Final report:

Phase out of Nuclear Power in Europe

– From Vision to Reality

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Phase out of Nuclear Power in Europe – From Vision to Reality

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Executive Summary

The core objective of this meta-study is to conduct an analysis of the energy-political prerequisites for as well as legal aspects and overall impacts of a gradual exit from nuclear power up to 2030 within the European Union (EU). This nuclear power phase-out shall be realized assuming that the climate targets of reducing greenhouse gas (GHG) emissions by 20% in 2020 and by 80-95% in 2050 (both compared to 1990 levels) shall be met. This meta-study builds on related existing modelling work (i.e. the study "energy [r]evolution, a sustainable EU 27 energy outlook" by Teske et al. (2012a), published by Greenpeace and the European Renewable Energy Council) and on an extensive literature-review. In a first step the literature review includes prestigious studies on meeting long-term climate, renewable energy source (RES), and/or energy efficiency targets. In a second step related aspects (RES, energy efficiency, infrastructural prerequisites) are covered and examined for derivable implications at the European level, focussing on supply and demand for electricity. Third, legal aspects of a nuclear power phase-out until 2030 in the EU are analysed. The study ends with a derivation of recommendations for practical policy implementation in accordance with the above mentioned European targets.

Scenario Assessment

Climate mitigation scenarios modelling a high share of energy supplied by RES technologies and additional energy efficiency instruments bear higher costs for the consumer in the short to medium term. When compared over a time period up to 2050, total energy system as well as electricity supply costs of climate mitigation set-ups for the EU are however expected to be lower compared to reference or current policy projections. Likewise specific electricity generation costs in European climate mitigation scenarios will undercut the reference or current policy developments in the long-term (EC, 2011b, 32, Teske et al., 2012a, 59).

An alternative "advanced scenario" (compared to the energy [r]evolution study) to allow an earlier nuclear phase-out

The energy [r]evolution Advanced scenario which forms the basis for our overall assessment takes a nuclear power phase-out until 2035 for the EU into account. This scenario projects an electricity generation of 78 TWh from nuclear power plants for the year 2030, what equates to 8.6% of nuclear generation in 2011 or 2.2% of total generation for the year 2030 (Eurostat, 2013c; Teske et al., 2012a, 125). The simple answer to the overarching question whether or not the supply gap that would arise in the case of an earlier nuclear phase out (i.e. by 2030 instead of 2035) can be compensated is "Yes" – according to our brief complementary assessment it appears feasible to compensate this gap. The recommended option to do so is to build on additional energy savings / efficiency measures, and as part of that we advocate to reduce the demand for hydrogen that serves as fuel for other sectors (i.e. transport and industrial processes). More precisely, the alternative renewable electricity (RES-E) supply scenario, assessed with the Green-X model, combined with the fossil electricity sector as envisioned in the energy [r]evolution and a nuclear power phase-out trajectory five years prior to the energy [r]evolution, is presented in Figure A-1.

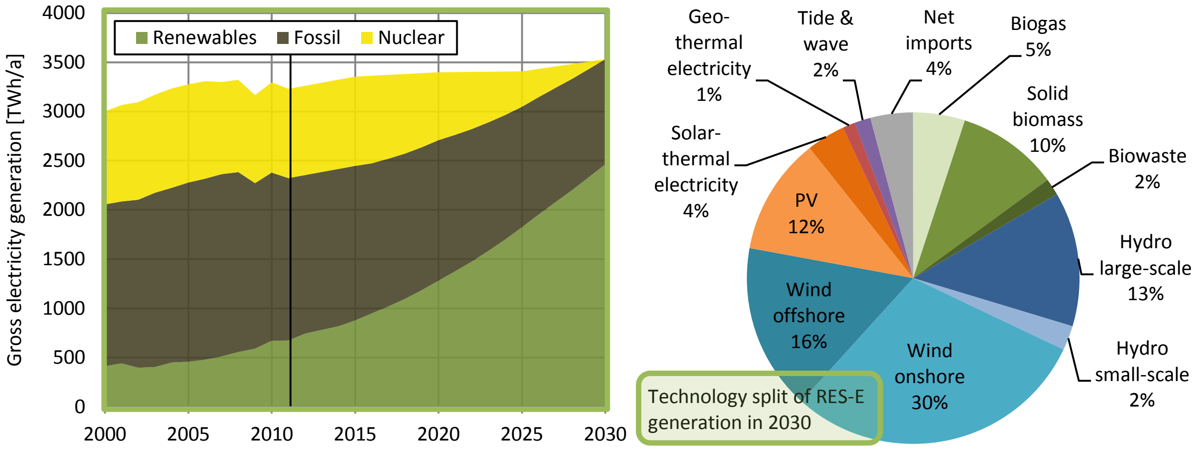

Figure A-1: Nuclear phase out scenario: Development of electricity supply up to 2030 (left) and technology-split of RES-E generation in 2030 (right) at EU level (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

The role of energy efficiency and RES

There are two main GHG mitigating possibilities to let the vision of a nuclear power free European energy system become a reality while maintaining the fulfilment of European climate targets: a fostering of energy efficiency / saving measures for lowering or at least stabilising the electricity demand and the enhanced use of RES technologies for decarbonisation.

Energy efficiency options can only be effectively addressed if the entire energy conversion chain is considered and a clear target has been defined in advance. This translates to an energy conversion chain from the actual provided energy service to the primary energy supplied and a target to provide the energy service at least as good while reducing the primary energy demand. The specific costs of energy saving measures are expected to decline due to learning effects and energy price increases. It appears worth to mention that all electricity savings as projected in the assessed energy scenarios lie within the savings potential evaluated by Boßmann et al. (2012).

As a second main pillar of this meta-study a closer look is taken on the potentials for RES that are applicable within the EU, comparing the needs set out by the underlying energy [r]evolution path, i.e. the Advanced scenario, with the applicable resources, specifically in the mid-term up to 2030. Finally, related deployment pathways for the individual RES technologies are derived by use of the Green-X model, a specialised energy system model with a detailed resource and policy description, and related policy implications are identified.

A strong RES uptake as anticipated by the energy [r]evolution Advanced scenario for 2030 appears feasible from a market / policy perspective – but for doing so a strong commitment towards RES needs to be taken from today onwards to the period beyond 2020 all across Europe. The increase of RES-E generation compared to 2011 is in magnitude of 1800 TWh at European level while a phase-out of nuclear means to take about 900 TWh out of the system. Thus, the simple comparison of these two figures may point out that additions from renewables overcompensate the arising supply gap, but additional challenges have to be taken into account: first, climate action requires to substantially reduce fossil generation, and, secondly, at country level there is occasionally a large discrepancy between power plant shut-downs and additions. For example, France would have to take 429 TWh of nuclear electricity out of operation while additional renewable generation is in magnitude of about 202 TWh. In contrast to that, its southern neighbour Spain may well end up with a surplus in power supply that is waiting to be consumed elsewhere. This exemplifies the need for intensified coordination and cooperation in the (renewable) energy sector, an issue that Europe, or at least the European Commission, is addressing in several of its energy-related publications and statements (compare e.g. EC, 2013). Furthermore, this nicely indicates the need for further network extensions to tackle the challenges arising from a massive uptake of (variable) renewables in the electricity sector.

Prerequisites and implications for the European electricity sector

An accelerated RES-E deployment and the achievement of real energy savings within the EU do have a price – but impacts on employment may remain positive

The anticipated strong uptake of RES-E deployment within the EU does have a price, but this is also accompanied by increased benefits. The price is that, compared to today, consumers have to pay more for their electricity consumed in the short- to mid-term.[1]

Parts of this cost burden may however be compensated by indirect effects that come along with the enhanced deployment of RES-E: From a consumer perspective a decrease of electricity prices can be expected due to the so-called "merit order effect" on the wholesale electricity (as well as on the carbon market)[2]. This price erosion on the wholesale electricity market may get substantial under the assumed enhanced RES-E expansion – it can be expected that this may lead to decrease electricity prices by about 10-15 €/MWh, and as such this may compensate about 30% to 50% of the increase in prices caused by the direct support for RES-E.

Benefits include the strong contribution of renewables to mitigate climate change, and, among others, the avoidance of fossil fuels and corresponding imports which goes hand in hand with a positive impact on Europe's trade balance. If policy interventions are properly designed and coordinated, a positive economic impact does not appear unlikely. This will contribute to strengthen the EU's competiveness and to increase employment and GDP in the mid-term. Innovation policy is therefore essential to strengthen the first-mover advantage of Europe's RES industries. If successful, these technologies can help the EU maintain a higher world market share in RES and a high net GDP increase.

The RES-E policy / market assessment discloses the need for corrective actions to bring RES "back on track" for meeting 2020 RES targets

It can be concluded that the short-term expectations of the energy [r]evolution study, i.e. the envisaged trend with respect to the RES-E uptake for the period up to 2020, appears too optimistic considering the existence of severe barriers that hinder a proper functioning of

1 A cost increase in the short- to mid-term is expected to come along with any type of climate mitigation measure. For example, as the recent discussions in the UK indicate, the build-up of new nuclear power plants that fulfil more stringent safety standards may be well in magnitude to offshore wind power – i.e. one of the more costly RES options as of today.

2 Note however, that both the merit order effect on electricity and CO_2 price are distributional effects between consumers and producers. These effects cause consumer profits on the one hand and losses for (conventional) producers. Therefore the benefit discussed above only exists from the consumers' point of view.

RES markets in several countries today. Removing currently prevailing barriers requires more time than anticipated in energy [r]evolution – but doing so appears imperative to assure an effective and from an economic perspective efficient deployment of renewable electricity in the near and mid future.

Key policy recommendations to enhance an effective and from an economic viewpoint efficient uptake of RES-E in the 2020 time horizon are:

- Apply best practice support system design and reduce investor risk
- Reduce non-economic barriers that limit a strong uptake of RES-E
- Apply technology-specific support at adequate levels

A clear commitment towards RES and ambitious binding RES targets are a necessity to achieve the ambitious 2030 RES-E deployment as anticipated

Binding national targets as defined by the RES directive (2009/28/EC) have created strong commitment for renewable energies throughout the EU and are the key driver for RES policies at the moment. Generally, they are a key element for setting up the administrative procedures, regulatory frameworks, regional planning and national infrastructure development. As these elements will also be crucial for the RES deployment after 2020, binding national targets appear an important element also for the period beyond 2020. Moreover, given the anticipated strong uptake of RES-E as necessary to compensate the supply gap arising from a nuclear power phase-out in Europe, binding (national) 2030 RES targets are a necessity if climate constraints are taken seriously.

The strong RES uptake puts the stable functioning of the EU's internal electricity market under challenge - complementary activities are of need to safeguard the process

Complementary to energy efficiency a strong uptake of RES in the electricity sector is required to pave the way to a nuclear power-free Europe, while maintaining the transition to a sustainable energy system in the mid- to long-term. Since meeting climate commitments represents a precondition for doing so, this already on-going transition process in parts of Europe has to accelerate in speed. It can be expected that this challenges the stable functioning of the EU's internal electricity market(s) as of today, and requires clear commitments across all societal levels. Strong and proactive policy action are ultimately required to define a level playing field for both RES and energy efficiency – but the list of policy actions has to tackle all areas and levels of the energy system and the society:

- A well-established carbon price to safeguard that climate commitments as otherwise dirty fossil fuels like lignite or coal are preferred against less carbon intensive sources
- An appropriate coordination of future targets for GHG, RES and energy efficiency
- Planning of network extensions that appropriately incorporates the strong RES uptake
- New market rules and appropriate incentives to assure that investments in complementary options like (fossil) back-up and storage capacities as well as network extensions are taken in forthcoming years
- Improved cross-border transmission policies to facilitate the efficient operation of the grid under increased RES penetration

Legal aspects of a European nuclear power phase-out

The legal part of this report focusses on the legal compatibility of possible national support schemes for the generation of electricity based on nuclear energy. The focus is laid on the provisions of the prohibition of state aids and its exemptions. The analysis is made against the background of the actual state aid modernization process, which was initialized by the EU Commission in May 2012, and the planned aid scheme for nuclear energy in the UK as part of the ongoing Electricity Market Reform.

In the field of nuclear energy the Treaty establishing the European Atomic Energy Community (Euratom Treaty) constitutes binding Primary law for all Member States of the European Union. The analysis of the interaction between the Euratom Treaty and the Treaty on European Union (the TEU) and the Treaty on the Functioning of the European Union (the TFEU) is of high relevance in various fields, but especially decisive when it comes to aspects of the common market. As the Euratom Treaty contains no provisions analogous to Article 107-109 TFEU, the application of the EU State aid law for the benefit of undertakings active in the nuclear energy sector is generally accepted. Any support scheme initialized by Member States to promote the further deployment of nuclear energy therefore falls under the general EU state aid rules.

As far as national support schemes by the Member States for nuclear energy constitute a state aid, it has to be assessed if there is an exemption from the general incompatibility of state aids with the common market. Though, the prohibition of state aid does not apply unconditionally and without exceptions. The TFEU knows a system of complex criteria of so called “facultative exemptions”, stated in Article 107 (III) TFEU. This article requires an in depth assessment of the compatibility of any state aid with the internal market and gives the Commission a wide discretion. As possible national support schemes for nuclear energy would not fall under one of the regulations guidelines, notices, communications etc., which were developed by the Commission in the last years, the measures could be declared only declared compatible with the common market if they are in line with the compatibility principles and pass the so called balancing test.

At the moment, the UK Government is planning the introduction of a support scheme, based on Feed-in Tariffs with Contracts for Difference (CfD). The European Commission opened an in-depth investigation on 18th of December 2013 to examine whether these are in line with EU state aid rules. The assessment of this scheme made in the report shows that the CfD scheme fails to be in line with the set out compatibility principles, so an exemption cannot be made. Especially, no common interest is given, there is no need for state aid and the appropriateness of the aid cannot be proven. Thus, the study concluded that the current UK aid mechanism proposal for the new nuclear power plant is incompatible with EU state aid regulations.

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Acronyms

BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit - A ministry of the Federal Republic of Germany
CCS	Carbon capture and storage
CfD	Contracts for Difference
CFI	Court of First Instance
CHP	Combined heat and power
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalents
CPS	Current Policy Scenario
CSP	Concentrated solar power
DG ENER	Directorate-General for Energy
DLR	Deutsches Zentrum für Luft- und Raumfahrt - German Aerospace Center
EACI	European Agency for Competitiveness and Innovation
EC	European Commission, the executive body of the European Union
ECI	European Citizens' Initiative
ECJ	European Court of Justice
EEA	European Environment Agency
EEG	Energy Economics Group
EEAP	Energy Efficiency Action Plan
ENTSO-E	European Network of Transmission System Operators for Electricity
EREC	European Renewable Energy Council
ESD	Directive on energy end-use efficiency and energy services
ESCO	Energy Service Company
EU	European Union
EU-15	European Union as of the 1 January 1995 to 30 April 2004 including 15 Member States
EU-27	European Union as of the 1 January 2007 to 30 June 2013 including 27 Member States
EU ER	European Union Energy Roadmap 2050
EU ETS	European Union Emission Trading Scheme
GBER	General Block Exemption Regulation
GDP	Gross domestic product
GHG	Greenhouse gas
Gt	Gigatonne
HVAC	High-voltage alternating current
HVDC	High-voltage direct current
IEA	International Energy Agency
kWel	Kilowatt electric
kWh	Kilowatt hour
LULUCF	Land use, land-use change, and forestry
Mtoe	Million tonnes of oil equivalent
MWh	Megawatt hour

NMS	12 EU Member States, which entered the EU between 1 May 2004 and 30 June 2013
NPS	New Policy Scenario
NREAP	National Renewable Energy Action Plan
NTC	Net transfer capacity
NTUA	National Technical University of Athens
O&M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
OHL	Overhead Lines
ppm	Parts per million
PV	Photovoltaics
UGC	Underground Cables
RES	Renewable energy sources
RES-E	Renewable electricity
RES-H	Renewable heat
SEI	Stockholm Environmental Institute
SUER	Stiftung Umweltenergierecht
TEU	Treaty on the European Union
TFEU	Treaty on the Functioning of the European Union
TWh	Terawatt hours
TYNDP	Ten-Year Network Development Plan
UCTE	Union for the Coordination of Transmission of Electricity, now ENTSO-E
UNFCC	United Nations Framework Convention on Climate Change
UNPD	United Nations Population Division
WEO	World Energy Outlook

1 Introduction

This report summarises the outcomes of the assessment of feasibility and impacts of a nuclear power phase out in Europe in the mid-term (up to 2030)

1.1 Rationale / Understanding

In general, the global commitment towards a more sustainable future energy supply portfolio yields several technical, economic and political new challenges. In this context, fundamental contributions are expected from renewable energy sources (RES) and from an increased mobilisation of energy efficiency/saving potentials, globally as well as at European level. The European Union (EU) has committed itself to reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050 in the context of necessary reductions by developed countries. As part of the European approach the European Council and Parliament have published the Directive 2009/28/EC on the support for renewable energies in 2009. This Directive established binding national targets for renewable energy to end up with a share of 20% stemming from renewable energy sources (RES) on Europe's energy consumption by 2020. Complementary to this, a new energy efficiency Directive 2012/27/EU is on the way to awake the currently still sleeping giant. And also in the long run RES and energy efficiency/savings are expected to take over a significant share under GHG emission reduction pathways. This view was confirmed by the European Commission in their European energy roadmap 2050 as published in December 2011 (EC, 2011b). The RES uptake has already experienced a significant boom over the last decade but this trend needs to be prolonged and strengthened to succeed in realising a sustainable low-carbon economy.

Other options for reducing greenhouse gas emissions in energy supply are nuclear energy and a carbon capture and sequestration (CCS) of fossil energy carriers. While possibilities and prospects for CCS remain uncertain, nuclear energy has deserved strong attention in the public debate. The Fukushima accident in 2011 has intensified criticism and triggered fears related to nuclear safety.

1.2 Objectives, research questions and expected results

The core objective of this study is to conduct an analysis of the impacts of a gradual exit from nuclear power up to 2030 within the European Union, assuming that long-term climate targets shall be met, as well as an identification of the related energy-political requirements. This meta-study, builds on related existing modelling work (i.e. the study "energy [r]evolution, a sustainable EU 27 energy outlook" (Teske et al., 2012a)) and on an extensive literature-review in which prestigious

European studies on meeting long-term climate, RES or energy efficiency targets and related aspects (RES, energy efficiency, infrastructural prerequisites), focused on the electricity sector, are examined for derivable implications at European level. Furthermore the study derives recommendations for practical policy implementation in accordance with the above mentioned European targets.

A list of key research questions related to a Europe-wide gradual phase-out of nuclear energy in the mid-term (2030) involves:

- Which potentials do exist for RES in the EU?
- Which potentials do exist for energy efficiencies/savings in the EU?
- Based on above, how can the supply gap by 2030 (compared to “energy [r]evolution”) and beyond be compensated by a faster growth of renewable energy sources (RES) or by an effective application of energy efficiency/saving strategies?
- What are the key implications on electricity grids / infrastructural prerequisites?
- What are the key implications on electricity prices?
- What (gross) impacts on employment can be expected through the accelerated deployment of RES (and energy efficiency)?
- Which country-specifics have to be considered?
- What are the legal aspects of a nuclear power phase-out until 2030 in the EU?

This report shall outline a limited set of feasible pathways for meeting the overall objective of a nuclear power phase-out at EU level by 2030 under the precondition to achieve long-term climate commitments. Furthermore, the report shall broadly discuss related implications by tackling the questions raised above.

1.3 Structure of this report

To begin with, Chapter 2 presents an energy scenario analysis, which puts the before mentioned energy [r]evolution EU 27 Advanced scenario (energy [r]evolution scenario) (Teske et al., 2012a) in context with other recently published energy scenarios, foremost with three scenarios of the EU 2050 Energy Roadmap (EC, 2011b), two scenarios of Europe’s Share of the Climate Challenge published by the Stockholm Environmental Institute (Heaps et al., 2009), and the European figures of three scenarios discussed in the World Energy Outlook 2012, published by the International Energy Agency (IEA, 2012). This first step serves to critically review the energy [r]evolution scenario, which constitutes a nuclear phase-out scenario for the European energy sector until 2035. In a second step policy implications for the two main pillars of energy efficiency and renewable energy sources of the European climate mitigation strategy, in accordance with the worldwide 2-degree stabilisation target, and for a mid-term nuclear power phase-out are discussed in Chapter 3. The overall prerequisites and implications for the European electricity sector are dealt with in Chapter 4. Legal aspects of a nuclear phase-out are then discussed in Chapter 5. The report concludes in Chapter 6 with a summary as well as a list of key conclusions and recommendations.

2 Scenario analysis

In order to analyse the impacts of an EU-wide phase-out from nuclear power until 2030 and to derive policy recommendations this meta-study builds on related existing modelling work and on an extensive literature review. As such the scenario analysis forms an important starting point, to compare and construe diverse scenario frameworks and outcomes in respect to one another.

A key pillar this analysis refers to forms the study “energy [r]evolution” (Teske et al., 2012a), including available background data at EU level (Greenpeace and EREC[3], 2012). This study together with the therein sketched “energy [r]evolution Advanced scenario” illustrates the feasibility and implications of a RES-based sustainable energy system in line with the international climate mitigation targets and including a nuclear power phase-out for the EU until 2035. Two key options appear of relevance for filling the supply gap: a faster growth of RES and/or an effective application of additional energy efficiency/saving strategies compared to a reference or a current policies scenario respectively. The energy [r]evolution scenario will serve as basis for own elaborations on how a full phase-out of nuclear energy may become feasible at EU level already at an earlier stage (i.e. by 2030 instead of 2035).

The scenario analysis in this chapter is accomplished by an intensive literature survey in order to put the existing outcomes of a nuclear power phase-out for Europe into perspective. Furthermore it forms a basis for assessing possibilities (RES, energy efficiency), implications (price impact, power system stability, impact on (gross) employment) and requirements (grid extension and storage) for the following chapters in this meta-study. As such contrasting and comparing the energy [r]evolution scenario with other key sources of the energy scenario literature in a detailed manner forms an important part of this chapter.

Key studies and assessments that offer prospects on the European energy supply and/or demand will be examined on statements according to the following points:

- Underlying assumptions (e.g. regarding economic growth, population, energy and electricity consumption growth, oil and energy price development, etc.)
- Quantitative structure of energy mix with a focus on the electricity sector (e.g. development of supply and demand over time, supply breakdown by technology)
- Energy policy implications
- Further aspects (e.g. use of innovative technologies, time frame etc.)

This chapter discusses the differences and key outcomes of the assessed scenario literature, focussing on those studies and assessments that have provided a general view on how Europe’s energy

[3] EREC - the European Renewable Energy Council

system may evolve in the mid- to long-term[4]. In a first step this chapter starts with an introduction of the essential literature. In Section 2.1 the therein sketched climate- and energy policy assumptions and according non-policy forecasts are presented. These non-policy suppositions are separated in future socioeconomic development assumptions, which act as driving forces for the European energy consumption. Thereafter estimates by the scenario literature for the forthcoming energy and CO_2 price developments are discussed critically.

In a second step the outcomes of the different modelling work included in the discussed scenario literature are put into perspective. This is done by a comparison of the central energy- and climate-specific indicators. Future developments of the European electricity sector, sketched by included scenarios, are presented in Chapter 2.3. At last a comparison of the cost assessments if included in the literature at European level is offered in Chapter 2.4.

