.3.1) will most probably further reduce the CCS deployment in 2030.

² In Austria, one TSO is 51% state owned and the other two are to more than 50% owned by one individual Lander (region) each. In Germany, one of the four TSOs is 100% state owned by the Dutch government (through the company TenneT), the ownership structure of another German TSO, EnBW, is currently in transformation. The 45% stake of EDF, which itself is more than 50% owned by the French government, is transferred to the German Land of Baden-Württemberg; the remaining shares are mainly owned by public entities at local level.

1.3. Recommendations for modifications and amendments of assumptions

1.3.1. Energy savings target(s)

The **energy savings target of 20% reduction** of primary energy consumption by 2020 compared to the baseline development **should be required to be met by the PRIMES Reference scenario**. As part of the so-called 20-20-20 goals, it is the declared political ambition of the European Union to achieve this target. The European Commission has announced to propose an updated EU Energy Efficiency Action Plan in early 2011 including concrete policies to achieve the target³. Independent analyses have demonstrated that the necessary energy savings potentials are existent and to a large extent cost effective. [ECF, 2010]

With increasing energy prices and technological progress, the potential for cost effective energy savings increases so as to allow setting further savings targets with a longer time horizon. Before defining further energy savings targets the potential should be analysed in detail.

1.3.2. Additional climate targets

It is suggested to include a scenario that achieves a 30% reduction of CO₂ emissions by 2020 in the PRIMES modelling. In addition, the **PRIMES reference scenario should include an additional input assumption that CO₂ emissions must further decrease after 2020 in line with a long-term target of 80-95% reduction by 2050**.

1.3.3. Drivers for infrastructure expansion

The five drivers for infrastructure development identified and taken into account in the Impact Assessment are influenced to a different extent by long-term assumptions beyond 2030. By 2020, investment needs are strongly driven by security of supply and market integration. This driver mainly concerns trans-border interconnections for electricity and natural gas.

Climate goals essentially drive off-shore wind development in the northern seas, and thus integration requirements in the Impact Assessment. Electricity grid connections to third countries do not play a major role until 2020. In modelling the infrastructure requirements, new **interconnections with North Africa should be included**. The Desertec Industrial Initiative backed by major industries in Europe as well as by relevant countries in Europe and North Africa has been set up with the ambition to supply up to 15 percent of Europe's electricity needs by 2050 from North Africa. Desertec is developing roll-out plans until 2012. The France-based Transgreen consortium studies the feasibility of a trans-Mediterranean electricity transport grid. So far, only one relatively weak grid connection between North Africa and Europe exists making infrastructure the main bottleneck for the implementation of solar power import to Europe.

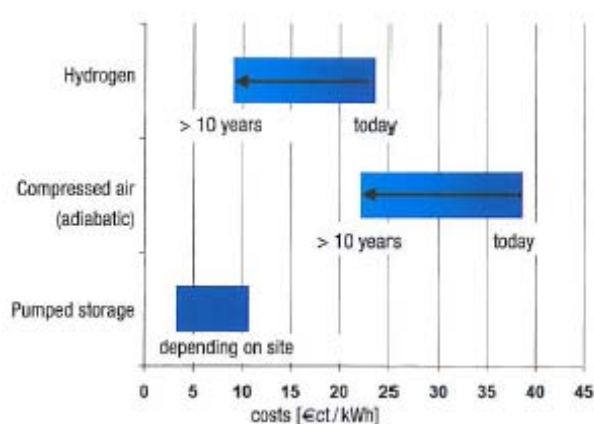
³ The European Commission has adopted the [Communication "Energy Efficiency Plan 2011"](#) on 8 March 2011, just as this briefing paper went to press

1.3.4. Technological development

The Impact Assessment mentions technological requirements and uncertainties related to their development: “In the medium term, new high-voltage long distance grid technologies and new electricity storage technologies will also be necessary. Uncertainties remain today as regards the potentials and risks of these different technologies.” [European Commission, 2010b]

Figure 1 shows the cost difference between the only established large-scale electricity storage technology, pumped hydro power, on the one hand and compressed air, and hydrogen storage solutions on the other hand, which are still in the research and development stage. It also highlights the large cost reduction potentials of these technologies over the coming decade.