2.1 Assessed scenario literature and underlying policy assumptions

Aside from the study “energy [r]evolution – A sustainable EU 27 energy outlook” (Teske et al., 2012a) as conducted by (and on behalf of) Greenpeace and EREC, the European Commission’s “Energy Roadmap 2050 - Impact assessment and scenario analysis” (EC, 2011b), “Europe’s Share of the Climate Challenge” published by the Stockholm Environmental Institute (Heaps et al., 2009), and the International Energy Agency’s (IEA) “World Energy Outlook 2012” (IEA, 2012) form the central scenario literature for this report. The scenarios sketched therein describe possible pathways of a future energy supply system for Europe, and partly globally. The overall range of pathways indicated appears broad, but not all of them are compatible with long-term climate targets. The range narrows down significantly if the overall objective of this study (to indicate possibilities and implications of a nuclear power phase-out) is taken into consideration. Before digging into the detailed literature review and scenario comparison, the aim of this subsection is to provide a concise introduction to the before mentioned literature, also discussing their central motivations.

2.1.1 energy [r]evolution (Greenpeace and EREC, 2012)

The 2012 edition of the EU 27 energy [r]evolution study (Teske et al., 2012a) presents a blueprint on how to achieve a more sustainable energy system in Europe in the short term as well as for future generations. The publication of October 2012 is a geographically specific analysis of the fourth edition of the global energy [r]evolution study which was published in July 2012 (Teske et al., 2012b). The therein sketched energy [r]evolution Advanced scenario is designed to achieve a set of global environmental- and climate policy targets. As a key target the worldwide carbon dioxide (CO_2) emissions from energy use are reduced by 2050 to a level of below 4,000 million tonnes (Mt) per year (Teske et al., 2012a, 39) form 30,190 Mt CO_2 from the year 2010 (IEA, 2012, 554). This constitutes a reduction of the global CO_2 emissions from energy use of 86.6% and represents a necessity in order to hold the increase in average global temperature under +2°C. A second target is a global nuclear

[4] Note that detailed topical assessments as conducted with respect to renewables and / or energy efficiency / savings as well as with respect to specific aspects such as network developments or employment impacts are added subsequently in Chapter 3 and 4. Therein additional scenarios of for example the future RES deployment or of the utilisation of energy efficiency measures are discussed where adequate.

power phase-out by 2050. The combination of these two targets is accomplished by a worldwide electricity generation which will be based by 61% on renewable energy sources (RES) by 2030 and 94% RES by 2050 (Teske et al., 2012b, 78). These global objectives translate to a specific carbon budget up to the year 2050 and a phase-out of nuclear power by 2035 for the European Union (Teske et al., 2012a, 39).

To see exactly what these global and European targets imply for the EU 27 countries, a brief overview on the European energy [r]evolution Advanced scenario is undertaken, see Box 1. As outlined in the introduction of this chapter, contrasting and comparing the energy [r]evolution scenario with other key sources in a detailed manner forms an important part of this scenario analysis.

Box 1. Overview on energy [r]evolution scenarios

energy [r]evolution scenarios at a glance

The **EU-27 energy [r]evolution reference** scenario is reflecting a continuation of current socioeconomic trends and policies. It is based on the 2011 edition of the Current Policies scenario published by the International Energy Agency (IEA) in the World Energy Outlook 2011 (WEO, 2011). It only takes existing international energy and environmental policies into account. Its assumptions include, for example, continuing progress in electricity market reforms, the liberalisation of international energy trade and recent policies designed to combat environmental pollution. The Reference scenario does not include specific policies to reduce greenhouse gas emissions. As the IEA's projections only range to 2035, they have been extended by extrapolating its key macroeconomic and energy indicators forward to 2050 (Teske et al., 2012a, 39). This scenario is thought to provide a baseline for comparison with the energy [r]evolution Advanced scenario.

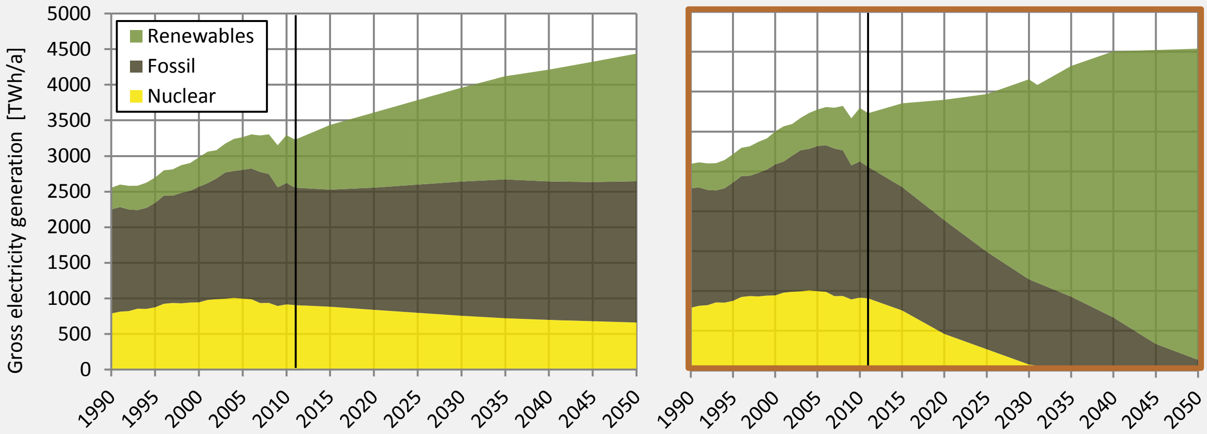

Figure 2-1. Historical (until 2011) and projected generated electricity to 2050 of energy [r]evolution Reference (left) and Advanced screnario (right) in comparison. (Eurostat, 2013e; Greenpeace and EREC, 2012)

The **EU-27 energy [r]evolution Advanced scenario** is designed to achieve a set of environmental policy targets. The energetic CO_2 emissions are reduced by 95% compared to 1990, which is in line with the EU's proposed greenhouse gas reduction target (EC, 2009, 3) and the internationally agreed on 2-degree climate stabilization target (UNFCCC, 2011, 3).

To achieve the target, the scenario includes significant efforts to fully exploit the large potential for energy efficiency, using currently available best practice technology. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation (see Figure 2-1) as well as the production of biofuels. The general framework parameters for population and economic growth remain unchanged from the Reference scenario. The sectorial explicit European energy [r]evolution electricity scenarios are appended in The Annex A.1. (Teske et al., 2012a, 39)

Assumptions for the heating sector include a fast expansion of the use of district heat and electricity for process heat in industrial sectors. Geothermal heat pumps are also included the generation of heat, which leads to a higher overall electricity demand, when considering a larger share of electric cars for transport as well. A fast expansion of solar heating systems is also assumed. (Teske et al., 2012a, 39)

Hydrogen generated by electrolysis complementary to biofuels and direct use of renewable electricity is introduced in this scenario as a third fuel option in the transport sector after 2025. Besides hydrogen is applied as a chemical storage medium for electricity from renewables and used in industrial combustion processes and cogeneration for the provision of heat and the reconversion into electricity. Hydrogen generation can have high energy losses. However the limited potential of biofuels and probably batteries as an energy storage option for electric mobility it is necessary to have a third option for renewable energies entering the transport sector at least in the long run. Alternatively, this renewable hydrogen could be converted into synthetic methane or liquid fuels depending on economic benefits (storage costs vs. additional losses) as well as technology and market development in the transport sector (combustion engines vs. fuel cells). (Teske et al., 2012a, 39)

The latest market development projections of the renewable energy industry have been taken into account for the assessment of this scenario. The fast introduction of electric vehicles, combined with the implementation of smart grids and fast expansion of super grids allows a high share of fluctuating renewable power generation (photovoltaic and wind) to be employed. The global scenario projects renewable energy to pass 30% of the global energy supply just after 2020 (Teske et al., 2012b, 48). The EU 27 energy [r]evolution Advanced scenario shows that supplied renewable energy would pass 20% of the EU's energy supply before 2020, what exceeds the energy policy goals of the EU's 20-20-20 directive (2009/28/EC). The quantities of biomass power generators and large hydro power remain limited in the new energy [r]evolution Advanced scenario, for reasons of ecological sustainability. (Teske et al., 2012a, 39)

The energy [r]evolution scenarios were jointly commissioned by Greenpeace and the European Renewable Energy Council (EREC) from the Systems Analysis group of the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model. The new energy demand projections were developed from the University of Utrecht, Netherlands, based on an analysis of the future potential for energy efficiency measures in 2012. The assumed biomass potential, judged according to Greenpeace sustainability criteria, has been developed by the German Biomass Research Centre in 2009. The forthcoming development for car technologies is based on a special report produced in 2012 by the Institute of Vehicle Concepts, DLR for Greenpeace International. Finally the Institute for Sustainable Futures (ISF) analysed the employment effects of the energy [r]evolution reference and Advanced scenarios. (Teske et al., 2012a, 40)

2.1.2 EU Energy Roadmap 2050 (European Commission, 2011)

In 2011 the European Commission published the Energy Roadmap 2050. Therein it was concluded that the current energy system and ways of producing, transforming and consuming energy are unsustainable due to following reasons (EC, 2011b, 8): About 80% of the EU's greenhouse gas (GHG) emissions of 2011 originate from the energy sector according to the accounting of the United Nations Framework Convention on Climate Change (UNFCCC) (EEA, 2013a, 12). Economic competitiveness is at risk if energy prices are higher compared to other world regions, and if the energy sector suffers from underinvestment. At last a reason for the unsustainability of the EU's energy system is the security of its supply (EC, 2011b, 9):

- The EU is highly dependent on imported foreign energy sources, which will slightly increase by 2050 rendered by projections, including supplies from politically unstable regions.
- Gradual depletion of fossil fuel resources and rising global demand increase the competition for known resources.
- Increasing electrification from more variable sources as solar photovoltaics (PV) and wind opens new challenges to the grid to ensure uninterrupted electricity deliveries.
- Low resilience to disasters and adverse effects of climate change;

The EU Energy Roadmap 2050 provides a framework for policy makers to move to low-carbon, domestic and more diversified sources of energy, produced and consumed in an efficient way (EC, 2011b, 9). The move toward this direction should bring significant benefits not only for the environment, the competitiveness, and the security of energy supply but also in terms of economic growth, employment, regional development, and innovation (EC, 2011b, 9). Furthermore barriers for the on-going energy system transformation have to be identified to realize a more sustainable energy supply in the near future.

2.1.3 World Energy Outlook 2012 (International Energy Agency, 2012)

The yearly published World Energy Outlook (WEO) by the International Energy Agency (IEA) in the edition of 2012 (IEA, 2012) forms the third extensively discussed energy scenario literature in this study. Even though the therein discussed scenario modelling work focuses on the global perspective, actual data and projections for the EU 27 countries up to the year 2035 is included in great detail and thus builds a good prospect to compare projected energy system developments. Within this report, the New Policy Scenario (NPS) forms an outlook for currently planned policies, if implemented in a relatively cautious way (IEA, 2012, 52). It should as such provide a benchmark for currently planned or potential achievements of recent developments in the global energy and climate policy (IEA, 2012, 35). The Current Policies Scenario (CPS) assumes no implementation of policies beyond those adopted by mid-2012. The CPS has the objective to provide a baseline that shows how energy markets would evolve if underlying trends in energy demand and supply are not changed (IEA, 2012, 35). The 450 Scenario forms an energy scenario including a global climate mitigation strategy consistent with having around a 50% chance of limiting the global average temperature increase to 2°C in the long term, compared to pre-industrial levels. It should demonstrate a plausible path to achieve the 2 degree target (IEA, 2012, 35). As a comparison the IEA projects a long-term temperature increase of 3.6°C above pre-industrial levels for the NPS and 5.3°C for the CPS (IEA, 2012, 52).

2.1.4 Europe’s Share of the Climate Challenge (Stockholm Environmental Institute, 2009)

The study “Europe’s Share of the Climate Challenge” published in November 2009 by the Stockholm Environmental Institute (SEI) examines how Europe can show political leadership and courageous policy initiatives to fulfil its part in the combat against global climate change: firstly, by undertaking domestic actions to rapidly reduce emissions of GHGs, and secondly, by fulfilling its international obligations to help other nations address the twin crises of climate change and development. A detailed mitigation scenario is presented sector-by-sector for all 27 EU countries that can achieve GHG emissions reductions of 40% in 2020 and 90% in 2050 relative to 1990 levels. This is achieved by a combination of radical improvements in energy efficiency, an accelerated retirement of fossil fuels and a dramatic shift toward various types of renewable energy, including wind, solar, wave, geothermal and biomass-based combined heat and power (CHP). (Heaps et al., 2009, 1)

The mitigation scenario presents a detailed bottom up assessment of the technologies and key policy options that can be enacted in each of the major GHG emitting sectors of the economy: buildings, industry (energy and process emissions), transport, electric generation, combined heat and power, solid waste, land use, and agriculture. A deliberately conservative approach is taken by only including options that are either already commercially available, or which are in development in present days and are expected to become commercialised in the coming 20–30 years. Potentially future technological pathways such as hydrogen fuel cells and second generation biofuels, which appear to be many years away from large-scale market penetration, are excluded. Options such as electric vehicles as key components for GHG mitigation in the transport sector are includes for the period of 2020–2050. (Heaps et al., 2009, 1-2)

To conclude the introductory part of the scenario assessment, Box 2 offers a brief glossary of assessed scenarios.

Box 2. Overview and glossary of assessed scenarios

A brief glossary of assessed scenarios

Principal scenario literature (Teske et al., 2012a; Heaps et al., 2009; EC, 2011b; IEA, 2012)	Acronym used in figures
energy [r]evolution EU-27 Advanced Scenario	energy [r]evolution Adv
energy [r]evolution EU-27 Reference Scenario	energy [r]evolution Ref
Europe’s Share of the Climate Challenge Mitigation Scenario	SEI Mitigation
Europe’s Share of the Climate Challenge Baseline Scenario	SEI Baseline
EU Energy Roadmap 2050 High RES Scenario	EU ER High RES
EU Energy Roadmap 2050 High Energy Efficiency Scenario	EU ER Efficiency
EU Energy Roadmap 2050 Reference Scenario	EU ER Reference
World Energy Outlook 2012 450 ppm Scenario	WEO 2012 450
World Energy Outlook 2012 New Policy Scenario	WEO 2012 NPS
World Energy Outlook 2012 Current Policy Scenario	WEO 2012 CPS

2.1.5 Non-policy assumptions of assessed scenarios

2.1.5.1 Socioeconomic developments

Economic growth is a key factor for energy demand. Though there is no consensus on the causality in the respective research reached yet. Some conclude that there is evidence for a bi-directional causal relationship between energy use and economic output (Dedeoglou and Kaya, 2013, 475). The applied GDP growth rates in the discussed scenario literature are therefore an important factor for the projected energy demand. In addition future population development is an important cause in energy scenario building because population size affects the composition of energy demand, directly and through its impact on economic growth and development (Teske et al., 2012a, 40).

The world population in the global energy [r]evolution scenarios is based on the United Nations Population Division (UNPD) World Population Prospects 2010 (Teske et al., 2012a, 40; UNPD, 2011). The specific projection for the EU 27 population is used for the energy [r]evolution scenarios in the year 2035 at 516.1 million inhabitants. The rates of population growth assumed for the EU in the WEO 2012 are also based on the World Population Prospects 2010 (IEA, 2012, 39; UNPD, 2011). For all scenarios of the EU Energy Roadmap 2050 the projection by Eurostat EUROPOP2008 convergence scenario was applied (EC, 2011b, 50), which was moreover used in the Aging Report 2009 (EC, 2009). The EU Energy Roadmap projection peaks in 2035 as the projection for the energy [r]evolution study at 521 million inhabitants. The projected EU 27 population in SEI scenarios has the lowest growth rates to begin with. The peak already takes place in 2020 with a maximum population of 498 million people (Heaps et al., 2009, 55). The latest population projection by Eurostat, included in Figure 2-2 on the left, projects a population peak for the year 2040 at 525.7 million people (Eurostat, 2013a). This later peak results in a significantly higher EU 27 population for the year 2050 compared to all other scenario projections.

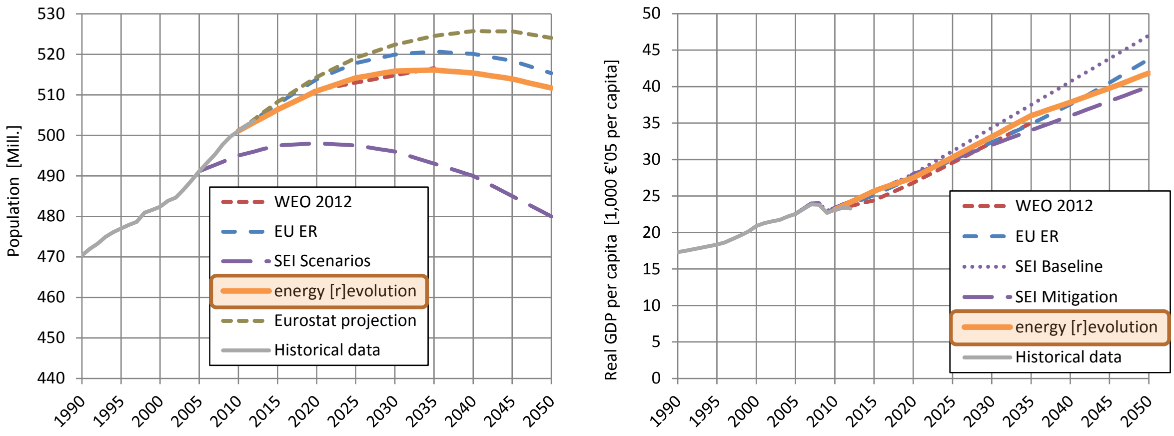

Figure 2-2. EU 27 Population and gross domestic product (GDP) per capita projections. (EC, 2011b, 159; Eurostat, 2013a, 2013b, 2013f; Heaps et al., 2009, 55; IEA, 2012, 37-39; Teske et al., 2012a, 40)

Figure 2-2 on the left depicts the population developments assumed for the presented scenarios. The growth rates in the EU Energy Roadmap 2050 are higher than the ones in the energy [r]evolution and WEO, but the difference of about 4 million people for the EU-27 countries in 2035 and 2040 should not have a serious impact on the energy modelling results. The population difference between energy [r]evolution and the EU Energy Roadmap is reduced to 3 million in the year 2050. The population projection used in the SEI study, lies significantly below all other included estimates, what may result in an underestimated energy demand for the EU 27 countries. In 2050 the energy [r]evolution population level is 12.4 million below the latest Eurostat projections. The EU energy Roadmap 2050 shows a difference of minus 8.5 million people compared to Eurostat. The SEI scenarios estimate 44 million less people for 2050 than the latest Eurostat projection.

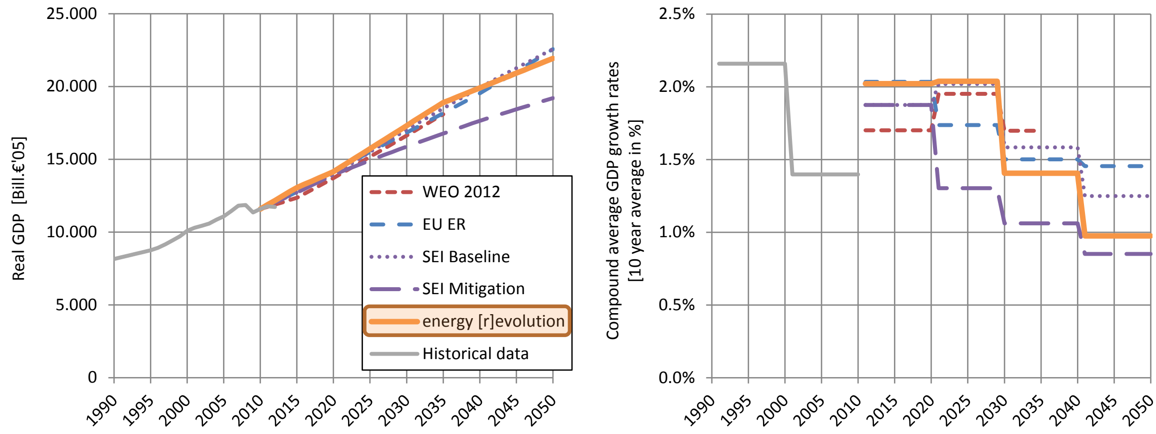

Figure 2-3. **Real GDP projections based in constant €'05 on the left with the respective compound average annual growth rates of GDP on the right. (EC, 2011b, 159; Eurostat, 2013b; Heaps et al., 2009, 55; IEA, 2012, 37-39; Teske et al., 2012a, 40)**

All included scenarios assume that the recent economic crises has long lasting effects, leading to a permanent loss in GDP compared to a short stagnation/loss in GDP and a bounce back shortly after the crisis to the former GDP growth path. Hence the GDP development is comparable to the "sluggish recovery" presented in the Europe 2020 strategy: A strategy for smart, sustainable and inclusive growth (COM(2010) 2020, 9). This scenario of the mentioned document sketches a future GDP growth where the growth rate of 2010 to 2020 is similar to the growth rate from 1990 to 2000 and no rebound effect after the economic crisis is included.

Table 2-1. **Compound average annual growth rates of GDP projections in real terms (constant €'05). (EC, 2011b, 159; Eurostat, 2013b; Heaps et al., 2009, 55; IEA, 2012, 37-39; Teske et al., 2012a, 40)**

Literature	Scenario	1990 - '00	2000 - '10	2010 - '20	2020 - '30	2030 - '40	2040 - '50
History		2.2%	1.4%				
energy [r]evolution	all			2.0%	2.0%	1.4%	1.0%
Europe's Share of the Climate Challenge	Baseline			1.9%	2.0%	1.6%	1.2%
	Mitigation			1.9%	1.3%	1.1%	0.9%
EU Energy Roadmap 2050	all			2.0%	1.7%	1.5%	1.5%
IEW WEO 2012	all			1.7%	2.0%		

As seen in Table 2-1 and in Figure 2-3 on the right the energy [r]evolution and the EU Energy Roadmap assume a slightly higher growth rate of 2.0% for the 2010 to 2020 period, whereas the WEO 2012 and SEI scenarios slightly lower rates of 1.7% and 1.9%. The growth rates of the energy [r]evolution are based on the World Energy Outlook 2011 (Teske, 2012, 40), but the assumptions between the 2011 and 2012 editions were revised to a somewhat slower GDP growth (IEA, 2012, 37). For the 2020 to 2030 and 2030 to 2040 periods the growth rates are virtually equal in all the studies, with the exception of the SEI mitigation scenario, which projects a slower growing economy form 2020 onwards with a difference of minus 0.4 percentage point compared to the EU Energy Roadmap for every decade. From 2040 to 2050 the energy [r]evolution GDP growth rates come down to 1.0% compared to steady 1.5% from 2030 onwards for the Energy Roadmap 2050. But as with the slightly different population numbers these marginally different dynamics in GDP development should not alter the comparability of the scenario results, except for the SEI mitigation scenario. This can also be seen in the Figure 2-2 on the right, where the GDP per capita development for the EU-27 is presented. The higher GDP growth and lower population growth of the energy [r]evolution scenario up to 2035 is compensated thereafter by the lower GDP growth and slower population reductions when compared to the EU Energy Roadmap 2050. The GDP per capita projections equal each other with the exception of the SEI scenarios around the year 2045.

The SEI assumptions for a lower GDP, seen in Figure 2-3 on the left, and a lower GDP per capita in Figure 2-2 on the right are that consumption of resources cannot continue to expand indefinitely. Sooner or later the richer countries and people of the world will need to find new ways of living that recognise the importance of sufficiency: living well without expecting ever continuing growth in consumption (Heaps et al., 2009, 10). So, while the mitigation scenario might have slightly lower economic consumption than the baseline scenario, it can still be assumed that higher welfare gains are realized through positive lifestyle changes such as more leisure (nonworking) time, better health, and greater opportunities for satisfying social connections (Heaps et al., 2009, 11).

The GDP projections of the WEO and energy [r]evolution were presented in the form of purchasing power parity exchange rates opposite to the EU Energy Roadmap where the GDP is noted in market exchange rates. For comparison all GDP values were converted to Euro noted in fixed 2005 market exchange rates. All monetary values in this chapter represent either 2005 or 2010 real values i.e. yearly inflation is not included.