Figure 1: Electricity storage cost assessments



Source: [VDE, 2008]

The Impact Assessment highlights the need for interconnections with Scandinavia and the Alps as electricity storage regions. Even though hydro power production in both regions represents some 6% of European electricity production⁴ each, pumped hydro⁵ only represents 0.03% of European production in Scandinavia, and 0.6% in the Alps.⁶ If we were to only consider pumped hydro, with the increased introduction of renewables into the electricity mix, the energy storage capacity requirements are likely to quickly reach heights way above the physical capacities of Scandinavia and the Alps alone. At the same time, wind power production in Europe already represented one third of hydro power production in Europe in 2008. With growth rates of 30% per year, wind power will reach hydro power production four years later, i.e. around 2012/13. This growth illustrates well the increase in renewable electricity sources.

Other alternative electricity storage and smart grid technologies resulting in effective demand-side management may therefore actually reduce the necessity of interconnectors, notably to Scandinavia and the Alps.

⁴ EU-27 plus Norway and Switzerland.

⁵ Hydro power includes run-of-the-river plants with a limited control capability of power output, dams with significant control capability of power output as well as pumped hydro power plants with storage capability, i.e. controlled power uptake and output.

⁶ Own calculations based on data taken from IEA statistics.

As a consequence of this discussion it is suggested to **check in detail the techno-economic assumptions made in the PRIMES model on electricity storage technologies.**

1.3.5. HVDC 'supergrids'

With respect to high-voltage direct current (HVDC) technology it should be noted that this is in commercial operation since many years. A list of existing world-wide HVDC lines, which represent many thousand kilometers at voltage levels up to 800 kV, and of projects under construction is provided by [IEEE, 2008]. There is definite further development potential and there are development needs, notably with respect to DC grids as opposed to point-to-point connections: "Still an open issue is connecting and disconnecting HVDC lines via DC switch. Until now connection/disconnection of HVDC without using a DC/AC and AC/DC converter is not possible." [Altmann et al., 2010b]

Longer term scenarios may notably increase the interconnection capacities required between the national grids. An analysis modelling demand until 2030 and infrastructure investment requirements until 2020 as in the Impact Assessment will in the best case ensure that infrastructure required in 2030 is in place. If infrastructure requirements, notably trans-border interconnections, increase further, it may be more economical to **oversize the interconnections initially.**

As an example, the interconnection capacity requirement by 2020 between Slovakia and Poland is estimated at 800 MW, which may be ensured by a single 380 kV AC line. [European Commission [2010b] Should a scenario calculation until 2040 result in a higher interconnection requirement by 2030 of, say, 1600 MW it may be more economical overall to initially install a 500 kV DC line. A retrofit after ten years of operation may not be economical. **Thus, taking long-term assumptions for 2030, 2040 and 2050 into account may change the infrastructure requirements.**

In case of pure point-to-point interconnections of national grids, this would have the additional advantage of integrating the grids energetically, while limiting domino effects such as the 2006 blackout, which "originated in North-West Germany, struck France, Austria, Belgium, Italy, Spain and even Morocco, leaving a total of about 15 million people without electricity for up to two hours." [European Commission [2010b]

HVDC technology allows for a 'loose' interconnection increasing overall security of power supply. HVDC is the preferred choice for point-to-point interconnections of AC grids if energy interconnection is intended without integration of other technical and system aspects enabling independent coupling of different control zones. The commercial viability of HVDC interconnections compared to AC interconnections depends on line length and power transmission capacity, with increasing values favouring HVDC.

The **relevance of HVDC supergrids** is acknowledged in the Impact Assessment noting that "the Europe 2020 strategy put again energy infrastructures in the forefront as part of the flagship initiative 'Resource efficient Europe'. It underlined the need to urgently upgrade Europe's networks towards a European 'smart' supergrid, interconnecting them at the continental level, in particular to integrate renewable energy sources." [European Commission, 2010b]

1.3.6. Natural gas infrastructure depends on CCS viability

The Impact Assessment notes: "while the evolution of gas demand is uncertain until 2030 and even more so until 2050, gas is expected to have an increasing share until 2020, which is unlikely to drop dramatically after 2030 from a projected share of 22.4%-24.3% of total energy demand under the PRIMES reference scenario, especially if carbon capture and storage technologies develop." [European Commission, 2010b]

If, however, CCS technologies do not prove to be economically and technically viable (see also section 1.2.7) a natural gas consumption at such a high level may violate the 2050 goal of a 80-95% greenhouse gas emissions, and may thus need to be reduced significantly.

Consequently, in the long term, investments in natural gas infrastructure depend on the technological and economic viability of CCS technologies. Without it, investments in natural gas infrastructure with lifetimes of several decades may increasingly be stranded.