2.1.5.2 Energy and CO_2 price developments

The prices of energy carriers as well as of final energy services define their future consumption. Actual and expected prices for each energy carrier affect the consumer choice of technology used to provide a particular energy service as well as the amount to consume these services. Energy and CO_2 prices affect the producer's production and investment decisions. A higher CO_2 price has also consequences for consumers, as energy intensive products as cars or the electricity generation based on fossil fuels will become relatively more expensive.

The energy import-price assumptions of the energy [r]evolution are anticipated to be slightly higher than those of the WEO 2011 CPS and are extrapolated forward from 2035 to 2050 (Teske et al., 2012a, 41). For the WEO 2012 the energy price projections are different for each scenario. This is a result of differing dedicated government policies that affect demand and supply of each fuel, aiming to reflect different global policy developments[5]. To keep the consumption rebound in the WEO

[5] Energy prices are exogenous to the IEA World Energy Model. Prices are only adjusted in an iterative manner, to ensure that demand and supply are in balance in each year of the projection period (IEA, 2012, 40).

450 scenario to a minimum, end-user prices for oil-based transport fuels are kept at a level similar to those in the Current Policies Scenario through administrative arrangements (price controls or higher taxes) (IEA, 2012, 40). The SEI study (Heaps et al., 2009) refers for projections for included energy prices to the World Energy Outlook 2008 (IEA, 2008b), combined with estimates of current and future technology costs drawn from a variety of sources including the IEA's Energy Technology Perspectives Report (IEA, 2008a), supplemented with additional estimates (Heaps et al., 2009, 42). As such the SEI Scenarios in Figure 2-4 and Figure 2-5 represent projections of the World Energy Outlook 2008 (IEA, 2008b, 68) up to 2030, combined with the respective trends of the projections presented in Energy Technology Perspectives Report (IEA, 2008a, 573),

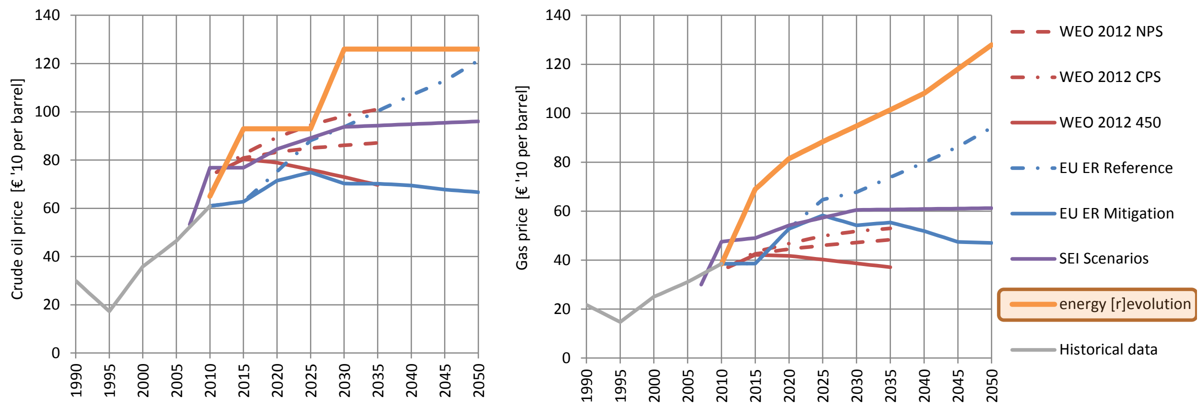

Figure 2-4. Assumed crude oil and gas prices by scenario[6]. (EC, 2011b, 55; IEA, 2008a, 574; IEA, 2008b, 68; IEA, 2012, 41; Teske et al., 2012a, 41-42)

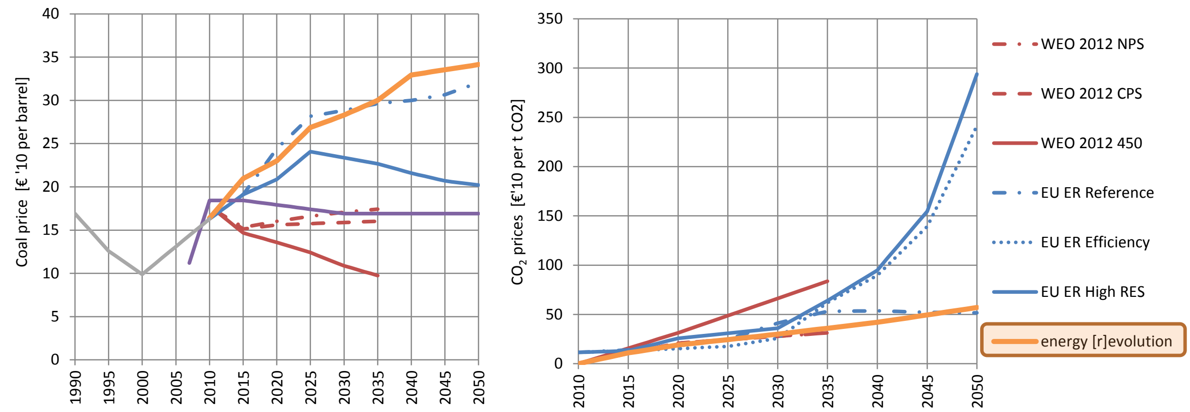

Figure 2-5. Assumed coal and CO_2 prices by scenario. (EC, 2011b, 35; Heaps et al., 2009, 55; IEA, 2008a, 574; IEA, 2008b, 68; IEA, 2012, 46; Teske et al., 2012a, 41-42)

All low-carbon scenarios of the EU Energy Roadmap 2050 are conducted under the hypothesis that the whole world commits itself to mitigate their carbon emissions, leading to a lower demand for fossil fuels and subsequently lower import-prices (EC, 2011b, 44). Figure 2-4 shows the international oil price projection on the left and gas price development for Europe on the right for all three studies and scenarios conducted therein. Figure 2-5 displays the international coal price and the CO_2 price developments. There are two different price projections for the EU Energy Roadmap scenari-

6 Energy and CO_2 prices are all quoted in € 2010 (€ '10) in real terms. The price development assumptions are linear interpolations of relating numbers extracted from cited reports.

os. One refers to the reference case and one to the low-carbon or mitigation scenarios. The two mitigation scenarios which are discussed in this chapter are the High RES (High Renewable Energy Sources) and the High Energy Efficiency scenario. The CO_2 price for these two scenarios is slightly different (see Figure 2-5 on the right).

The CO_2 price estimates for the energy [r]evolution scenario are rather conservative with 57 €'10 per tonne CO_2 for the year 2050. Unlike other studies the prices are not reflecting estimates of the external total costs of greenhouse gas (GHG) emissions (Teske et al., 2012a, 44). Emission pricing and related costs are also not used (nor modelled) as dominant variable that affects our patterns of energy consumption and/or supply (as this may be the case in the WEO and PRIMES energy model). Instead the authors argue that dedicated energy policy measures are of need: a comprehensive package of legislative regulatory measures are quoted in the report including regulations in the transport sector (Teske et al., 2012a, 120), agriculture and biomass sector guidelines (Teske et al., 2012a, 104), and RES support schemes including sustainability criteria (Teske et al., 2012a, 100). Generally a phase-out of nuclear energy and fossil fuels is assumed (Teske et al., 2012a, 63). In a similar manner the authors assume a constant (or growing) public acceptance of RES technologies although they would become more visible for the consumer (Teske et al., 2012a, 100).

2.2 Scenario results

The GHG mitigation or low-carbon scenarios as the energy [r]evolution Advanced scenario, the High RES and High Energy Efficiency scenario of the Energy Roadmap, and the WEO 450 ppm scenario show substantial reductions of primary energy consumed. The EU scenarios and the energy [r]evolution scenario indicate comparable reduction rates, while the WEO 450 is less steep. This is the case because of less strict energy efficiency policies adapted by the WEO as discussed in Chapter 3.1 and shown in Figure 3-3.

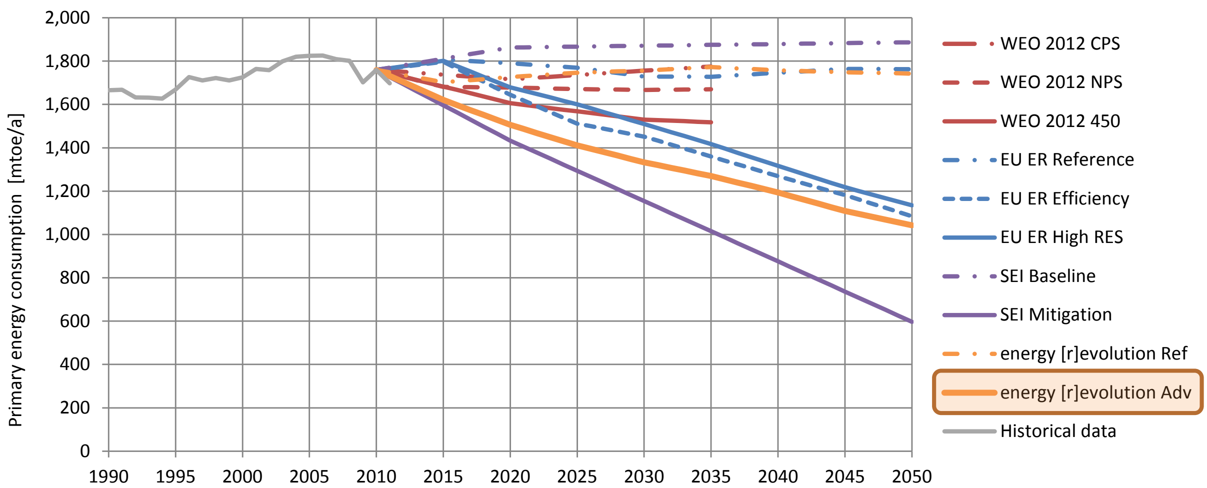

Figure 2-6. Primary energy consumption projections. (EC, 2011b, 158-175; Eurostat, 2013d; Greenpeace and EREC, 2012; Heaps et al., 2009, 57; IEA, 2012, 572-575)

The SEI reference correspondingly mitigation scenarios mark the upper- respectively lower-bound of primary energy consumption in Figure 2-6. One cause for the lowest primary energy consumption in the SEI mitigation scenario is the most intensive application of energy efficiency measures. A second reason may be that a lower GDP per capita compared to the remaining scenarios, results in lower consumption of goods and services, what consequences in a lower demand of energy. The same can be said about the SEI reference scenario, which assumes the highest GDP per capita and projects the highest consumption of primary energy.

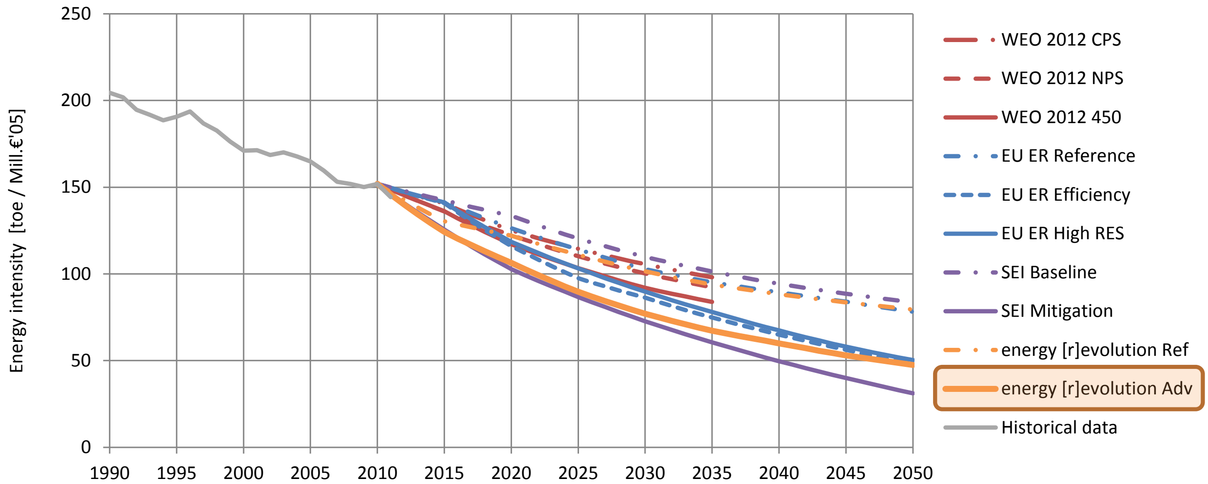

Figure 2-7. Energy intensity. (EC, 2011b, 158-175; Eurostat, 2013b, 2013d; Greenpeace and EREC, 2012; Heaps et al., 2009, 55-57; IEA, 2012, 572-575; Teske et al., 2012a, 40)

The primary energy consumption divided by the GDP of each year is described to be the energy intensity of the economy and is used as an indicator for the energy efficiency. The historic development and all scenarios from 2010 onward show a downward trend. The SEI mitigation scenario draws the lowest energy intensity and is as such the most energy efficient scenario in the long run. The change in the trend from 2010 ahead seems not as dramatic and as such realizable. The problem with this assumption is that the shrinking energy intensity in the EU 27 countries over the period of 1990 to 2010 was not only a result of higher energy efficiency for the same output, but as well an outcome of economic change from industry intensive economies to more service oriented economies, what is particularly true for Eastern European countries. In any case, energy or environmental policy aiming at reducing energy consumption should be designed to do this through energy-intensity reduction (Dedeoglou and Kaya, 2013, 476).

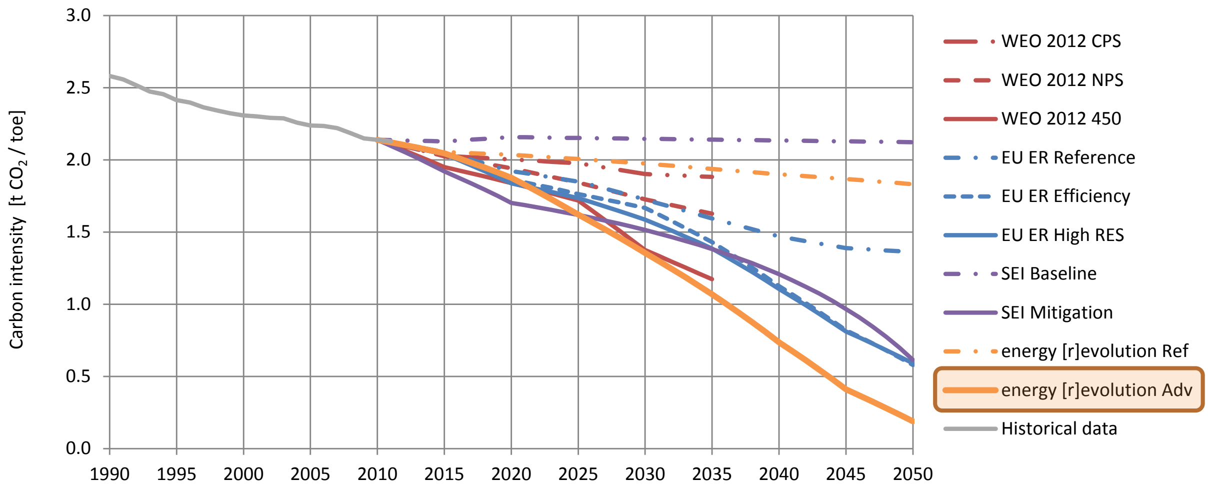

Figure 2-8. Carbon intensity. (EC, 2011b, 158-175; Eurostat, 2013d; EEA, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 55-57; IEA, 2012, 572-575)

The carbon intensity depict in Figure 2-8 is an indicator of the energy supply system, which represents the energetic carbon emissions divided by primary energy consumption. The historical trend is only slightly sloped downward in opposition to the projected developments of all mitigation scenarios. Only a shift to low-carbon technologies in all sectors of the European economy will make as low intensities possible as the energy [r]evolution in 2050 presumes. Only on tenth of the carbon is emitted for the same amount of energy consumed in the energy [r]evolution Advanced scenario in 2050.

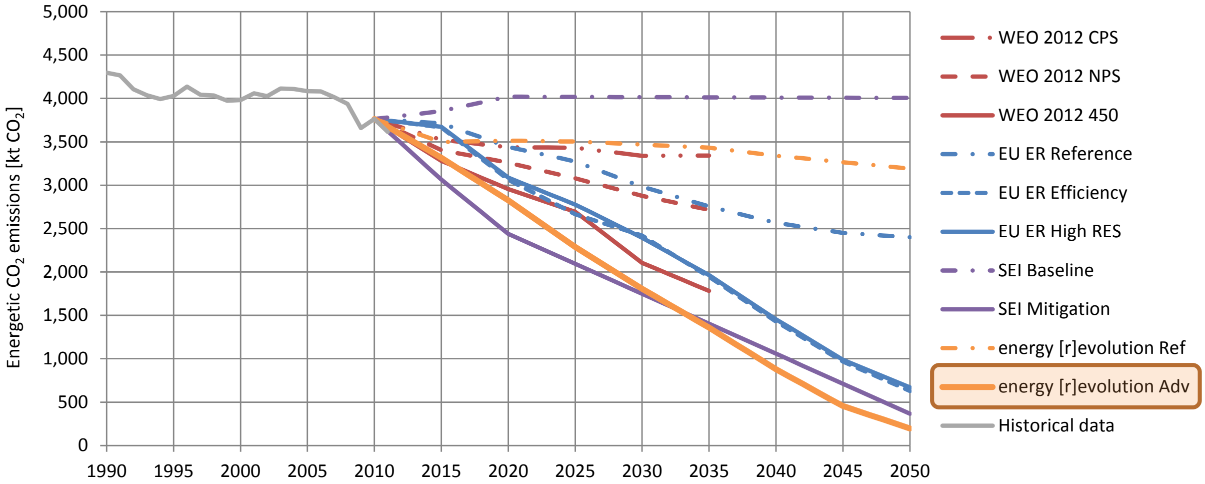

Figure 2-9. Energetic CO_2 emission projections. (EC, 2011b, 158-175; EEA, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 57; IEA, 2012, 572-575)

The decarbonisation process of the energy system and change in trend from 2010 onwards is visible in Figure 2-9 even more drastically than it is the case with the development of the European energy efficiency or the carbon intensity in Figure 2-8. Table 2-2 compares the projected carbon emissions with the year 2005, when the energetic carbon emissions where only slightly lower than in 1990, the base year for the Kyoto protocol. It shows the highest reduction of energetic CO_2 emissions for the energy [r]evolution Advanced scenario with -95% compared to 2005.

Table 2-2. Rduction of energetic CO_2 emissions with 2005 as base year. (EC, 2011b, 158-175; EEA, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 57; IEA, 2012, 572-575)

Energetic CO_2 reductions	2005- 2010	2005 - 2020	2005 - 2030	2005 - 2040	2005 - 2050
History	9%				
energy [r]evolution Ref		11%	12%	15%	19%
energy [r]evolution Adv		28%	54%	78%	95%
SEI Mitigation		38%	56%	73%	91%
EU ER Reference		13%	24%	35%	39%
EU ER Energy Efficiency		22%	39%	63%	84%
EU ER High RES		22%	39%	64%	83%
WEO 2012 450		25%	47%		

In Figure 2-10 the absolute CO_2 emission projections are translated in five year average reduction rates. This shows that the energy [r]evolution Advanced scenario is the only scenario with steadily falling reduction rates. All other mitigation scenarios show higher relative CO_2 reductions from 2015 to 2020 compared to 2020 to 2025 except for the WEO 450 scenario, which shows its highest average reduction rate between 2025 and 2030. From 2030 onwards the energy [r]evolution Advanced scenario indicates the significantly highest reduction rates. Reduction rates of minus 10% per year can only be explained through ambitious investments from now onwards in the (energetic) infrastructure for the decarbonisation of the EU economy.

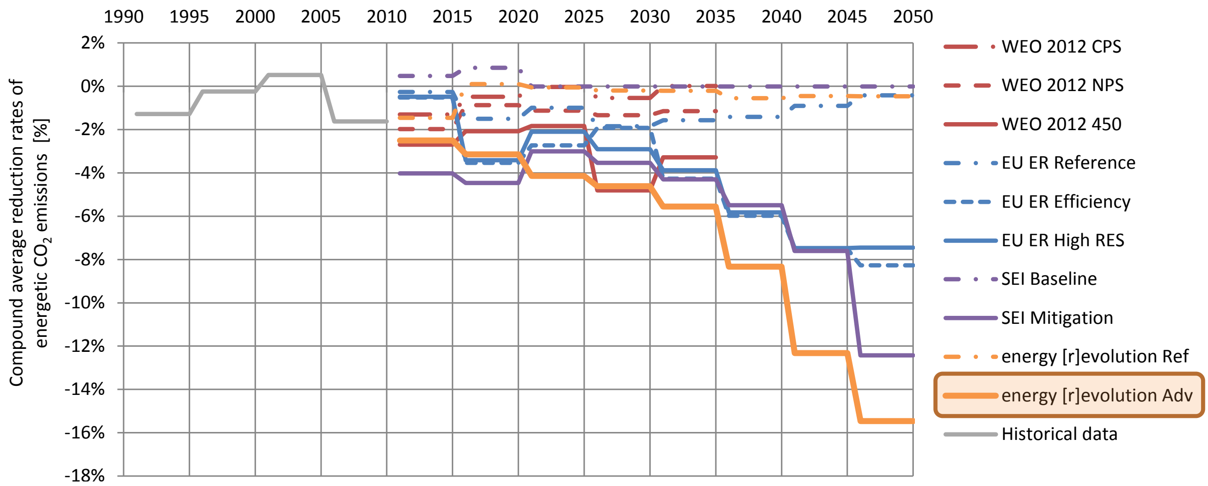

Figure 2-10. Needed yearly reduction rates (5-year average) for energetic CO_2 emissions to meet the scenarios mitigation targets. (EC, 2011b, 158-175; EEA, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 57; IEA, 2012, 572-575)

To put energetic CO_2 emissions in perspective Figure 2-11 shows their share of the total EU emissions of 2010, excluding land use, land-use change, and forestry (LULUCF) emissions, which were negative with about 288 Gt CO_2 equivalents (CO_2eq) of sunk emissions (EEA, 2013a, 12).

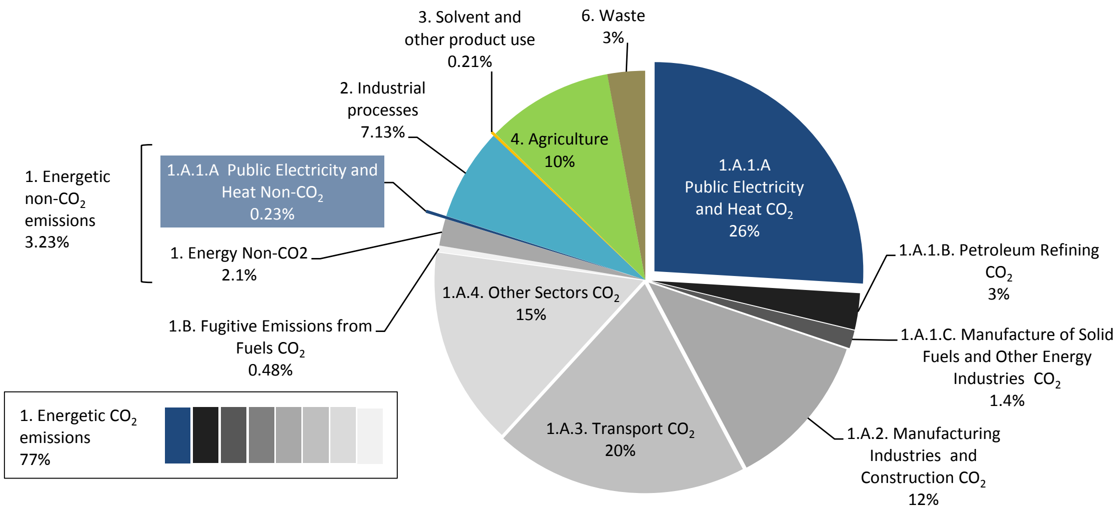

Figure 2-11. GHG composition in the EU 27 countries of 2010. Sectors according to UNFCCC split. (EEA, 2013b)

Total emissions without LULUCF emissions in 2010 amounted to 4,705 Gt CO_2eq (EEA, 2013a, 13). The by far largest sector, according to UNFCCC definitions, contributing to GHG emissions is the energy sector, with a share of 80% of total GHG emissions. Since all discussed scenario work, except the SEI study (Heaps et al., 2009) just covers the CO_2 part of the energetic emissions, this share is curcial to know the EU's GHG composition shares as shown in Figure 2-11 for understanding the scenarios calculated impact on the EU's contribution to global climate change. In 2010 about 77% of of european GHG emissions were CO_2 emissions by the Energy sector, and only 3.23% were non CO_2 emissions (EEA, 2013b). The public electricity and heat sector emissions[7] of 26% in 2010 put the electricity and grid-connected heat generation by combined heat and power plants (CHP) and district heating plants of the EU in perspective.