In this case, it is not possible to make other or amended assumptions for the Impact Assessment. Rather, **the sensitivity of the results with respect to the assumptions on CCS needs to be analysed in detail.**

1.3.7. Fossil resources availability

The issue of fossil resources availability and its impact on the PRIMES modelling results are discussed in section □ below. It is recommended to **carry out PRIMES scenario model runs based on pessimistic resource assessments.**

2. Setting long-term targets for PRIMES projections

This section is devoted to answering the following question:

The PRIMES projections developed under the Energy Infrastructure Communication are limited to 2020 / 2030. When developing a roadmap for 2050, would it be recommended to set intermediate targets for 2030 and 2040?

KEY FINDINGS

- Energy price modelling is based on fossil resources availability. The Impact Assessment is based on an optimistic resources availability scenario which is certainly not undisputed in the scientific community. Evidencing the more pessimistic scenarios is the fact that future energy price forecasts have increased significantly in recent years – forecasts for 2030 have more than tripled since 2003, and the then worst case scenario has today become the base case scenario.
- It is therefore recommended to also carry out PRIMES scenario model runs based on pessimistic assessments of all fossil energy resources in order to understand system sensitivities and economic risks. The analysis of PRIMES scenario model runs should be updated regularly to evaluate the achievement gaps towards the long-term and the intermediate targets.
- Because uncertainties of energy projections increase with increasing time horizon and notwithstanding the absolute need to developing longer term targets it will be useful to also develop intermediate targets both for planning and control purposes.
- It is recommended to set intermediate targets for 2030 and 2040 when developing a roadmap for 2050 in order to allow for intermediate checks and corrective action upon non-achievement of intermediate targets.

2.1. Natural resources availability and energy price developments

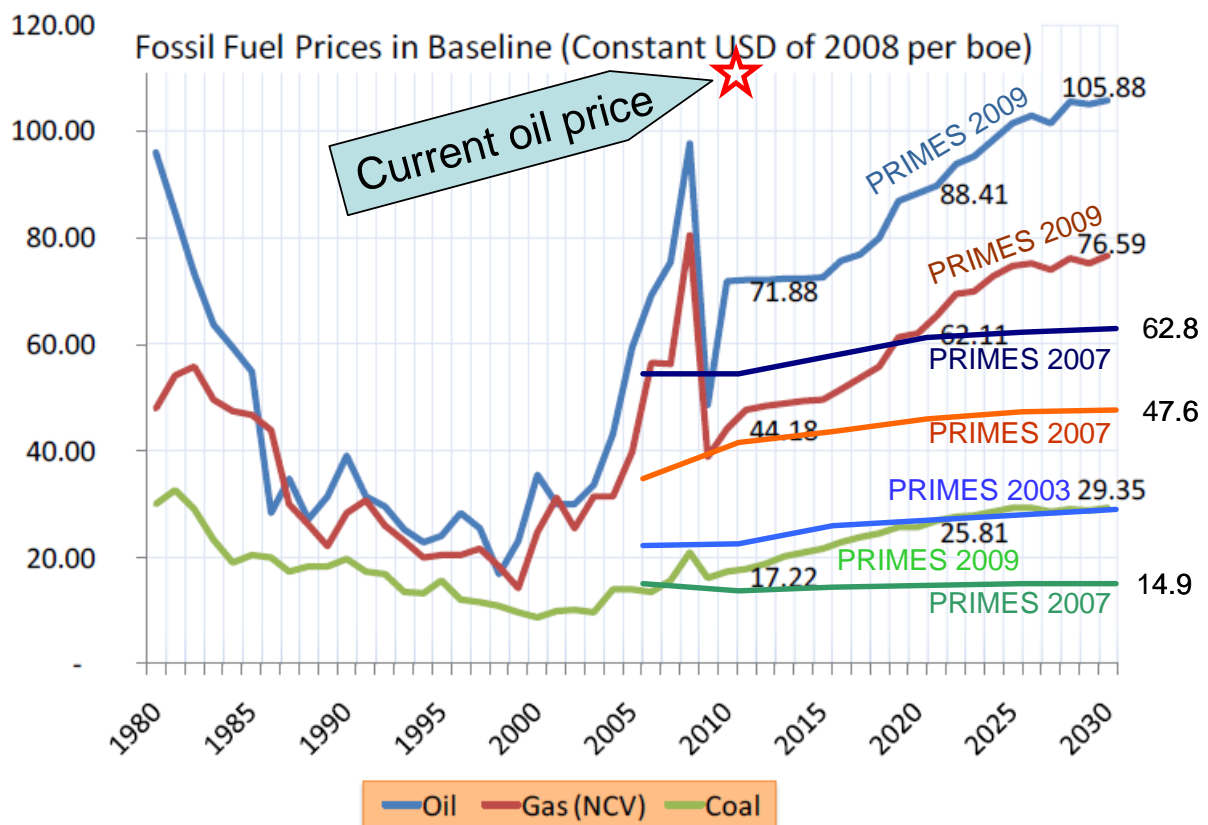
Primary energy prices are a major factor influencing the model results. The input assumptions governing the price development in the model are thus of critical importance.