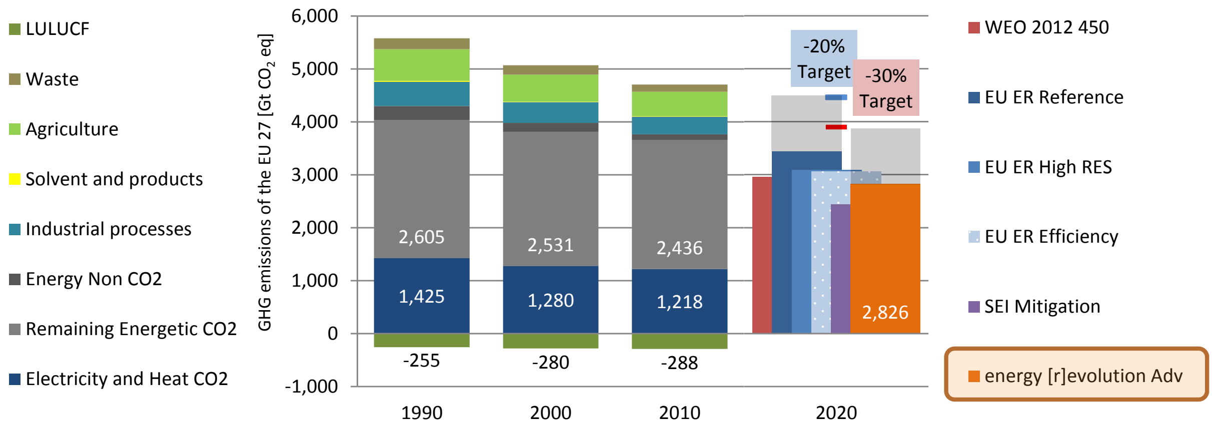

Figure 2-12. GHG Emissions of the EU27 countries. Historic development compared to szenario projections for the year 2020. (COM(2010) 639, 2; EC, 2011b, 158-175; EEA, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 57; IEA, 2012, 572-575)

To show the share of calculated GHG impacts of the respective scenario literature further, Figure 2-12 draws the historic total GHG emissions for the EU for 1990, 2000, and 2010 in comparison to the year 2020 projection of the four discussed low-carbon scenarios and the EU Energy Roadmap Reference scenario. The numbers in the orange bar show the projected energetic carbon emissions of the energy [r]evolution in Mt CO_2. The emission targets for 2020[8] for the European Union are included in Figure 2-12 and in Figure 2-13 for 2050[9]. The non-assessed part of EU's GHG emissions accounted for 1,096 Gt CO_2eq in 2010. The 20% reduction target in 2020 is reached by all included scenarios, also if the non-assessed emissions would not (or only slightly for the reference case) be reduced. The EU Energy Roadmap mitigation scenarios would fulfil the 30% reduction target in 2020 if the non-assessed emissions would be reduced by around 25% by then.

Assessing the compliance of the scenarios with a 2050 reduction target of 80% to 95% is more uncertain. Figure 2-13 illustrates that the EU mitigation scenarios would hardly meet a -80% emission target if not-assessed emissions are included. The energetic CO_2 projections of the energy [r]evolution scenario would comply with the target on the upper end, with low reduction of the not-assessed emissions and at the lower end with comparable reductions of the remaining emissions.

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7 The public power generation and heat production sector is defined by the UNFCCC and has the official code 1.A.1.a. This is a combination of characters of all higher-ranked sectors, which are 1 Energy, 1.A Fuel Combustion Activities, and 1.A.1 Energy Industries. It comprises district heating plants and electricity and heat production of power plants. Waste incineration is also included.

8 The reduction pledge of 20% is unconditionally and a reduction pledge of 30% becomes relevant provided that other developed countries commit themselves to comparable emission reductions (Directive 2009/29/EC).

9 The EU has committed itself to reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050 in the context of necessary reductions by developed countries (COM(2011) 112, 3).

The projected emissions of the energy [r]evolution scenario for 2050 plus 20% of the not-assessed emissions of the year 2010 (assuming a reduction of 80% by 2050) and an allowance of subtraction of the negative 2010 LULUCF emissions (assuming a steady carbon sink because of a sustainable use of land) would result in only 129 Gt CO_2eq in 2050. This is a reduction of 98% of the EU's 1990 emission.

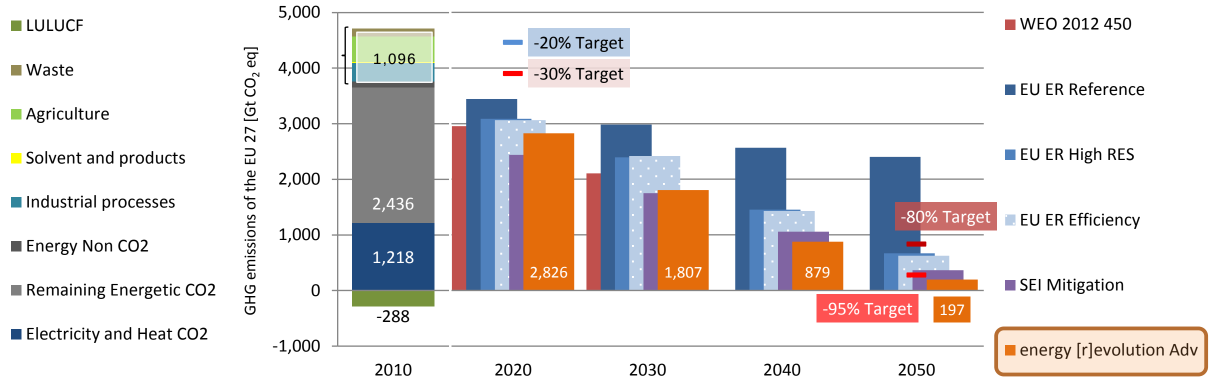

Figure 2-13. GHG Emissions of 2010 compared to szenario projections. (COM(2011) 112, 3; EC, 2011b, 158-175; EEA, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 57; IEA, 2012, 572-575)

2.3 Future developments of the electricity sector in the assessed scenarios

After a general discussion of the assessed scenario literature, projections for the electricity sector are in focus in this subchapter. To begin with Figure 2-14 shows the final demand of electricity. Within these numbers the own consumption of the power generation facilities and transmission losses in the electricity grid are not included. As such the energy efficiency gains respectively reduction in the use of electricity of mitigation scenarios compared to reference scenarios are clearly visible.

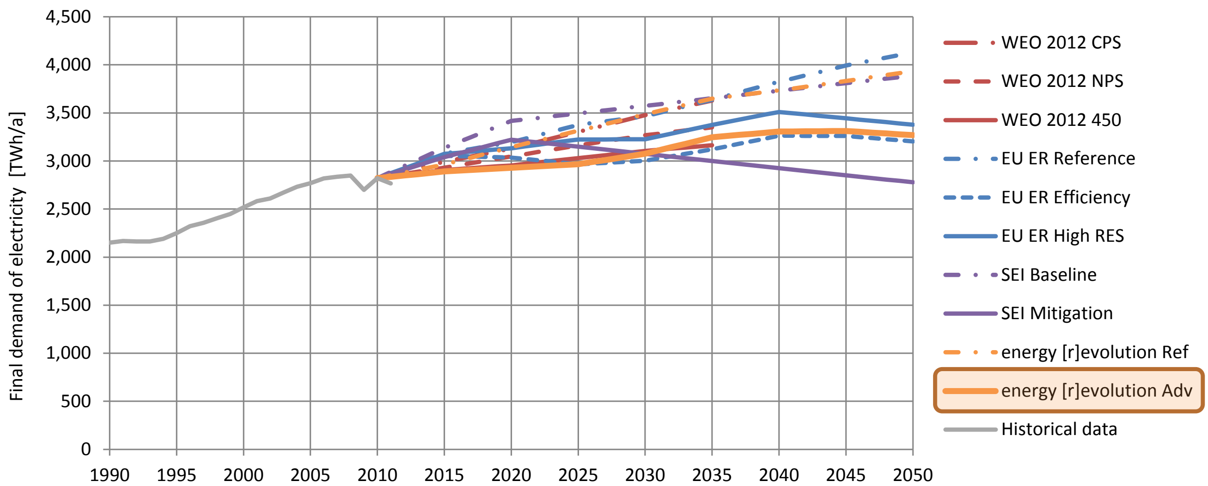

Figure 2-14. Final demand of electricity. (EC, 2011b, 158-175; Eurostat, 2013e; Greenpeace and EREC, 2012; Heaps et al., 2009, 56; IEA, 2012, 572-575)

The total electricity generation is depicted in Figure 2-15. Here the energy branch consumption including refineries (also for biomass) as well as transmission and distribution losses are included.

Because of the assumed growing electrification of all infrastructure and higher energy branch consumption, the electricity generation in the case of the EU High RES scenario is as high as in the Reference scenario. The WEO scenarios are not explicitly included in Figure 2-15. Instead the darker grey shaded area describes the upper and lower boundary of all scenario results for the EU 27 electricity generation up to 2050.

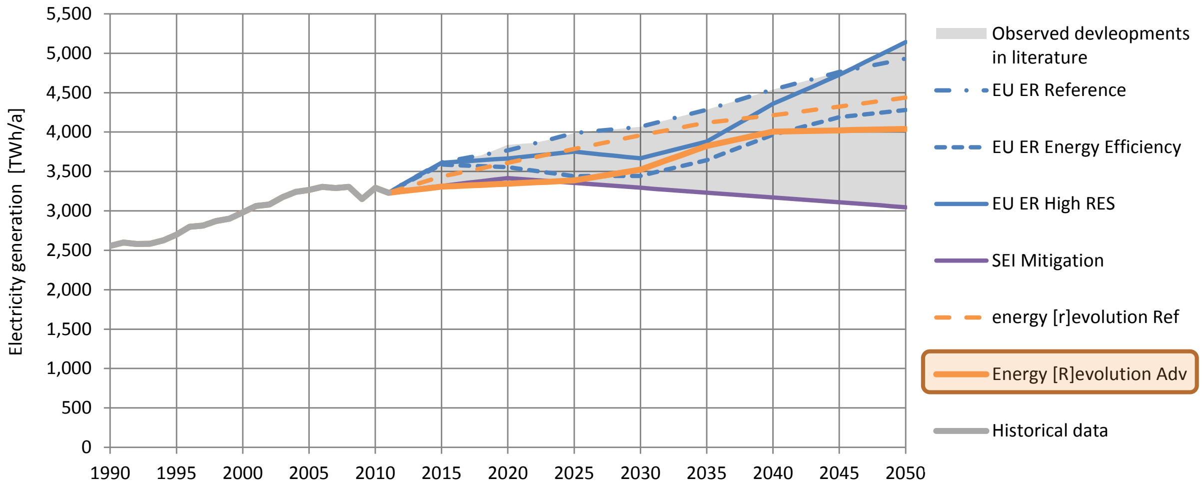

Figure 2-15. Total electricity generation. (EC, 2011b, 158-175; Eurostat, 2013e; Greenpeace and EREC, 2012; Heaps at al., 2009, 56; IEA, 2012, 572-575)

Figure 2-16 provides the shares of fossil, renewable, and nuclear power in total electricity generation within the EU 27. The first two bars show the historic shares for the years 1990 and 2010 in comparison with 6 scenario results for 2020 and 2030. These two projected years were selected, as the discussed nuclear power phase-out for the EU in this study is assumed to be accomplished by 2030. The RES share of the electricity generation is an important indicator to accomplish this goal.

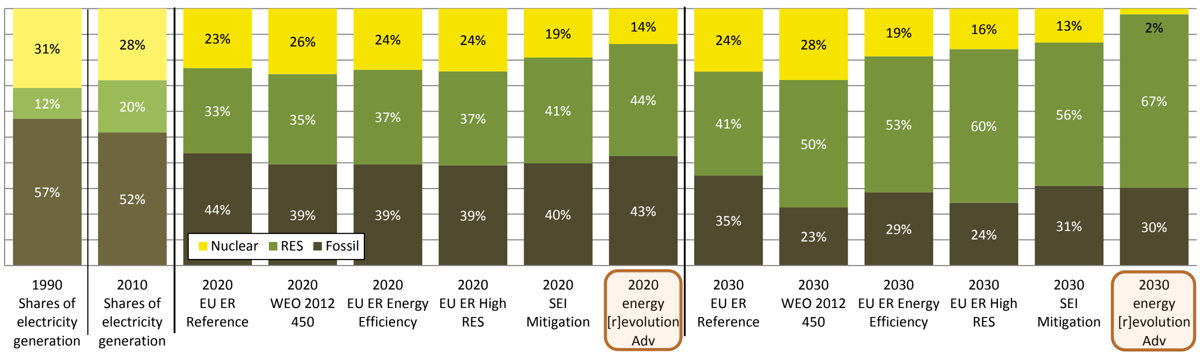

Figure 2-16. Shares of (domestic) electricity generation in 1990 and 2010, and respective scnario projections for 2020 and 2030. (EC, 2011b, 158-175; Eurosat, 2013e; Teske et al., 2012a, 125; Heaps at al., 2009, 56; IEA, 2012, 572-575)

In Figure 2-17 the electricity generation of fossil, renewable, and nuclear facilities is provided in TWh per year. All scenarios contribute to the grey, green, and yellow shaded arrears to indicate the lowest and highest contributions to the total electricity generation in comparison. The energy [r]evolution forms the upper boundary of the RES generation from year 2011 up to around 2040, afterwards only excelled by the EU High RES scenario. This results in the formation of the lower boundary by the energy [r]evolution Advanced scenario for nuclear generation. The fossil generation of electricity is lowest in the WEO 2012 450 scenario until its projection ends in the year 2035. This is caused by a surge of nuclear generation as a GHG mitigation option in this scenario. After 2035 the EU High RES scenario shows the lowest generation of electricity by fossil fuel combustion power plants replaced only by the energy [r]evolution Advanced scenario until 2040.

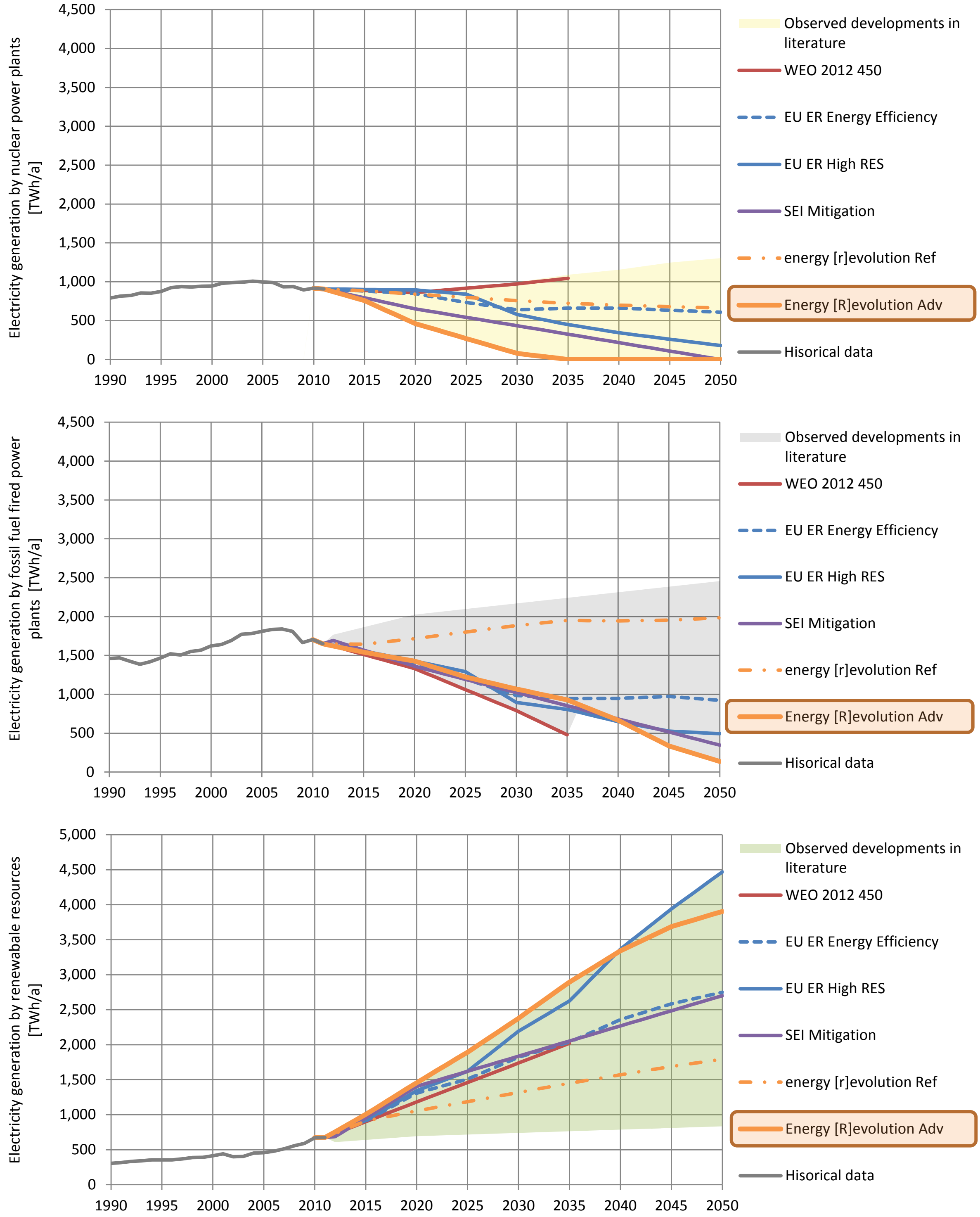

Figure 2-17. Future development of nuclear (top), fossil (middle), and renewable (bottom) erlectricity generation in selectet scenarios. (EC, 2011b, 158-175; Eurostat, 2013e, Fürsch et al., 2011, 119-134; Greenpeace and EREC, 2012; Heaps at al., 2009, 56; IEA, 2012, 572-575)

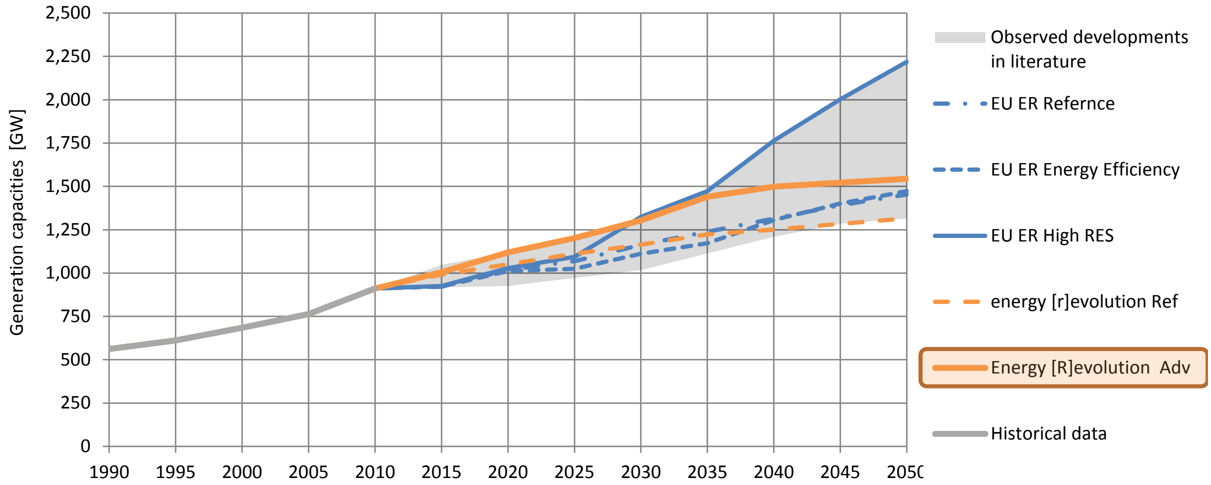

Figure 2-18. Total generation capacities. (EC, 2011b, 158-175; Eurostat, 2013c; Greenpeace and EREC, 2012; IEA, 2012, 572-575)

The total electricity generation capacities are depicted in Figure 2-18. Until 2035 both scenarios with a high generation share of electricity by renewables (RES-E) show equivalent high amounts of generation capacities compared to all other scenarios. It becomes obvious, that because of the fluctuating generation of most RES technologies higher spare capacities for electricity generation are needed. A higher generation capacity counteracts the fact that power generation facilities won't produce simultaneously throughout the year. The fact that after 2035 the energy [r]evolution scenario shows a significantly lower extension rate of generation capacities than the EU High RES scenario can be explained by the production of hydrogen in the energy [r]evolution vs. EU High RES for the storage of energy by excess production of RES-E in certain periods, and by a higher amount of RES-E imports from third countries.

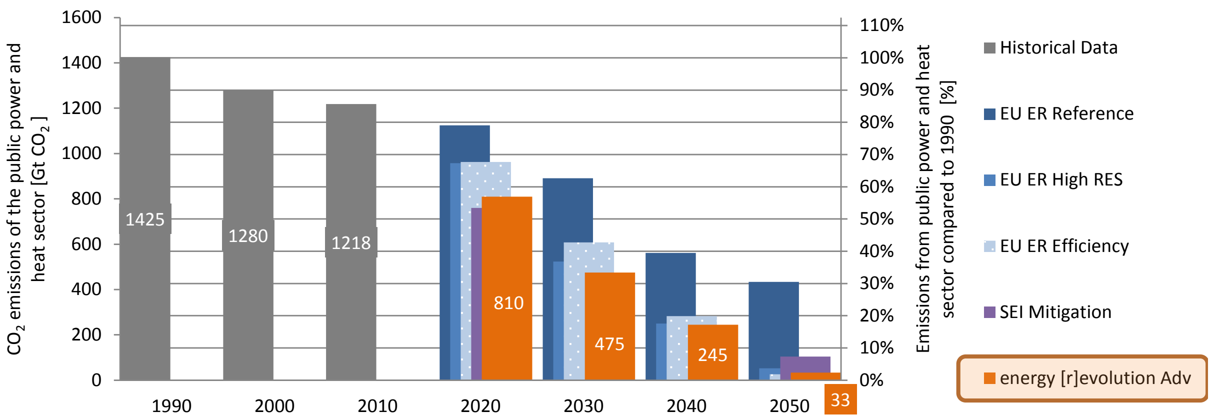

Figure 2-19. The historical development of CO_2 Emissions from public power generation and heat production sector compared to scenario projections. (EC, 2011b, 158-175; EEA, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 57; IEA, 2012, 572-575)

At last the CO_2 emissions caused by the public power generation and the heat production sector are discussed as a subsector of the total energetic CO_2 emissions. All included energy scenarios reduce the emissions of the public power generation and heat production sector extensively. Figure 2-19 shows the past development of CO_2 emissions of this sector from 1990 to 2010, which already show a significant downward trend especially in the first decade. In 2011 the European Commission wrote in a Communication for the Energy Roadmap 2050 with regards to the power generation sector (COM(2011) 885 final): "To achieve this, the power generation system would have to undergo structural change and achieve a significant level of decarbonisation already in 2030 (57-65% in 2030 and 96-99% in 2050)." These goals are reachable by all decarbonisation scenarios. The WEO 2012 scenarios are not included in Figure 2-19 because of different accounting methods for CO_2 emissions in the power sector, what results in a comparability problem.

2.4 Cost assessments in the scenario literature

This chapter compares included cost assessments by the scenario literature. This is rather difficult, as the cost indicators, which are presented, do mostly not relate to each other. Cost indicators that can be found in the energy [r]evolution study, the EU Energy Roadmap 2050, and the SEI study on Europe's share on climate change are included in the following subchapters. The WEO 2012 published by the International Energy Agency is excluded, as no EU 27 specific cost indicators are presented in the study. Moreover the energy [r]evolution study includes no indicators on the total energy system costs, and is as a result only included in the discussion on the costs for electricity generation and supply. The opposite is true for the SEI study, which is only discussed shortly in regards to its projected total costs. Note that all expressed monetary values refer to the year 2010 and are expressed in real terms (i.e. €$_{2010}$).

2.4.1 Total energy system costs

The SEI study on Europe's share on climate change compares the total Net Present Value (NPV) of the mitigation scenario to the included baseline scenario trough 2020. The balance of the two scenarios NPVS amounts to 2.17 trillion 2010 Euros additional costs for the mitigation scenario. This number correlates to the sum of added demand-side efficiency investments of € 2.06, added investments in the transmission and distribution network of € 0.06, added investments in the electricity generation infrastructure of € 0.66, and fuel cost savings of € 0.6 all in trillion 2010 Euros compared to the SEI reference scenario. This value amounts to about 1.7 % of the NPV of Europe's GDP between 2010 and 2020, what is within a reasonable range compared to other cost assessments of studies on climate change mitigation[10]. It is argued that these are not unacceptably large costs compared to possible damage costs of uncontrolled climate change[11]. (Heaps et al., 2009, 42)

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[10] The SEI study includes the following comparison for its cost estimation (Heaps et al., 2009, 42):
These estimates are consistent with a variety of other studies, such as those recently reviewed and discussed by Ackerman and colleagues in the recent report, The Economics of 350: the Benefits and Costs of Climate Stabilization (Ackerman et al., 2009): … the much more ambitious reductions in emissions required to reach 350 ppm CO_2 might have net costs of 1 to 3 percent of world output.

[11] *The Stern review on climate change (Stern, 2006) … estimates that losses to global GDP will amount to at least five per cent but perhaps more than 20 per cent. Thus, the cost of uncontrolled climate change will be significantly higher than the scale of financial contributions discussed today to address the financial crisis. Moreover, delay in implementing significant GHG reductions is likely to increase these costs.*
(Heaps et al., 2009, 42)

A comparison of total energy system costs is also included in the EU Energy Roadmap 2050. These costs are presented in Table 2-3 including the Diversified Supply Technologies scenario, as it is the most cost-effective scenario presented in the Energy Roadmap. Table 2-4 shows the absolute difference of the cost figures in comparison to the reference scenario.

Table 2-3. A comparison of total energy system costs of selected sceanrios according to the EU Energy Roadmap 2050. The table presents the average annual costs of the modelled timespan from 2011 to 2050. (EC, 2011b, 32)

Average annual total energy system costs 2011-2050 [Bill. €'10]

	Capital cost	Energy purchases	Direct efficiency investment cost	Total cost for final consumers (excl. Auction payments and disutility)
EU ER Reference	1000	1699	29	2704
EU ER Diversified Supply Technologies	1152	1356	168	2655
EU ER High Renewables	1141	1419	172	2713
EU ER High Energy Efficiency	1168	1278	309	2739

The cost measures are explained as follows in the Energy Roadmap:

> Total costs for the entire energy system include capital costs (for energy installations such as power plants and energy infrastructure, energy using equipment, appliances and vehicles), fuel and electricity costs and direct efficiency investment costs (house insulation, control systems, energy management, etc), the latter being also expenditures of capital nature. Capital costs are expressed in annuity payments. Total costs exclude disutility and auction payments.
>
> Auction payments are expenditures for individual actors/sectors that are not costs for the economy as a whole, since the auctioning revenues are recycled back to the economy. Disutility costs are a concept that captures losses in utility from adaptations of individuals to policy impulses or other influences through changing behaviour and energy consumption patterns that might bring them on a lower level in their utility function. Such disutility costs correspond to a monetary estimation (income compensating variation) of lower utility from useful energy services (lighting, heating, mobility, etc.) resulting from a more rational use behaviour by consumers who for example adjusts thermostats, switch lighting off or travel less in order to adapt to higher costs of useful energy services. (EC, 2011b, 143)

Table 2-4. A comparison of total energy system costs of selected sceanrios according to the EU Energy Roadmap 2050. The table shows the absolute differences in comparison with the reference scenario of the EU Energy Roadmap 2050. (EC, 2011b, 32)

Absolute Difference to Reference [Bill. €'10]

	Capital cost	Energy purchases	Direct efficiency inv. cost	Total cost for final consumers (excl. Auction payments and disutility)
EU ER Reference	-	-	-	-
EU ER Diversified Supply Technologies	152	-342	138	-49
EU ER High Renewables	140	-280	142	8
EU ER High Energy Efficiency	168	-421	280	35

The Diversified Supply Technologies scenario has the lowest level of annual energy system costs, representing a cost saving compared to the reference scenario (-49 bill € 2010). This is foremost a result of the large fossil fuel import cost savings, what has roots in the more efficient use of fuels and a higher share of renewables, but as well in the lower fossil fuel prices assumed in the mitigation scenarios. To remind, these lower fossil fuel prices are anticipated as all nations act globally to counteract climate change, and thus use less fossil fuels what reduces global demand and in turn international fossil fuel prices. The High Renewables and High Energy Efficiency cases pose additional energy system costs on consumers compared to the reference scenario (8 and 2035 bill € 2010).

The cost in the Energy Efficiency scenario are higher given that very high energy efficiency progress requires strong action on the building stock entailing major investments for accelerated building renovation, in addition to costs for further energy efficient equipment including the costly transition to electric and plug in hybrid vehicles. High renovation rates are one of the salient features of the energy efficiency scenario. Electro mobility also provides for greater energy efficiency in the system. However, this higher cost does not disqualify energy efficiency policies as such, as strong energy efficiency policies leading to substantial improvements and energy savings are present in all Energy Roadmap scenarios. The High Energy Efficiency scenario just shows that there are certain limits from where on other decarbonisation routes are less costly than further reductions of energy consumption. (EC, 2011b, 146)

2.4.2 Costs for electricity generation and supply

Figure 2-20 depicts specific electricity generation costs in € 2010 per MWh relative to 2010. It shows that the introduction of renewable technologies under the energy [r]evolution Advanced scenario slightly increases the costs of electricity generation in EU 27 compared to the energy [r]evolution Reference scenario. This difference will be less than 0.7 € cents/kWh up to 2020, is argued in the study (Teske et al., 2012a, 59). Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become as cheap as in the energy [r]evolution Reference scenario between 2030 and 2035, and will be lower than in the Reference scenario afterwards.

The energy [r]evolution Advanced scenario projects the highest generation costs compared to 2010 for 2025 with an increase of 26%. Afterwards the generation costs will decrease until they reach the level of 2010 approximately the year 2040. For 2050 the modelling results in generation costs which are 22 percentage points below the costs of 2010.

The EU Energy Roadmap High Renewables scenario projects the highest increase of electricity generation costs for 2020 and beyond. In contrast to the energy [r]evolution Advanced scenario this upward trend does not change after 2025, but continues until 2050, what leads at the 60% higher generation costs in 2050 compared to 2010. This upward dynamic is caused by the fact that no curtailment of renewable electricity is included. Expensive electricity storage techniques are used for capturing excess production during production peaks to balance supply and demand of generated and consumed electricity. The generation costs in the EU reference scenario peak in 2035 at around 33% higher costs than in 2010 and projects the same costs for 2050 with an increase of 31% as the reference scenario of the energy [r]evolution study. The EU High Energy Efficiency scenario mimics the EU reference until 2040, and includes sinking generation costs afterwards, what results in costs for the year 2050 24 percentage points higher than in 2010.

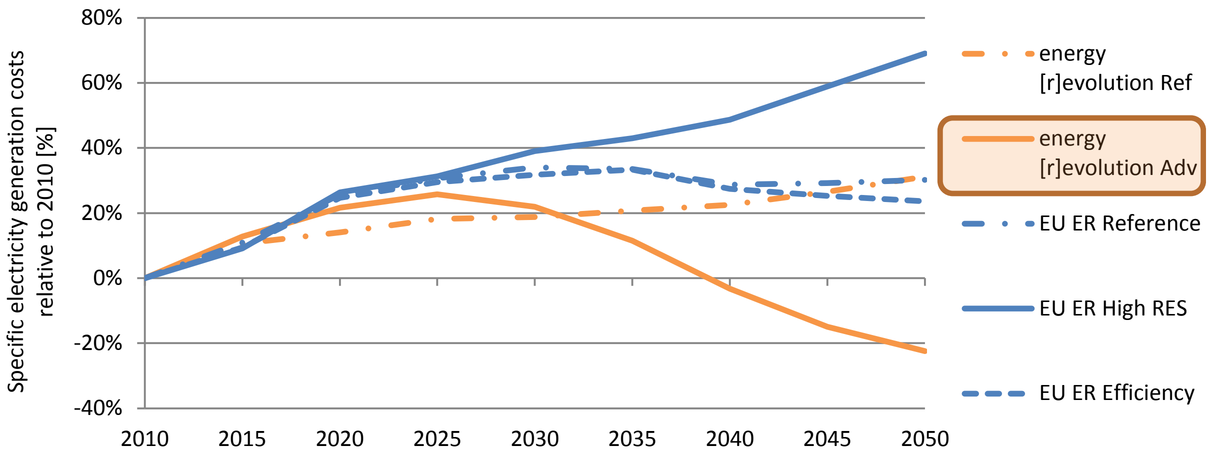

Figure 2-20. Electricity generation costs in specific terms relative to costs of 2010. (EC, 2011b, 158-175; Greenpeace and EREC, 2012)

The total electricity supply costs per year projected by the energy [r]evolution and EU Energy Roadmap 2050 are compared in Figure 2-20 . These costs include all investment, operating, and CO_2 costs of the power generation sector, the costs for the import of electricity, and costs for transmit ion and distribution. In the case of the energy [r]evolution Advanced scenario also the investment costs for additional efficiency measures compared to the Reference scenario are included as separate bars in Figure 2-21 on top of the total electricity supply costs. Additional efficiency investments in case of the EU Energy Efficiency scenario are not included in this cost indicator.

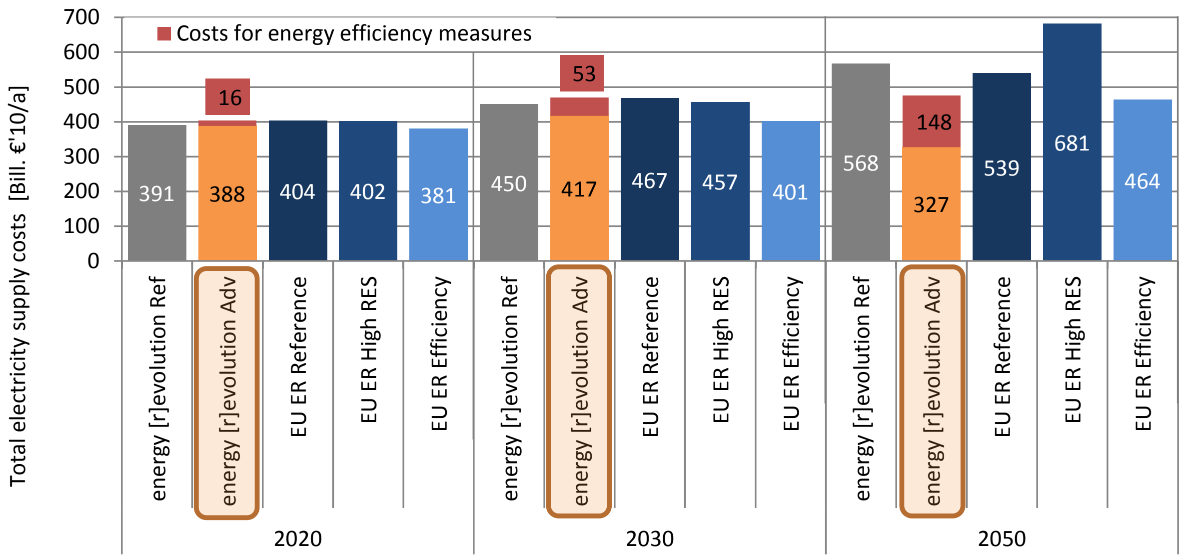

Figure 2-21. Electricity supply costs projected by the energy [r]evolution and EU Energy Roadmap 2050 scenarios. (EC, 2011b, 158-175; Greenpeace and EREC, 2012)

The High Energy Efficiency scenario of the EU Energy Roadmap has the lowest total costs in 2020 and 2030. This reflects the lower demand for electricity, the lower prices for imported fossil fuels in the EU mitigation scenarios, and the fact that electricity saving measures are not included in the costs. The energy [r]evolution Advanced scenario projects the lowest total costs for 2050 if costs for energy efficiency measures are excluded. The most expensive scenario in 2050 is the EU High RES scenario, what is due to the already mentioned expensive electricity storage facilities.

In conclusion it can be said that climate mitigation scenarios with a high amount of energy supplied by RES technologies and additional energy efficiency instruments bear higher costs for the consumer in the short to medium term. It may be that total energy system costs of climate mitigation realities are lower compared to the reference or current policy worlds, when compared over a time period up to 2050 as it is the case with the EU Diversified Supply scenario. Furthermore it can become reality, that the electricity supply in mitigation scenarios will be cheaper than in reference scenarios, as the energy [r]evolution Advanced scenario reflects. All parameters, as fuel and CO_2 price developments, economic and population dynamics, which were assumed in the scenario literature have a crucial impact on future outcomes, and outcomes of the assessments.

3 The role of energy efficiency and RES – Implications of assessed scenarios

There are two main GHG mitigating possibilities to let the vision of a nuclear power free European energy system become a reality including the constraint that long-term climate targets shall be met: a fostering of energy efficiency / saving measures for lowering or at least stabilising the electricity demand and the enhanced use of renewable energy sources for decarbonisation. The feasibility and implications of both options will be discussed intensively within this chapter.

3.1 Implications for future energy efficiency developments

Reducing demand for energy and improving efficiency became one of the key policy objectives in terms of addressing climate change in a cost effective way. The technical potentials for energy savings are often classified as substantial in all sectors of consumption. Also the questions, how the technological savings potential is estimated and at which costs these savings can be realized, appear of core relevance. Exhausting these potentials is bonded with numerous obstacles. Several energy efficiency/conservation policy instruments and measures have to get implemented to overcome these barriers, where every country is allowed to use different policy instruments to reach the "energy demand reduction targets".

> The (European) Union is facing unprecedented challenges resulting from increased dependence on energy imports and scarce energy resources, and the need to limit climate change and to overcome the economic crisis. Energy efficiency is a valuable means to address these challenges. It improves the Union's security of supply by reducing primary energy consumption and decreasing energy imports. It helps to reduce greenhouse gas emissions in a cost-effective way and thereby to mitigate climate change. (EU, 2012)

Beside the supply side measures, e.g. strategies for promoting renewables, the demand side measures, i.e. energy conservation and increasing efficiency, play a fundamental role in achieving climate change targets. The complexity of demand side measures can be handled through several aspects: First, the policy instruments need to get understood. Then, the output of changing different instruments are important or the question which parameters are affected by implementing different instruments.

> Finally, there are several challenges related to the evaluation of policy instruments in action and their corresponding achievements, respectively:
>
> - The energy efficiency measures lead in most cases not to the predicted "savings".
> - The savings targets are defined in different ways;
> - The impact factors are neglected partially or even totally;
> - The evaluation of achieved savings and related costs differs between similar policy instruments. (Suna, 2013)

3.1.1 Policy context - status quo

The energy consumption reduction and energy wastage elimination are among the main goals of the European Union. As said, the EUs target "improving energy efficiency" will lead to a better competitiveness, more security of supply and meeting the climate change targets in the Kyoto Protocol. There is significant potential for reducing consumption, especially in the sectors buildings, manufacturing, energy conversion and transport. At the end of 2006, the EU pledged to cut its annual consumption of primary energy by 20% by 2020. To achieve this goal, it is working to mobilise public opinion, decision-makers and market operators and to set minimum energy efficiency standards and rules on labelling for products, services and infrastructure.

The majority of the 20% reduction target can be reached through energy efficiency improvements. It is on the realisation of this potential that the EU action plans are focussed. The Energy Efficiency Action Plan (EEAP) of 2006 is an important first step towards reaching the 20% objective. The Plan contained 85 policy measures, together forecast to permit about a 14% reduction by 2020. A good deal of work has been done to implement the plan, including via implementation of the Energy Services Directive of 2006 and the Cogeneration Directive of 2004 (revision of the Ecodesign Directive), the Energy Performance of Buildings Directive and the Energy Labelling Directive and the development of the Energy Efficiency Plan 2011. (EC, 2011a, 5)

From a legal perspective, the following Directives form the integral part of energy efficiency policy at European level:

1. <u>Energy Efficiency Directive (2012/27/EU)</u>
   On 25 October 2012, the EU adopted the Directive 2012/27/EU on energy efficiency which "establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date". It contains rules to remove barriers in the energy market and overcome market failures in terms of energy efficiency in the supply and use of energy, and provides for the establishment of national energy efficiency targets until 2020.
   The Directive forces legally binding measures to step up Member States' efforts to use energy more efficiently at all stages of the energy chain. (2012/27/EU)

2. <u>Energy performance of buildings Directive (2010/31/EU)</u>

   The Energy performance of buildings Directive of the 19th of May 2010 reveals the buildings sector as one of the key-sectors to look at, in terms of energy savings. This is, because buildings represent 40% of the European Union's total energy consumption. Reducing energy consumption in this area is therefore a priority under the "20-20-20" objectives beside 20% GHG reduction and a RES-share of 20% at EU level. "This Directive contributes to achieving this aim by proposing guiding principles for Member States regarding the energy performance of buildings" (2010/31/EU).

   This Directive is less relevant for this study since it focusses largely on energy for heating (and cooling) of buildings.

3. Cogeneration Directive (2004/8/EC)
   The Cogeneration Directive (CHP Directive) of the European Parliament and of the Council of 11 February 2004 aims on the promotion of cogeneration based on a useful heat demand in the internal energy market. The energy-saving potential of cogeneration is currently under-utilised in the European Union which leads to the purpose of the Directive, which is to facilitate the installation and operation of electrical cogeneration plants. Cogeneration is a technology which allows the production of heat and electricity in one process. (2004/8/EC) This increases the systems energy efficiency and saves energy and combats climate change at the same time.

4. Ecodesign Directive (2009/125/EC)
   On 21 October 2009, the recast of the Ecodesign Directive 2005/32/EC was adopted (extension to energy related products). The Ecodesign Directive aims at reducing the environmental impact of a number of products sold in the EU, with emphasis on their energy consumption. The Directive covers most energy-using products (domestic appliances but also commercial and industrial equipment), covering products responsible for as much as 80% and 60% of the EU's electricity and heat consumption, respectively. Ecodesign regulations do not prescribe the method for achieving higher energy efficiency but only the required objective, thereby leaving the manufacturers free to determine their own technical solution. Until 2011, 12 products have been regulated under Ecodesign but it has been observed that there are problems with the implementation of regulations for specific groups that put these economic benefits at risk. For this 12 regulated measures the timeframe was reasonable and to be expected. However, 6 more appliance groups have failed to result in measures up until now, years after the preparatory study was finished. The delays are due to the complexity of the products and the lack of sufficient manpower at the European Commission to handle this complexity. Other product groups contain a risk that standards do not go far beyond business as usual and do not reach the Ecodesign ambition of lowest life cycle costs. (Molenbroek et al., 2012)

3.1.2 Potentials for energy efficiencies and savings in the EU

An estimation of the energy saving potentials by sector and corresponding energy use areas is essential to identify where policy priorities can be laid and which results can be expected. In order to make a realistic estimation of saving efforts the "net savings" and related factors have to be considered. The study "Contribution of Energy Efficiency Measures to Climate Protection within the European Union until 2050" by BMU and Fraunhofer ISI (2012) contains a summary of the main results and potentials to increase energy efficiency in different sectors in reference to the EU Energy Roadmap 2050. These theoretic energy efficiency potentials are illustrated in Figure 3-1 as the primary energy saving potentials and in Figure 3-2 as the final energy saving potentials. To demonstrate the potentials and possible contributions of energy efficiency and energy saving options the following issues were highlighted in detail and furtheron compared with the included scenario literature. By comparing the energy saving potentials with the energy demand trajectories, which were presented in the energy [r]evolution study, the EU Energy Roadmap 2050, and the SEI study on Europe's share of climate change it can be seen, that none of the Energy Roadmap and energy

[r]evolution scenarios meet the 20% efficiency target, highlighted in Figure 3-1 in 2020. Only the SEI study fulfils the target with its trajectory for the primary energy demand.

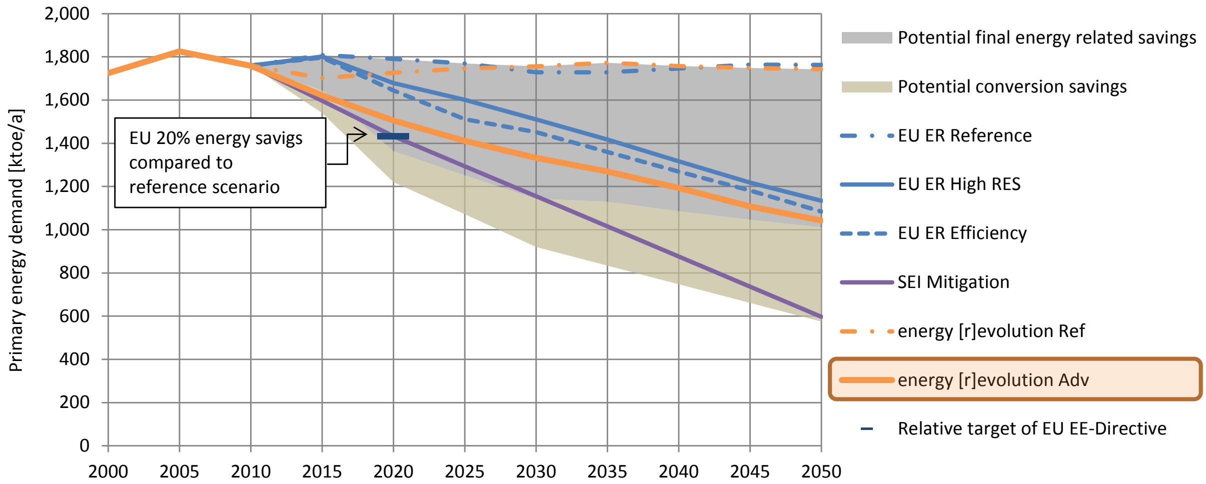

Figure 3-1. **The primary energy demand of selected scenarios compared to conversion and final energy savings pontentials. The European relative energy efficiency target is marked in 2020. (BMU and Fraunhofer ISI, 2012, 30; Directive 2012/27/EU; EC, 2011b, 158-175; Greenpeace and EREC, 2012)**

Despite substantial steps taken towards this 20%-objective, the European Commission suggests that only half of the objective will be reached. To fill the gap, a new Energy Efficiency Directive with an improved set of measures was proposed and later on adopted. The Energy Efficiency Directive states, that the largest savings can be achieved in buildings and by the transport sector.