“The projections, based on the POLES and Prometheus models, take into account world energy resources and the formation of world energy prices as a result of interactions between energy demand and energy supply reflecting resource availability and technological progress.” [E3M, 2008]

The essential input parameters for the calculation of the price developments of oil, natural gas and coal are the estimates of the respective natural resources. Here, the PRIMES “world oil outlook is based on resource data supporting the view that oil supply can meet a smoothly growing demand at affordable prices over the next twenty five years.” [E3M, 2008] This **optimistic view** is debated heavily in the scientific arena and in the general public. The **pessimistic view** comes to the conclusion that by 2030 world oil production will have declined to about half the value of the global production peak in 2006-2009. [Schindler, Zittel, 2008], [Zittel, 2010]

Figure 2 shows the oil, natural gas and coal price developments as forecasted by the PRIMES baseline 2009. For comparison, energy price forecasts of PRIMES 2007 and PRIMES 2003 are also included in the figure.⁷ The oil price forecast for 2030 has increased threefold over six years of modeling to 106 US-\$ per barrel. This however is the current February 2011 spot market price, which may be due to singular unforeseeable effects, or may indicate that the price model and/or the assumed resource availabilities need to be adjusted. The scientific debate is essentially about the question of whether the physical oil resources will be limited compared to the demand development. [Kesicki et al., 2009] see a limited oil availability until 2030, but which is still much higher than pessimistic assessments. Nonetheless, they model oil prices of 150 US-\$₂₀₀₈ in 2030, which is more than 40% higher than the PRIMES estimates.

Figure 2: Development of primary energy prices according to PRIMES 2009, PRIMES 2007 and PRIMES 2003



Source: Own analysis based on [E3M, 2010], [E3M, 2008], [E3M, 2003]

Based on these indications it is recommended to **carry out PRIMES scenario model runs based on pessimistic resource assessments of all fossil energy resources**. Even though scenario calculations with "soaring oil and gas prices" [E3M, 2006] have been carried out in 2006 these were done with the above mentioned 2030 oil and gas prices of the PRIMES Baseline 2009. In other words, these worst case scenario calculations have

⁷ PRIMES 2009 baseline is in constant 2008 US-\$, PRIMES 2007 baseline is in constant 2005 US-\$, PRIMES 2003 baseline is in constant 2000 US-\$.

become the base case within only three years. These “soaring oil and gas prices” [E3M, 2006] scenario calculations have not resulted in significant expected changes by 2030 as coal prices are essentially expected to remain at low levels. Thus, high oil and natural gas prices lead to a somewhat reduced energy consumption, to somewhat higher shares of renewable energies and to a substitution of natural gas consumption by coal, notably in electricity production. [E3M, 2006]

Whether coal prices can be expected to remain at low levels is not so certain. In fact the past 2.5 years have shown that **coal prices actually also follow the oil price**, and pessimistic estimates of coal resources also hint at possible availability constraints. Other considerations around the coal prices are that international analyses show a highly concentrated market with 90% of coal being consumed in the country of production and that only seven countries are net coal exporters, with Australia covering 43% thereof. [Zittel, Schindler, 2007] [Kavalov, Peteves, 2007]

It is therefore recommended to also carry out **PRIMES scenario model runs based on pessimistic assessments of all fossil energy resources** in order to understand system sensitivities and economic risks. The analysis of PRIMES scenario model runs should be updated regularly to evaluate the achievement gaps towards the long-term and the intermediate targets.

2.2. Long-term energy modelling

As discussed in section 0, the longer the time horizon of forecasts, the larger will be the uncertainty of the results. Furthermore, it is difficult to quantify the uncertainty of the model results. As a consequence, there is no easy answer to the question of how reliable long-term energy forecasts are.