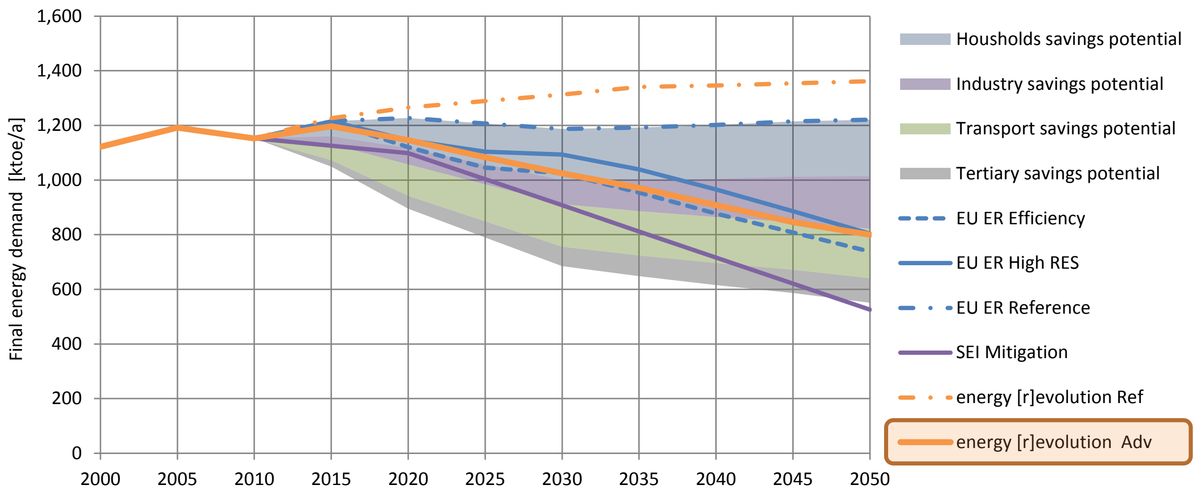

Figure 3-2. **The final energy demand of selected scenarios compared to mid- and longterm energy efficency potentials. (BMU and Fraunhofer-ISI, 2012, 14-20; EC, 2011b, 158-175; Eurostat, 2013b; Greenpeace and EREC, 2012; Heaps et al., 2009, 55;)**

The household sector reveals to have the largest final energy saving potential, followed by the industry, transport, and tertiary sector (BMU and Fraunhofer-ISI, 2012, 29). The highest financial benefits can be gained in the transport sector (BMU and Fraunhofer-ISI, 2012, 29). Compared to the baseline projection, the overall final energy demand could be reduced by 57% in 2050. The increase of efficiency in the power sector would lead to annual cost savings of about 500 billion € BMU and Fraunhofer-ISI, 2012, 29) and reductions of 25% in the primary energy demand BMU and Fraunhofer-

ISI, 2012, 30) and 15% in GHG emissions (BMU and Fraunhofer-ISI, 2012, 32). Final energy use saving options can cause additional reductions of GHG emissions of up to 52% (BMU and Fraunhofer-ISI, 2012, 33). When the potential of final energy savings in Figure 3-2 are compared to the scenario trajectories, it can be followed that all mitigation scenarios include substantial energy efficiency measures. In case of the SEI study, the final energy demand in 2050 is even lower, than the projected saving potentials by BMU and Fraunhofer ISI (2012).

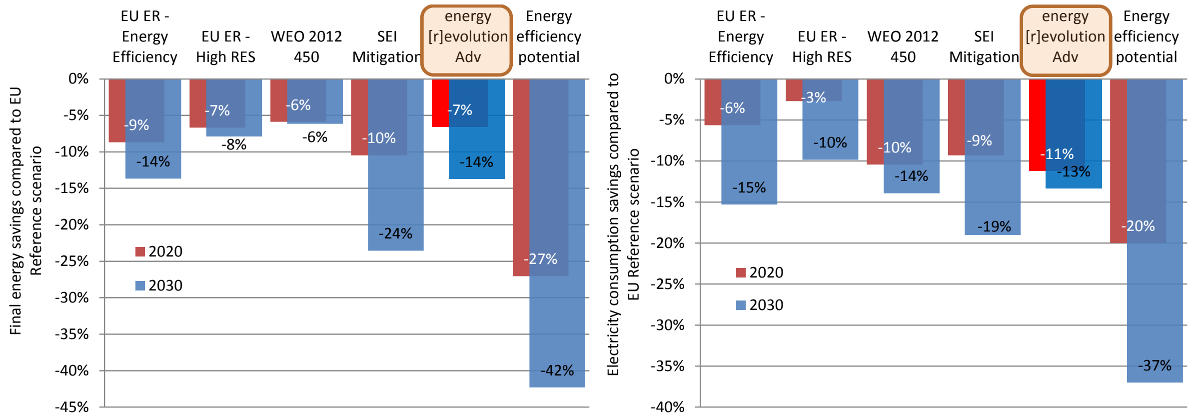

Figure 3-3. Final energy demand and electricity consumption savings compared to the EU Reference scenario. The midterm energy efficiency potentials for the final energy demand (left) and electricity consumption (right) in 2020 and 2030 are shown for comparison. (BMU and Fraunhofer ISI, 2012, 14-20; EC, 2011b, 158-175; Greenpeace et al., 2012b; Heaps et al., 2009, 55-56;)

Figure 3-3 depicts the final energy on the left and electricity consumption savings on the right compared to the EU refererence scenario. In 2030 the EU Energy roadmap High Energy Efficiency scenario predicts the same savings of final energy and higher savings of final electricity consumption as the energy [r]evolution Advanced scenario. In generall the energy efficiency potentials in 2020 and 2030 published in BMU and Fraunhofer ISI (2012) are noticably higher than the projected energy savings of all scenarios.

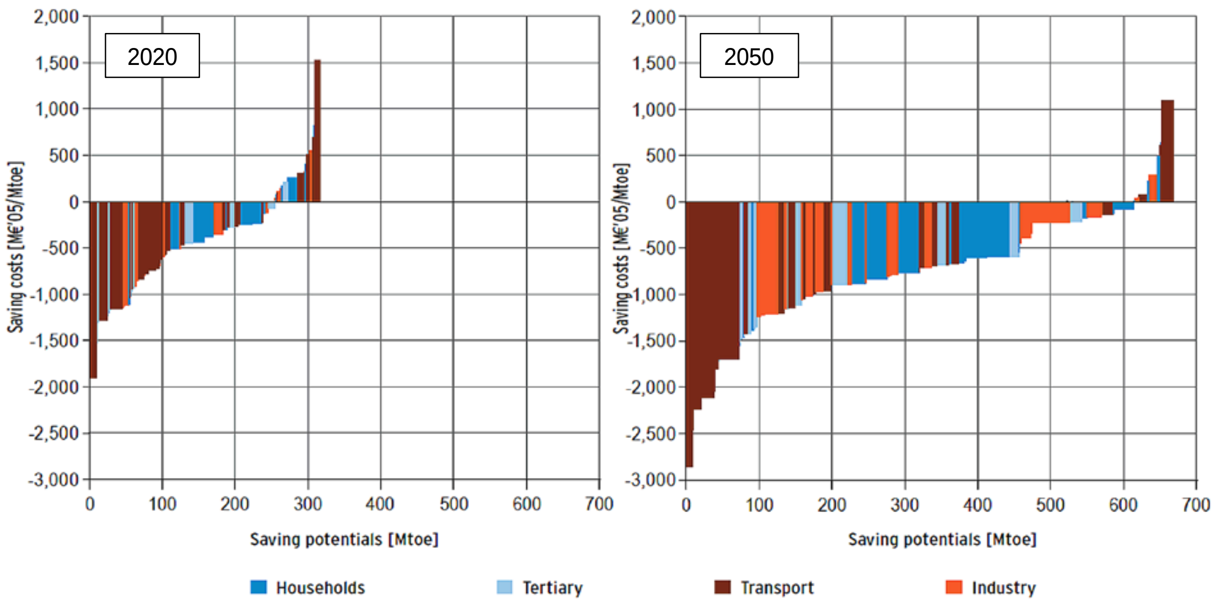

Figure 3-4. Multi-sectoral cost curves for 2020 and 2050. (BMU and Fraunhofer ISI, 2012, 24)

Energy efficiency options can only be effectively addressed if the entire energy conversion chain is considered and a clear target has been defined in advance. Figure 3-4 describes the overall technical saving potentials. It can be seen, that these potentials more than double from 2020 to 2050. The specific costs of energy saving measures are expected to decline due to learning effects and assumed energy price increases (mostly relying on relatively expensive fuels such as gasoline and electricity). In addition, because of this decrease of specific cost, the share of cost-effective measures, compared to the total technical saving potential identified, increases from 80% in 2020 to 92% in 2050 (BMU and Fraunhofer ISI, 2012, 24).

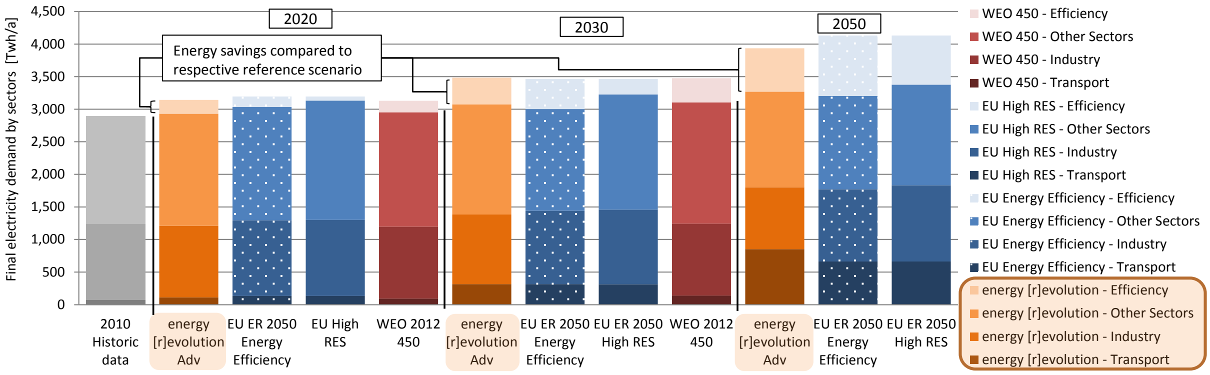

Figure 3-5. Final consumption of electricity by sectors compared to the respective reference scenarios. The differences of the total electricity demands of reference vs. mitigation scenarios is accounted for in the efficiency bars. (EC, 2011b, 158-175; Greenpeace and EREC, 2012; IEA, 2012, 572-575)

In Figure 3-5 the final consumption of electricity is compared to each respective reference scenario scenario. In case of the WEO 450 scenario, the energy savings are the difference of the final conomption of electricity in the WEO CPS minus the final consumption of electricity in the WEO 450 what accounts to 372 TWh in 2030. In 2030 the EU Energy Roadmap 2050 High Energy Efficiency scenario models the largest electricity savings compared to the EU reference with 463 TWh. The energy [r]evolution Advanced scenario in comparison projects savings of 410 TWh. The EU Energy Roadmap 2050 High Renewables scenario models the least savings with 250 TWh in 2030. Besides the bars representing the final electricity consumption in Figure 3-5 are splittet into three sectors. The projected demands for electricity in the industry, transport, and other sectors are incuded.

While the whole energy chain has to be looked at, the result of electricity reductions is the sum of all reductions in all of the following sectors. To reduce energy consumption, measures in every sector have to be made, where the buildings sector reveals to have the largest final energy saving potential.

3.1.2.1 Household sector

By 2030, the final energy saving potentials identified lead to a reduction in final energy demand of about 61% compared to baseline which stands for at least 187 Mtoe. The baseline development would continue to a level of 308 Mtoe in the same time. Electric appliances and lighting represent the most attractive energy saving options regarding their specific cost reduction per unit of energy saved. Compared to building-related measures their contribution to the overall energy cost reduction is rather small. Half of the savings relate to the building shell refurbishment of existing buildings (BMU and Fraunhofer ISI, 2012, 14f). In turn, such an ambitious reduction of electricity demand implies a limited electrification of the heat generation but would lead to savings of nearly 70 TWh in 2050 for electric heat pumps in the households and tertiary sector (BMU and Fraunhofer ISI, 2012, 28).

3.1.2.2 Tertiary sector

In the tertiary sector the final energy demand of the baseline scenario stops increasing after 2030 and returns to today's level. The final energy demands maximum amounts to 157 Mtoe in the baseline scenario 2030 and could be reduced up to 45%. As in the residential sector approximately two thirds of the savings are building-related. Due to the fact that the final energy demand of the tertiary sector is dominated by electricity, building-related measures are responsible for nearly 60% of the total net cost reductions (BMU and Fraunhofer ISI, 2012, 16f).

3.1.2.3 Industry sector

The energy savings in the industry sector are mostly related to optimised electric motor driven systems and energy-efficient heat generation systems in the short-term. In the long term, further energy savings can compensate the increased baseline energy demand and promise even higher demand reductions. Compared to the baseline, which results in 344 Mtoe of final energy demand in 2030, 88 Mtoe (26%) could be reduced. (BMU and Fraunhofer ISI, 2012, 18f)

3.1.2.4 Transport sector

Due to the fact, that, beside train transports, the present transport system depends more on fossil fuels than on electricity, the transport sector takes only a small part overall. Electric vehicles are currently being discussed as one way to decarbonise the transport sector and provide electricity storage to better integrate fluctuating renewable energy sources. However, they also represent a relevant option for reducing final energy demand, but also increase the electricity consumption in a marginal degree. With a moderate stock increase of electric vehicles from 2025 onwards, leading to a 30% share of electric vehicles by 2050 and roughly 80 million electric vehicles, this would lead to at least 16 Mtoe or 11% reduction of final energy demand for transport but would also lead to increases of 140 TWh of electricity demand.

In the case of an ambitious scenario where two out of three cars on Europe's roads are electric in 2050 (190 million electric cars of total stock 280 million passenger cars) 36 Mtoe or 25% reduction of final energy could be gained. In this case 318 TWh additional electricity supply has to be provided (BMU and Fraunhofer ISI, 2012, 24). With 23 million electric vehicles (8% of the total car stock) the electricity demand would increase by 60 TWh in 2050 (BMU and Fraunhofer ISI, 2012, 28).

Pathways and policy implications for achieving required energy saving targetsFigure 3-6 describes the issues of electricity saving potentials and their relation to the electricity consumption pathway of the included scenario literature. The grey wedge reflects the electricity savings potential from the Boßmann et al. (2012) study.

> If substantial electricity saving measures were undertaken, gross electricity consumption in the EU 27 could be reduced to less than 2,500 TWh by 2050. This value is comparable to a 37% reduction below the projected baseline electricity demand and 13% below the value of the year 2008. (Boßmann et al., 2012, 248)

These measures are described in Section 3.1.2, which are e.g. optimised electric motor driven systems and energy-efficient heat generation systems in the industry sector, electric appliances and lighting as the key possibilities to save energy in the household sector, and mainly building-related measures in the tertiary sector. The energy [r]evolution Advanced scenario is included twofold in Figure 3-6. One graph includes the electricity intensive production of hydrogen (H_2) and one graph does not (energy [r]evolution no H_2). This was done to make the scenario more comparable to the others which don't model any significant hydrogen production before the year 2050.

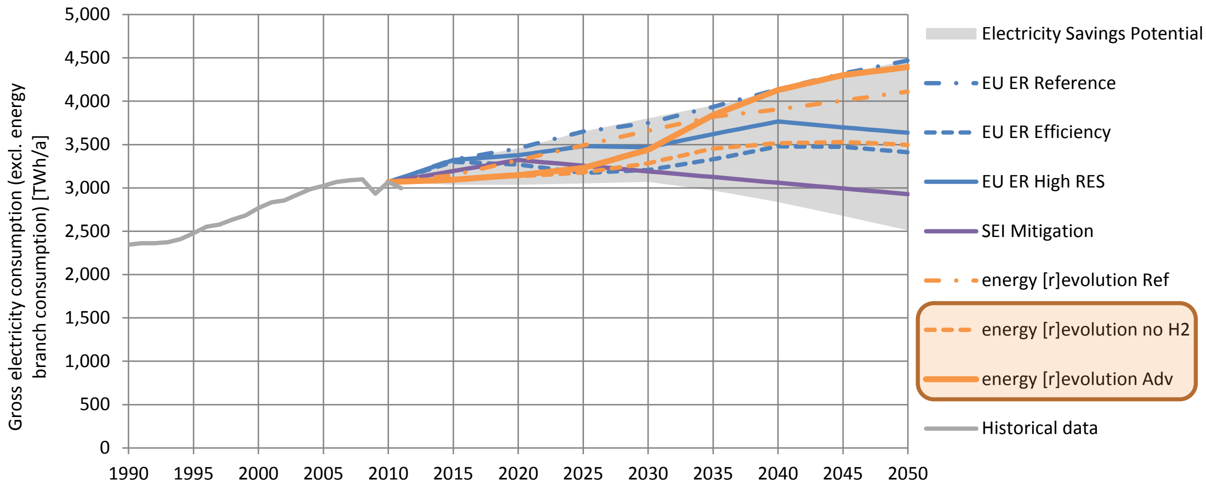

Figure 3-6. Electricity saving potential. (Boßamn et al., 2012, 247; EC, 2011b, 158-175; Greenpeace and EREC, 2012; Heaps et al., 2009, 56)

In accordance with the Energy Efficiency Directive (2012/27/EU), which follows the Energy Efficiency Plan, many efficiency measures need to be implemented through new legislative proposals. A correct implementation of these directives (also seen in Chapter 3.1.1) would be the right way to achieve the expected targets in 2020. The most important measures to take are drawn as follows:

- Include the setting of clear political objectives to stimulate higher political commitment to energy efficiency.
- The development of energy services markets and support for a functioning commercial market for delivering energy efficiency improvements which provide equal playing field rules for all energy efficiency market actors.
- To increase the role of the public sector, decrease the administrative burden and simplify the legislative framework.
- Improve consumers' awareness of their energy consumption and therefore ensure that consumers are empowered with correct, understandable and regular information on their energy use.
- Increase efficiency in energy supply and therefore trigger measures on the supply side to transform, transmit and distribute energy in the most cost-effective way, as well as support the establishment of smart grids.

Box 3 explains policy instruments for promoting energy efficiency and energy conservation.

Box 3. Classification of policy instruments for promoting energy- efficiency and conservation

Classification of policy instruments for promoting energy efficiency and energy conservation

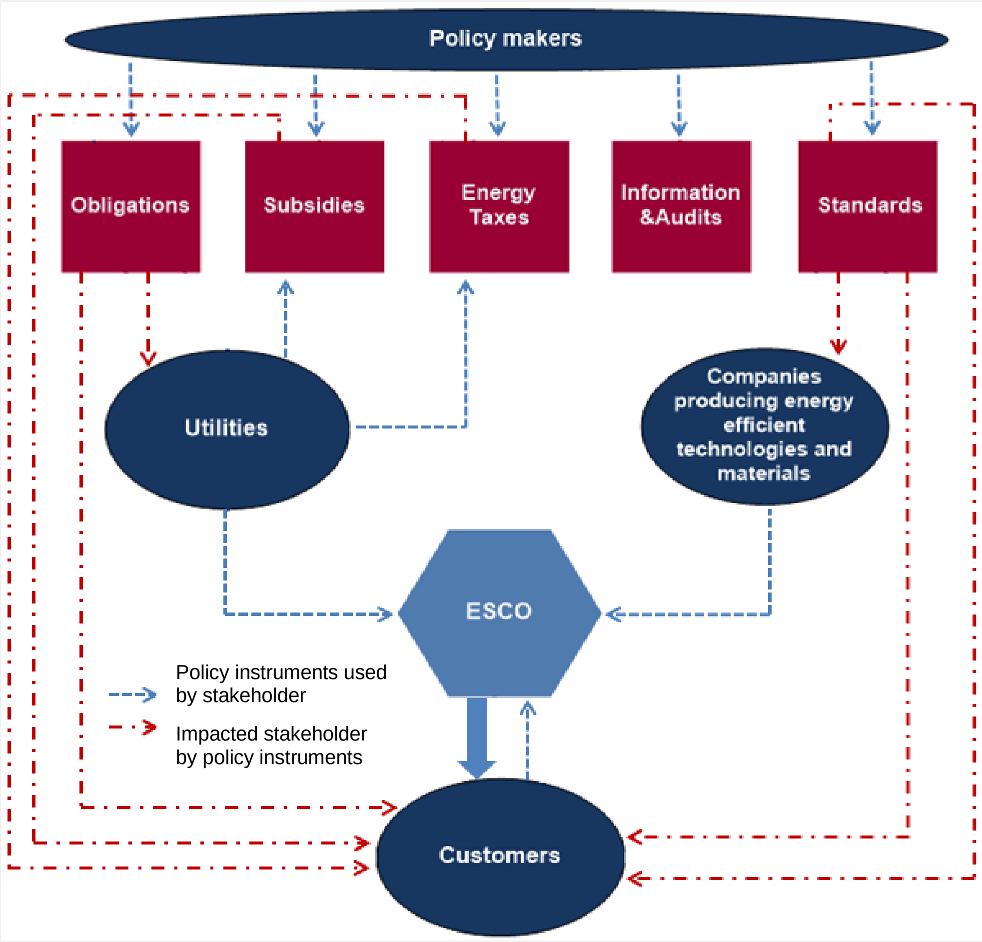

Figure 3-7. Basic formal frameworks of main energy efficiency policy instruments and related stakeholders. (Suna, 2013)

As illustrated in Figure 3-7 key instruments set by policy makers and the way how the energy efficiency / savings targets should be achieved are:

- Energy savings obligations – imposed either directly on costumers or on utilities by defining an energy savings target, which defines the minimum level of total saving to be achieved
- Standards – Defining the minimum efficiency for the efficiency level of a new technology
- Taxes – Imposed taxes on energy prices to lead to an energy demand reduction

These instruments are often accompanied by policy instruments such as subsidies and information & audits. Investments subsidies are given to costumers, which implemented high-efficient technologies. Gathering information related to efficient technologies is mainly bonded with transaction costs and each activity for increasing consumer's awareness would lead to a reduction of their energy consumption. Therefore these activities are defined as a specific kind of subsidy on transaction costs. Besides these players, Energy Service Companies (ESCOs) are one of the main energy efficiency actors, which offer implementation of efficiency measures while maintaining a service level, which is at least equal to consumer's initial services. (Suna, 2013)

The policy options as discussed above can be further specified as three levels of policy options for a successful implementation of energy efficiency and savings measures.

- First level options include national targets/options and relates to whether there should be legally binding energy efficiency targets on member states.
- Second level policy options include:
    - Energy savings obligation
    - Further measures to realise potential at the end-use stage
    - Measures to realise potential at the stage of energy transformation and distribution
    - National reporting
- Third level policy decisions include options concerning the purpose and scope of the legislative proposal and the choice of legal instruments.
  (EC, 2011c, 16-25)

After the release of EU Directive 2012/27/EU each member state needs to set up an energy obligation scheme which ensures the achieving of the end-use energy savings target by 31 December 2020. This target shall be at least equivalent to 1.5% p. a. energy savings. Member states shall also express the amount of energy savings required of each obligated party and the chosen method for expressing these amount to be used for calculating the savings claimed. Once a year, member states shall publish the achieved energy savings. (DIRECTIVE 2012/27/EU, 2012, 15f)

As an alternative to setting up an energy efficiency obligation scheme, member states may use other policy measures to achieve energy savings. Overall the actual EU Directive (DIRECTIVE 2012/27/EU, 2012, 16) proposes following policy measures or combinations thereof, which may be included, but are not restricted to in the national Energy Efficiency Plans:

- Energy or CO_2 taxes that have the effect of reducing end-use energy consumption
- Financing schemes and instruments or fiscal incentives that lead to the application of energy-efficient technology or techniques and have the effect of reducing end-use energy consumption
- Regulations or voluntary agreements that lead to the application of energy-efficient technology or techniques and have the effect of reducing end-use energy consumption
- Standards and norms that aim at improving the energy efficiency of products and services, including buildings and vehicles, except where these are mandatory and applicable in Member States under Union law
- Energy labelling schemes with the exception of those that are mandatory and applicable in the Member States under Union law

Based on the EU Energy Roadmap High Energy Efficiency scenario the economic, social, and environmental impacts have been analysed with the following results: (EC, 2011c, 26ff)

3.1.2.5 First level policy options

Retaining the current approach would mean, that no further targets are defined, which leads to 9% reduction up to 2016 while the achievement of the target cannot easily be monitored through official statistics and does not allow any conclusions about impacts of the measures. Proposing further aspects would lead to primary energy savings:

- 15,4% in a pessimistic approach and 19,3% by an optimistic approach by setting voluntary targets, whom level of ambition is in the hand of the various member states.
- 20% reduction by implementing binding national targets for primary energy consumptions.

3.1.2.6 Second level policy options

Energy Saving Obligations

"Energy saving obligations mean in general manner that the energy suppliers and/or distributors are obliged to achieve a specific energy saving target in a specific timeframe. After implementation of different energy saving measures they obtain certificates which are commonly called as "White Certificates" that can be traded and exchanged, but this issues is not pre-condition." (Suna, 2013, 89)

Because of the fact, that the impacts on energy savings depends on the level of ambition, on average 0.8% annual savings would be achieved, if EU Member States would be free to set their level of ambition. In case of aiming more ambitious 1.5% savings per year, saving of about 108-118 Mtoe of primary energy consumption in 2020 would be achieved. It is assumed that the binding character of the obligations to be placed on energy suppliers/distributors will mean that in both cases these obligations are fully translated into energy savings.

Table 3-1. Main characteristics of assessed obligation schemes. (Suna, 2013, 94)

Design Features	UK	France	Italy	Denmark	BE-Flemish region
Obligation holder	Electricity and gas suppliers with at least 50,000 residential customers	All Energy suppliers (except transport)	Electricity and gas distributors	Electricity, gas and heat distributors	Electricity distributors
Policy scope	Residential	All except EU- ETS	All end users	All end users	Residential and non energy intensive industry and service
Main delivery agents	Energy suppliers	Energy suppliers	ESCOs	Commercial daughter companies	ESCOs
Price Regulation	None	To be defined	Distribution charge (regulated tariffs)	Distribution charge (regulated tariffs)	Distribution charge (regulated tariffs)
Trading	Only between suppliers (No transparent white certificates)	Yes (White certificates market)	Yes (White certificates market)	n/a	n/a
Size of certificates	n/a	1 kWh cumac	1toe	n/a	n/a
Trading actors	Energy suppliers only	Energy suppliers, public sector and businesses	Any	Non	Non
Target set by	Regulator	Government	Government	Government	Flemish Government
Administrator	Regulator (Ofgem)	Government	Regulator (AEEG)	Danish energy authority	Flemish Government
Penalty	A fine up to 10% of the suppliers turnover (related to size of miss)	2 €cents per kWh	not explicitly defined (related to non -compliance)	Non	1 €cent/kWh missed + fine not eligible for tariff
Dominant measures in terms of savings	Insulation	Heating equipments	Lighting	Horizontal technologies in industry	Glazing, boilers, insulation

The introduction of savings obligations for energy suppliers/distributors is estimated to have positive economic impact and so will be highly effective by saving a clear amount of energy. The efficiency would be higher, if harmonisation of the administration costs of the member states is used (EC, 2011c, 32 and 36). The social impact on consumption and employment is forecast to be positive compared to the reference scenario. The majority of jobs created will be in the higher quality segment, while the environmental effects depend on the level of ambition of the obligation and the mitigation of local air pollutants through less energy consumption from conventional energy sources (EC, 2011c, 34f). Table 3-1 indicates the main characteristics of analysed obligation programs with a variation of implemented measures in different countries. There are big differences in the question of the terms of savings as well as in the question of the responsible administration and penalties (Suna, 2013, 93).

Further measures to realise potential at the end-use stage

This includes measures that aim to increase the role of the public sector and ensuring that information on savings is provided for consumers and industry as well as the development of energy service companies is supported. It makes sense to focus on the refurbishment of public buildings, which represent a small but still considerable part (i.e. 12%) of the total building stock, because they have a high visibility in public life (e.g. schools) and their status and performance have a significant impact for the private building sector (EC, 2011c, 37f). Energy efficiency improvements only account for part of the investment needed when renovation is carried out. Energy related investments are usually 1.5 times lower than total investment needs. That is why energy efficiency measures should be carried out when general renovation is done (EC, 2011c, 40). The increased activity in the construction sector would lead to impacts on job creation and retention. Further it can be expected, that this impacts will be sustained over the long term. In case of final consumption, reductions in electricity/gas of 10% and heat of 20% would lead to significant reductions in GHG (EC, 2011c, 46).

National reporting

Depending on the legislative context, the purposes of planning and reporting requirements can be some or all of the following:

- To encourage the setting of a clear comprehensive plan and the monitoring of progress at national level
- To present information on progress in member states in a form that allows member states with good performance to be identified and recognised for this where member states with poor performance would be put under pressure to improve
- To permit the Commission to provide feedback, enabling weaknesses in planning to be identified and corrected in a timely way
- To serve as the basis for remedial action when progress towards binding targets is insufficient
- The administrative burden imposed by each option.
  (EC, 2011c, 64)

The direct impact of each option depends on the extent to which they permit these purposes to be fulfilled. Overall ESCOs are an important player that could take some of the burden of the initial required investments in energy efficiency measures. Even in well-established ESCO markets, transaction costs are too high for potential customers to easily assess the available service offer. Therefore establishing structures to carry out market monitoring, providing lists of energy service offers and standard contracts is suggested. (EC, 2011c, 70)

3.1.2.7 Third level policy options

In order to reach the level of ambition of the EU 20% energy efficiency objective, EU policies need to look at every sector to reap energy saving potential, including potential in sectors excluded from the scope of application of the Directive on energy end-use efficiency and energy services (ESD). Merging the ESD and CHP Directive into one legislative text would provide for simplification and better coherence (EC, 2011c, 70). Beside all energy policy options energy audits and management systems as well as metering are playing a main role in the (DIRECTIVE 2012/27/EU, 2012, 17f). In the daily usage the word “smart metering” is very common.

In the term of energy audits and management systems the availability to all final consumers of high quality energy audits has to be guaranteed, which requires transparent and non-discriminatory minimum criteria for energy audits. This has to be done by independent and qualified experts. In addition, member states shall develop programs to raise awareness among household about the benefits of such audits and may stand alone (or be part of a broader environmental audit).

In the field of metering, member states shall ensure that, as far it is “technical possible, financially reasonable and proportionate in relation to the potential energy savings”, final consumers are provided with competitively priced individual meters that reflect the consumers’ actual consumption and that provide information on actual time of use. Besides security of this smart meters and data communication as well as the privacy of the consumer have to be granted.

3.2 Implications for future renewable energy developments

This section is dedicated to shed light on future RES developments necessary for a sustainable European energy system that shall beyond 2030 no longer rely on nuclear power. We start with a short summary of the starting point for doing so, discussing the policy context and past developments. Next, a closer look is taken on the potentials for RES that are applicable within the European Union, comparing the needs set out by the underlying energy [r]evolution path, i.e. the Advanced scenario, with the applicable resources, specifically in the mid-term up to 2030. Finally, related deployment pathways for the individual RES technologies are derived and related policy implications identified.

3.2.1 Policy context - status quo

As outlined in detail in the Re-Shaping study (see Ragwitz et al., 2012), the last decade was characterized by the successful deployment of RES across EU Member States – total RES deployment increased by more than 40%. More precisely:

- RES electricity generation grew by approximately 40%, RES heat supply by 30% and biofuels by a factor of 27 during the last decade,
- New renewables in the electricity sector (all technologies except hydropower) increased fivefold during the same period,
- Total investments in RES technologies increased to about € 40 billion annually in 2009, and more than 80% of all RES investments in 2009 were in wind and PV.

These impressive structural changes in Europe's energy supply are the result of a combination of strong national policies and the general focus on RES created by the EU Renewable Energy Directives in the electricity and transport sectors towards 2010 (2001/77/EC and 2003/30/EC).

Despite the challenges posed by the financial and economic crisis, RES investments have increased even further over the last two years. The European Energy and Climate Package is one of the key factors that contributed to this development. The EU ETS Directive has introduced full auctioning post 2012, thus exposing fossil power generation to the full cost of carbon allowances. As a result, it has become less attractive for utilities to continue to pursue conventional power projects, and attention has shifted towards generation options relying on renewable sources. The renewable energy trajectory towards 2020 was set and accepted by all the European Council, the European Commission and the European Parliament in April 2009. The related policy package, in particular the EU Directive on the support of energy from renewable sources (2009/28/EC), subsequently named as RES Directive, comprises the establishment of binding RES targets for each Member State, based on an equal RES share increase modulated by Member State GDP. This provides a clear framework and vision for renewable technologies in the short to mid-term.

Implementing the 2020 RES Directive has taken another step forward with the formulation of the National Renewable Energy Action Plans (NREAPs), which outline the national strategies concerning support schemes, cooperation mechanisms and (non-cost) barrier mitigation, in particular with respect to grid-related and administrative issues. In addition, a detailed reporting framework for the European Commission and Member States has been drawn up to ensure that these strategies are well established and coordinated.

Despite the successful development of the RES sector over the last decade, substantial challenges still lie ahead. For the renewable energy electricity and heating sectors (RES-E and RES-H), the growth rate of total generation has to continue in line with the trend observed during the last three years. For meeting 2020 RES targets, compared to the last decade, growth in RES-E needs to almost double from 3.4% per year to 6.7% per year by 2020. There also needs to be a substantial increase in growth in the RES-H sector from the 2.7% per year achieved over the last decade to 3.9% per year until 2020. Therefore, the EU as a whole should continue to uphold the past level of achievement and the most successful countries could even over-achieve the 2020 targets by continuing to follow their present trend.

In order to create the investment climate for reaching the 2020 targets the longer term commitment for renewable energies in Europe is an important condition. The more confidence investors have in the market growth for RES technologies beyond 2020, the better they will develop the supply chain and align structures within utilities and other companies.

Additionally we observe that national RES targets at Member State level have created strong commitment for renewable energies throughout the EU and are the key driver for RES policies at the moment. They are a key element for setting up the administrative procedures, regulatory frameworks, regional planning and national infrastructure development. As these elements will also be crucial for the RES deployment after 2020 binding national targets appear an important element also for the post 2020 horizon.

3.2.2 Potentials and costs for RES in the electricity sector

Nowadays, a broad set of different renewable energy technologies exists. Obviously, for a comprehensive investigation of the future development of RES it is of crucial importance to provide a detailed investigation of the country-specific situation – e.g. with respect to the potential of the certain RES technologies in general as well as their regional distribution and the corresponding generation cost.

This section illustrates the consolidated outcomes of an intensive assessment process on Europe's RES potentials and accompanying costs that has been conducted within several studies in this topical area. This shall provide clarification on the pending question if sufficient RES are applicable to meet Europe's power demand in the absence of nuclear power. More precisely, a comparison will be provided that refers to 2030, indicating the demand for renewable sources according to the Advanced scenario of the energy [r]evolution study as well as the applicable potentials.

The derived data on realisable mid-term (2030) potentials for RES fits to the requirements of the ***Green-X*** model, a specialised energy system model developed by TU Wien / EEG that allows to perform a detailed quantitative assessment of the future deployment of renewable energies on country-, sector- as well as technology level within the EU and its neighbouring countries.[12] Within the course of this study Green-X will be used to complement the literature-based assessment of RES policy implications as well as of related costs / expenditures.

[12] The core strength of this tool lies on the detailed RES resource and technology representation accompanied by a thorough energy policy description, which allows assessing various policy options with respect to resulting costs and benefits. For a detailed model description we refer to www.green-x.at.

3.2.2.1 Classification of potential categories

We start with a discussion of the general background and subsequently present the status quo of consolidated data on potentials and cost for RES in Europe as applicable in the Green-X database. These figures indicate what appears to be realisable within the 2030 timeframe.

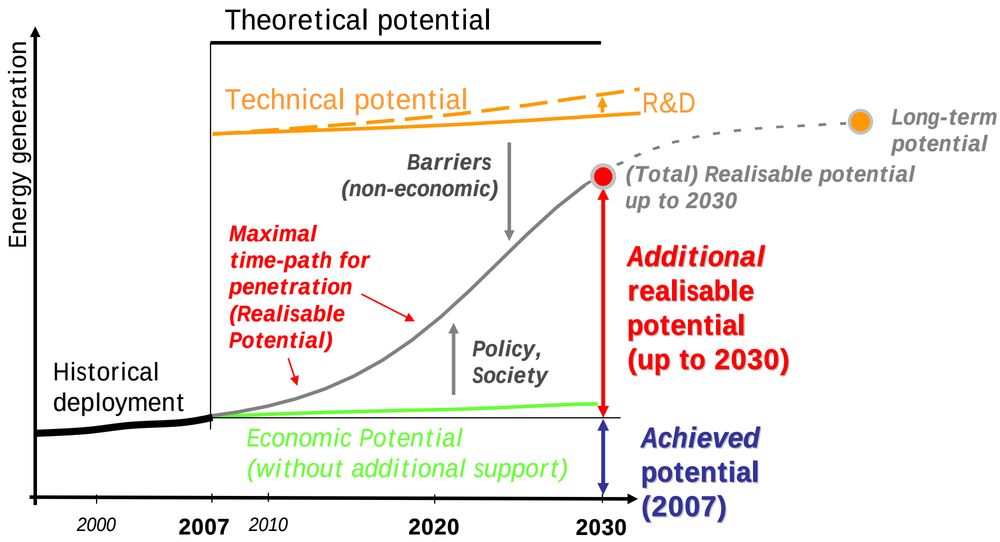

Figure 3-8. Definition of potential terms

The possible use of RES depends in particular on the available resources and the associated costs. In this context, the term "available resources" or RES potential has to be clarified. In literature, potentials of various energy resources or technologies are intensively discussed. However, often no common terminology is applied. Below, we present definitions of the various types of potentials as used throughout this report:

- *Theoretical potential:* To derive the theoretical potential, general physical parameters have to be taken into account (e.g. based on the determination of the energy flow resulting from a certain energy resource within the investigated region). It represents the upper limit of what could be produced from a certain energy resource from a theoretical point-of-view, based on current scientific knowledge;
- *Technical potential:* If technical boundary conditions (i.e. efficiencies of conversion technologies, overall technical limitations as e.g. the available land area to install wind turbines as well as the availability of raw materials) are considered, the technical potential can be derived. For most resources, the technical potential must be considered in a dynamic context. For example with increased R&D expenditures and learning-by-doing during deployment, conversion technologies might be improved and, hence, the technical potential would increase;
- *Realisable potential:* The realisable potential represents the maximal achievable potential assuming that all existing barriers can be overcome and all driving forces are active. Thereby, general parameters as e.g. market growth rates, planning constraints are taken into account. It is important to mention that this potential term must be seen in a dynamic context – i.e. the realisable potential has to refer to a certain year;

- Realisable potential up to 2030: provides an illustration of the derived realisable potential for the year 2030.
- Long-term potential: in this report, long-term potentials refer to the 2050 timeframe and consequently what can be realised until then. Obviously, this is closely linked (among other constraining factors) to infrastructural prerequisites.

Figure 3-8 shows the general concept of the realisable potential up to 2030 as well as in the long-term (2050), the technical and the theoretical potential in a graphical way.

3.2.2.2 The Green-X database on potentials and cost for RES in Europe – background information

Box 4. About the Green-X potentials and cost for RES in Europe.

Assessment of potentials and cost for RES in Europe – Method of approach

The Green-X database on potentials and cost for RES technologies in Europe provides detailed information on current cost (i.e. investment -, operation & maintenance -, fuel and generation cost) and potentials for all RES technologies within each EU Member State. The assessment of the economic parameter and accompanying technical specifications for the various RES technologies builds on a long track record of European and global studies in this topical area. From a historical perspective the starting point for the assessment of realisable mid-term potentials was geographically the European Union as of 2001 (EU-15), where corresponding data was derived for all Member States initially in 2001 based on a detailed literature survey and an expert consultation. In the following, within the framework of the study “Analysis of the Renewable Energy Sources’ evolution up to 2020 (FORRES 2020)” (see Ragwitz et al., 2005) comprehensive revisions and updates have been undertaken, taking into account recent market developments. Consolidated outcomes of this process were presented in the European Commission’s Communication “The share of renewable energy” (European Commission, 2004). Later on throughout the course of the futures-e project (see Resch et al., 2009) an intensive feedback process at the national and regional level was established. A series of six regional workshops was hosted by the futures-e consortium around the EU within 2008. The active involvement of key stakeholders and their direct feedback on data and scenario outcomes helped to reshape, validate and complement the previously assessed information.

Within the Re-Shaping project (see e.g. Ragwitz et al., 2012) and parallel activities such as the RES-Financing study done on behalf of the EC, DG ENER (Directorate-General for Energy) (see De Jager et al., 2011) again a comprehensive update of cost parameter was undertaken, incorporating recent developments – i.e. the past cost increase mainly caused by high oil and raw material prices, and, later on, the significant cost decline as observed for various energy technologies throughout 2008 and 2009. The process included besides a survey of related studies (e.g. Krewitt et al. (2009), Wiser (2009) and Ernst & Young (2009)) also data gathering with respect to recent RES projects in different countries.

The input database of the ***Green-X*** model offers a detailed depiction of the achieved and feasible future deployment of the individual RES technologies in Europe – in particular with regard to costs and penetration in terms of installed capacities or actual & potential generation. Realisable future potentials (up to 2030 / 2050) are included by technology and by country. In addition, data describing the technological progress such as learning rates are available. Both serve as crucial input for the model-based assessment of future RES deployment. Note that an overview on the method of approach used for the assessment of this comprehensive data set is given in Box 4 (above).

3.2.2.3 Mid-term (2030) realisable potentials for RES in the electricity sector – extract from the Green-X database

Next, we take a closer look on the mid-term prospects for RES in the electricity sector, illustrating the identified potentials that can be principally realised in the 2030 timeframe. In the power sector, RES-E options such as hydropower or wind energy represent energy sources characterised by a natural volatility. Therefore, in order to provide an accurate depiction of the future development of RES-E, historical data for RES-E is translated into electricity generation potentials[13] – the *achieved potential* at the end of 2005 – taking into account the recent development of this rapidly growing market. The historical record was derived in a comprehensive data-collection – based on (Eurostat, 2007; IEA, 2007) and statistical information gained on national level. In addition, future potentials – i.e. the additional realisable mid-term potentials up to 2030 – were assessed[14] taking into account the country-specific situation as well as overall realisation constraints.

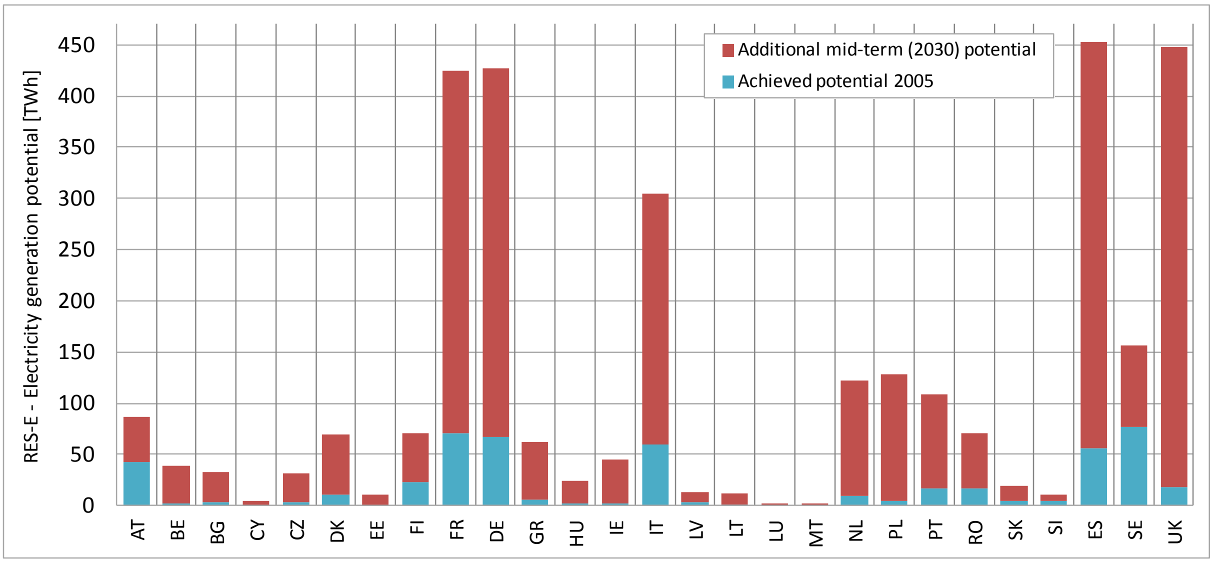

Figure 3-9. Achieved (2005) and additional mid-term potential 2030 for electricity from RES in the EU 27 on country level.

Figure 3-9 depicts the achieved and additional mid-term potential for RES-E in the EU 27 at country level. For EU 27 countries, the already achieved potential for RES-E equals 503 TWh, whereas the additional realisable potential up to 2030 amounts to 2676 TWh (about 81% of 2005's gross electrici-

13 The electricity generation potential with respect to existing plant represents the output potential of all plants installed up to the end of 2005. Of course, figures for actual generation and generation potentials differ in most cases – due to the fact that in contrast to the actual data, potential figures represent, e.g. in case of hydropower, the normal hydrological conditions, and furthermore, not all plants are installed at the beginning of each year.

14 A description of the potential assessment is given e.g. in (Resch et al., 2006) from a methodological point of view.

ty consumption). Obviously, large countries such as France, Germany, Spain or UK possess the largest RES-E potentials in absolute terms, where still a huge part is waiting to be exploited. Among the new Member States Poland and Romania offer the largest RES-E potentials in absolute terms.

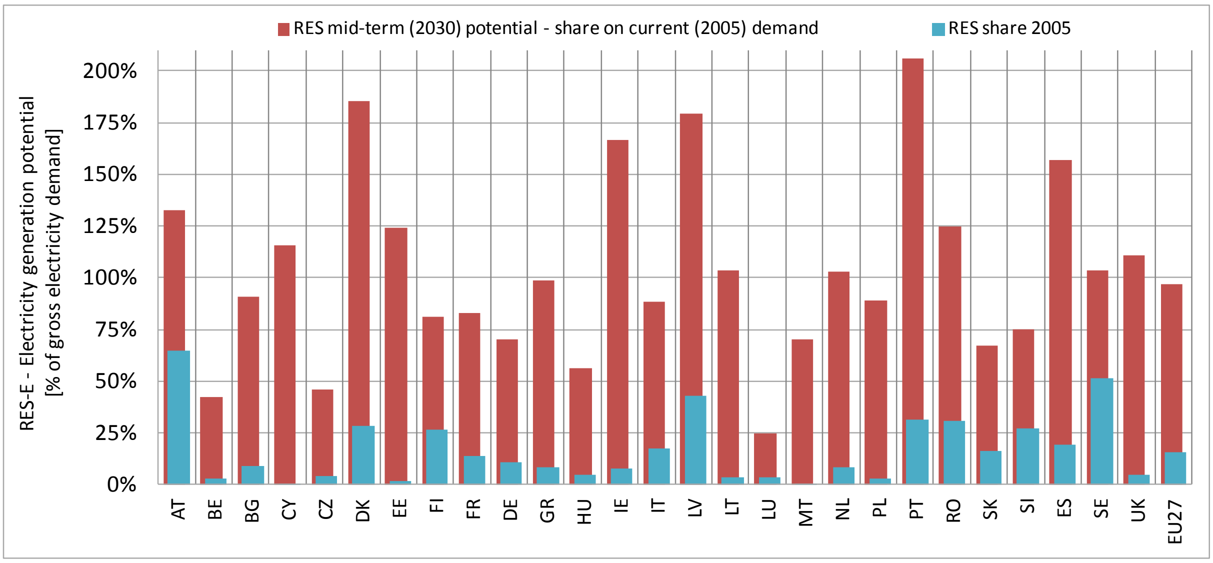

Figure 3-10. Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries as share of gross electricity demand (2005).