The discussion in the previous section □ has demonstrated the crucial importance of the input assumptions on fossil resources availability and the energy prices calculated. A first step towards a better understanding of this would thus be to **critically validate the energy price models and their input assumptions**. Very obviously, the energy price models used for PRIMES calculations have failed to forecast the energy prices correctly. This may be caused by shortcomings of the model, by unrealistic input assumptions on resources availability or by singular unforeseeable effects in the ‘real world’. Other models such as the one used by the International Energy Agency (IEA) have not been more successful. [Altmann et al., 2010c]

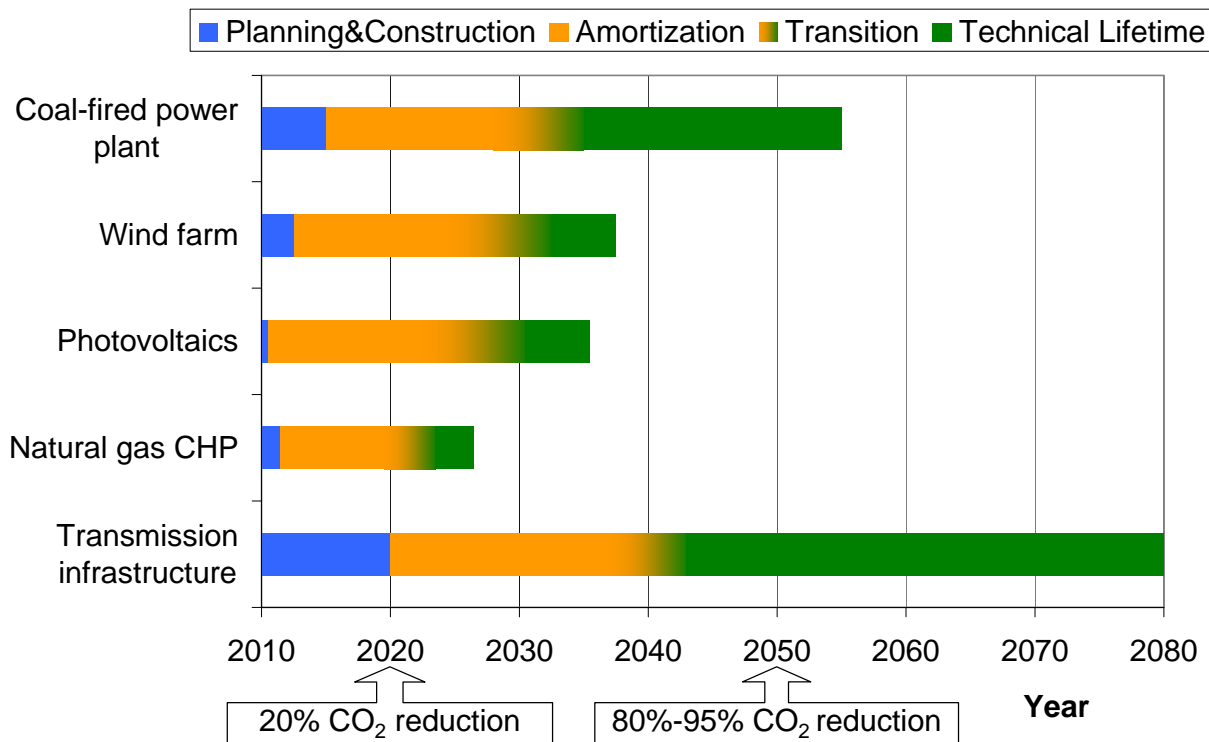
The European energy trends to 2030 using the PRIMES model have first been published in 2003, and thus made a 27 year forecast. It would be interesting to check this forecast against reality up to 2010, but this is beyond the scope of this analysis.

2.3. Setting intermediate targets

It is recommended to follow the twofold approach of critically checking both the energy price modelling and the energy demand and supply modelling on the one hand, and in parallel to develop a roadmap to 2050 with intermediate targets for 2030 and 2040.

The lead-times for energy systems, both infrastructure and generation equipment, are long. The same holds true for technical and economic lifetimes (see Figure 3).

Figure 3: Typical time horizons of energy generation equipment and energy transmission infrastructure



Source: Own analysis based on various sources

With this in mind, long-term targets need to be the basis for decisions in the energy sector. At the same time, this requires intermediate targets to be set in order to have intermediate checks of ultimate target achievement. **Without intermediate checks corrective action may become very costly or even impossible to achieve.**

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