Consequently, Figure 3-10 relates derived potentials to gross electricity demand. More precisely, it depicts the total realisable mid-term potentials (up to 2030), as well as the achieved potential (2005) for RES-E as share of gross electricity demand in 2005 for all Member States and the EU 27 in total. As applicable from this depiction, significant additional RES potentials are becoming apparent for several countries. In this context especially notable are Portugal, Denmark and Ireland, as well as most of the new Member States. If the indicated realisable mid-term potential for RES-E, covering all RES-E options, would be fully exploited up to 2030, almost all our electricity needs as of today (97% compared to 2005's gross electricity demand) could be covered in principle[15]. For comparison, by 2005 already installed RES-E plants possess the generation potential to meet about 15% of demand. Additionally, the above-mentioned relations of the total realisable mid-term potential (2030) to the gross electricity demand are addressed in Figure 3-11 with respect to different scenarios on the future development of the electricity demand. A strong impact of the electricity demand development on the share of renewables is noticeable: In a baseline demand scenario (according to PRIMES), a total achievable RES-E share of 76% in the year 2030 would appear feasible, whereas in a (moderate) efficiency demand scenario, 87% of the expected future electricity demand by 2030 could be generated by renewables. As already discussed in the previous Figure 3-10, if the total realisable mid-term potential for RES-E was fully exploited up to 2030, 97% of current (2005) gross

15 In practice, there are important limitations that have to be considered: not all of the electricity produced may actually be consumed since supply and demand patterns may not match well throughout a day or year. In particular this statement is getting more and more relevant for variable RES like solar or wind where curtailment of produced electricity increases significantly with increasing deployment. This indicates the need for complementary action in addition to the built up of RES capacities, including grid extension or the built up of storage facilities.

consumption could be covered, meaning even the efficiency demand scenario takes an increasing electricity demand into account.

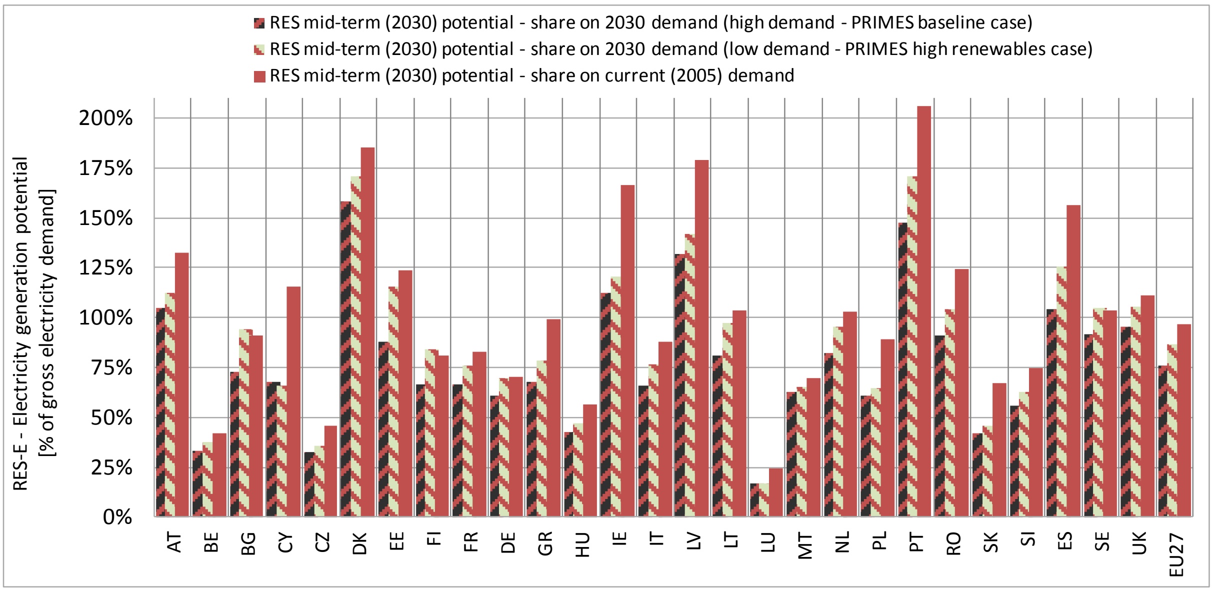

Figure 3-11. Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries as share of gross electricity demand (2005 & 2030) in a baseline and an efficiency demand scenario.

Figure 3-12 demonstrates both the achieved and the additional realisable mid-term potential up to 2030 on a technology level for the whole EU 27. The figure depicts a high penetration and a small additional realisable potential for hydropower, both small- and large-scale. Wind onshore and solid biomass technologies are both already well developed, but still an enormous additional potential has to be realized to meet future RES-E targets. Moreover, technologies like wind offshore, tidal stream and wave power as well as photovoltaics provide a large additional potential, waiting to be exploited in forthcoming years.

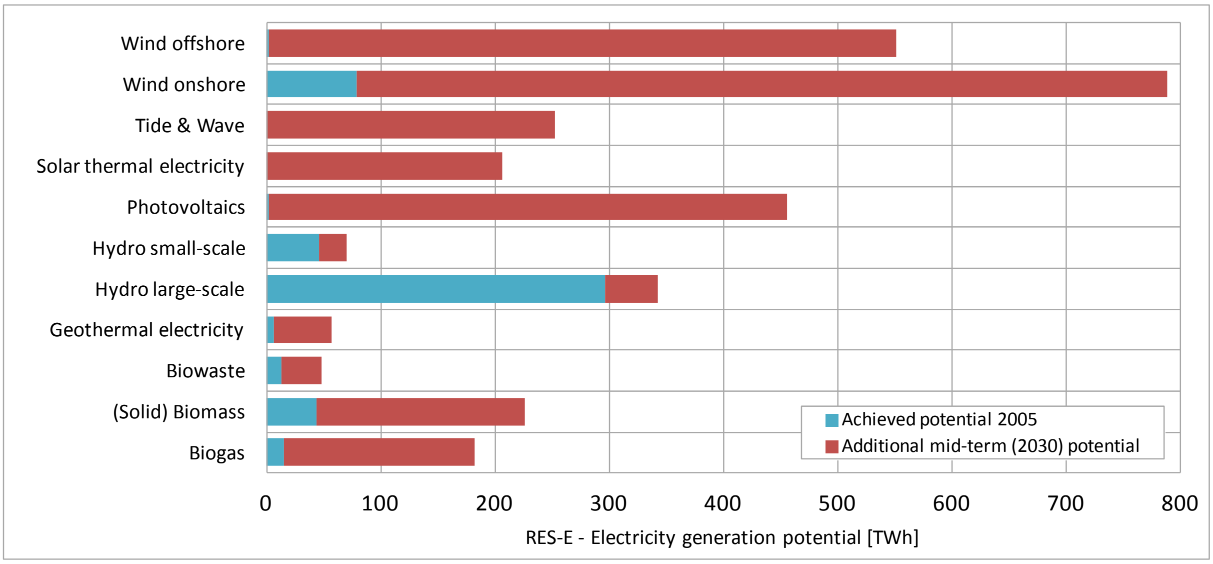

Figure 3-12. Total realisable mid-term potentials (2030) and achieved potential for RES-E in EU 27 countries on technology level.

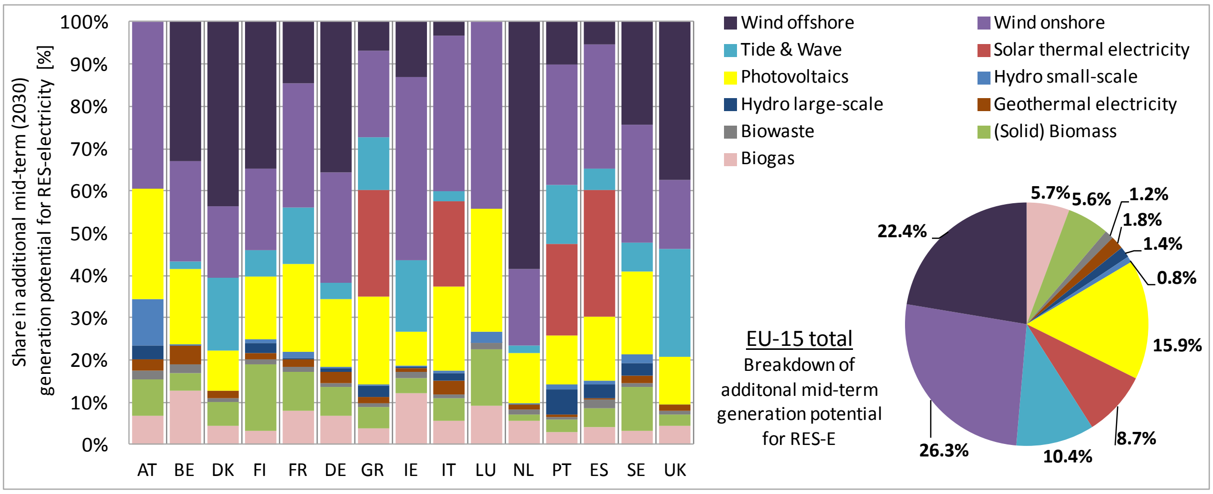

Figure 3-13. RES-E as a share of the additional realisable potential in 2030 for the EU-15 - by country (left) as well as for total EU-15 (right).

Next, future perspectives are indicated at the country level. As already mentioned, hydropower dominates current RES-E generation in most EU countries, followed by wind, biomass, biogas and biowaste. Figure 3-13 shows the share of different energy sources in the additional RES-E mid-term potential up to 2030 for the EU-15. The largest potential is found for wind energy (49%) followed by photovoltaics (16%) and biomass (13% - as aggregate of solid and gaseous biomass as well as biowaste), as well as promising future options such as tidal & wave (10%) or solar thermal energy (9%).

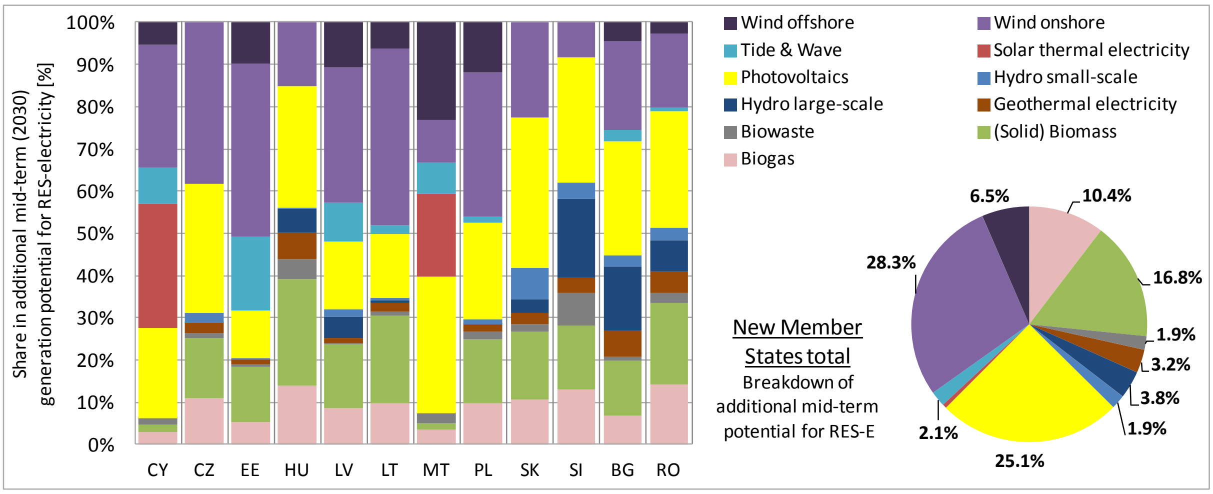

Figure 3-14. RES-E as a share of the additional realisable potential in 2030 for the New Member States - by country (left) as well as for total NMS (right).

In the New Member States, currently (2005), almost 88% of the renewable electricity is generated by hydro power plants and 10% by solid biomass, mainly co-fired in thermal fossil fuel-based power plants. Only a minor part is provided by more novel technologies such as wind energy and biogas. Figure 3-14 provides the 2030 depiction for New Member States (NMS), illustrating the share of different RES-E options in the additional mid-term potential up to 2030. In line with the EU-15, the largest potentials for these countries exist in the sectors of wind energy (35%) and photovoltaics (25%) followed by solid biomass (17%) and biogas (10%). Unlike the situation in the EU-15, the refurbishment and construction of large hydro plants holds significant potentials in some countries (4% of total NMS's future RES-E potential).

To conclude the discussion on future potentials for RES a closer look is taken on how the above discussed realisable potentials match with the projected deployment of the energy [r]evolution study. More precisely, Box 5 offers a comparison of Green-X potentials as outlined above with the expectations underlying the calculation of the energy [r]evolution Advanced scenario.

Box 5. Comparison of RES potentials (Green-X) vs required RES deployment (energy [r]evolution)

Comparing realisable RES potentials with projected deployment: how do the underlying assumptions of the energy [r]evolution study fit?

Table 3-2. Electricity generation from RES - comparison of the required deployment by 2030 and applicable potentials.

Electricity generation from RES - required deployment 2030 and applicable potential (at EU level by technology)	Unit	Energy [r]evolution Adv 2030	Green-X - realisable potential 2030	Literature review - long-term potential (technical or economic)	
				min	max
Biomass	[TWh/a]	306	456	421	650
Hydro	[TWh/a]	362	413	472	650
Wind Onshore	[TWh/a]	480	789	353	2,888
Wind Offshore	[TWh/a]	459	550	361	2,696
PV	[TWh/a]	414	456	131	1,162
Geothermal	[TWh/a]	153	58	180	180
CSP	[TWh/a]	141	206	172	2,239
Ocean Energy	[TWh/a]	63	252	119	252
RES-E total	[TWh/a]	**2,378**	**3,180**	**2,208**	**10,717**

Finally, a concise comparison of the identified RES potentials in the mid- (2030) to long-term (2050) with the needs set out by the Advanced scenario of energy [r]evolution is undertaken. With respect to potentials, in addition to the mid-term (2030) potentials according to the Green-X database also long-term potentials (up to 2050) are illustrated in Table 3-2, summarising the outcomes of a literature survey.

Generally, a proper match between the projections on technology-specific RES deployment according to the Advanced scenario of the energy [r]evolution study and the identified realisable potentials for 2030 can be seen. In other words, expected deployment is (well) below applicable resources. One exception to this general rule is geothermal electricity where a significantly more rapid progress and take-off of advanced geothermal power generation technologies to make use of mid-to low temperature geothermal sources is expected.

This can be seen as questionable from today's perspective – however, since the magnitude of overall expected deployment by 2030 is small this does not imply to put the whole scenario projection under question. The overall up-take of renewables appears ambitious and it can be anticipated that proactive policy action is required to tackle current deficits and problems related to RES-E deployment well in time.

3.2.2.4 Costs for RES in the electricity sector

The current situation (as of 2010)

Economic conditions of the various RES technologies are based on both economic and technical specifications, varying across the EU countries. In order to illustrate the economic figures for each technology Table 3-3 represents the economic parameters and accompanying technical specifications for RES technologies in the electricity sector. Note that all expressed data refer to the year 2010 and are expressed in real terms (i.e. $€_{2010}$).

The ***Green-X*** database and the corresponding model use a quite detailed level of specifying costs and potentials. The analysis is not based on average costs per technology. For each technology, a detailed cost-curve is specified for each year, based on so-called cost-bands. These cost-bands summarize a range of production sites that can be described by similar cost factors. For each technology a minimum of 6 to 10 cost bands are specified by country. For biomass, at least 50 cost bands are specified for each year in each country.

In the following the current investment cost for RES technologies are described alongside the data provided in Table 3-3, whereby a focus may be put on the description of some key technology options. Since the original development of the ***Green-X*** database in the year 2004, several updates and adjustments have become necessary due to cost dynamics of RES technologies. In many cases, there was a trend for an increase of investment costs in the years up to 2008, followed by a stagnation or decrease in subsequent years.

Firstly, explanatory notes are provided on the technology-specific investment costs as depicted in Table 3-3:

- The current costs of biogas plants range from 1445 €/kW_{el} to 5085 €/kW_{el} with landfill gas plants offering the most cost efficient option (1445 €/kW_{el} – 2255 €/kW_{el}) and agricultural biogas plants (2890 €/kW_{el} – 5085 €/kW_{el}) being the highest cost option within this category;
- The costs of medium- to large-scale biomass plants only changed slightly and currently lie in the range of 2540 €/kW_{el} to 3550 €/kW_{el}. Biomass CHP plants typically show a broader range (2950 €/kW_{el} – 4885 €/kW_{el}) as plant sizes are typically lower compared to pure power generation. Among all bioelectricity options waste incineration plants have the highest investment costs ranging from 5150 €/kW_{el} to 7695 €/kW_{el} whereby CHP options show about 5% higher investment cost but offer additional revenues from selling (large amounts of) heat;
- The current investment costs of geothermal power plants are in the range of 2335 €/kW_{el} to 7350 €/kW_{el}., whereby the lower boundary refers to large-scale deep geothermal units as applicable e.g. in Italy, while the upper range comprises enhanced geothermal systems;
- Looking at the investment costs of hydropower as electricity generation option it has to be distinguished between large-scale and small-scale hydropower plants. Within these two categories, the costs depend besides the scale of the units also on site-specific conditions and additional requirements to meet e.g. national / local environmental standards etc. This leads to a comparatively broad cost range from 870 €/kW_{el} to 6265 €/kW_{el} for new large-scale hydropower plants. Corresponding figures for small-scale units vary from 980 €/kW_{el} to 6590 €/kW_{el};

- In 2010 typical PV system costs were in the range 2675 €/kW_{el} to 3480 €/kW_{el}. These cost levels were reached after strong cost declines in the year 2008 and thereafter. This reduction in investment cost marks an important departure from the trend of the years 2005 to 2007, during which costs remained flat, as rapidly expanding global PV markets and a shortage of silicon feedstock put upward pressure on both module prices and non-module costs (see e.g. Wiser et al 2009). Before this period of stagnation PV systems had experienced a continuous decline in cost since the start of commercial manufacture in the mid 1970's following a typical learning curve. The new dynamic began to shift in 2008, as expansions on the supply-side coupled with the financial crisis led to a relaxation of the PV markets and the cost reductions achieved on the learning curve in the meantime factored in again. Furthermore, the cost decrease has been stimulated by the increasing globalization of the PV market, especially the stronger market appearance of Asian manufacturers.
- The investment costs of wind onshore power plants are currently (2010) in the range of 1350 €/kW_{el} and 1685 €/kW_{el} and thereby slightly lower than in the previous year. Two major trends have been characteristic for the wind turbine development for a long time: While the rated capacity of new machines has increased steadily, the corresponding investment costs per kW dropped. Increases of capacity were mainly achieved by up-scaling both tower height and rotor size. The largest wind turbines currently available have a capacity of 5 to 6 MW and come with a rotor diameter of up to 126 meters. The impact of economies of scale associated with the turbine up-scaling on turbine cost is evident: The power delivered is proportional to the diameter squared, but the costs of labour and material for building a turbine larger are constant or even fall with increasing turbine size, so that turbine capacity increases disproportionally faster than costs increase. From around 2005 on the investment costs have started to increase again. This increase of investment cost was largely driven by the tremendous rise of energy and raw material prices as observed in recent years, but also a move by manufacturers to improve their profitability, shortages in certain turbine components and improved sophistication of turbine design factored in. Beyond 2010 a downward trends related to wind costs is however getting apparent again, indicating that technological learning is continued and that increased competition on the manufacturing side is apparent.

Table 3-3. Overview on economic-& technical-specifications for new RES-E plant (for the year 2010)

RES-E sub-category	*Plant specification*	*Investment costs*	*O&M costs*	*Efficiency (electricity)*	*Efficiency (heat)*	*Lifetime (average)*	*Typical plant size*
		[€/kW$_{el}$]	*[€/(kW$_{el}$* year)]*	*[1]*	*[1]*	*[years]*	*[MW$_{el}$]*
Biogas	Agricultural biogas plant	2890 – 4860	137 - 175	0.28 - 0.34	-	25	0.1 - 0.5
	Agricultural biogas plant - CHP	3120 – 5085	143 – 182	0.27 - 0.33	0.55 - 0.59	25	0.1 - 0.5
	Landfill gas plant	1445 - 2080	51 – 82	0.32 - 0.36	-	25	0.75 - 8
	Landfill gas plant - CHP	1615 - 2255	56 - 87	0.31 - 0.35	0.5 - 0.54	25	0.75 - 8
	Sewage gas plant	2600 - 3875	118 – 168	0.28 - 0.32	-	25	0.1 - 0.6
	Sewage gas plant - CHP	2775 - 4045	127 – 179	0.26 - 0.3	0.54 - 0.58	25	0.1 - 0.6
Biomass	Biomass plant	2540 - 3550	97 – 175	0.26 - 0.3	-	30	1 – 25
	Cofiring	350 - 580	112 – 208	0.35 – 0.45	-	30	-
	Biomass plant - CHP	2600 - 4375	86 – 176	0.22 - 0.27	0.63 - 0.66	30	1 – 25
	Cofiring – CHP	370 - 600	115 – 242	0.20 – 0.35	0.5 - 0.65	30	-
Biowaste	Waste incineration plant	5150 – 6965	100 - 184	0.18 - 0.22	-	30	2 – 50
	Waste incineration plant - CHP	5770 - 7695	123 – 203	0.16 - 0.19	0.62 - 0.64	30	2 – 50
Geother-mal elec-tricity	Geothermal power plant	2335 - 7350	101 - 170	0.11 - 0.14	-	30	5 – 50
Hydro large-scale	Large-scale unit	1600 - 3460	33 – 36	-	-	50	250
	Medium-scale unit	2125 – 4900	34 – 37	-	-	50	75
	Small-scale unit	2995 – 6265	35 – 38	-	-	50	20
	Upgrading	870 – 3925	33 – 38	-	-	50	-
Hydro small-scale	Large-scale unit	1610 - 3540	36 – 39	-	-	50	9.5
	Medium-scale unit	1740 - 5475	37 – 40	-	-	50	2
	Small-scale unit	1890- 6590	38 – 41	-	-	50	0.25
	Upgrading	980 - 3700	36 – 41	-	-	50	-
Photovol-taics	PV plant	2675 - 3480	30 – 39	-	-	25	0.005 - 0.05
Solar thermal electricity	Concentrating solar power plant	6135 -7440	136 - 200	0.33 - 0.38	-	30	2 – 50
Tidal stream energy	Tidal (stream) power plant - shoreline	6085 – 7100	95 – 145	-	-	25	0.5
	Tidal (stream) power plant - nearshore	6490 – 7505	108 – 150	-	-	25	1
	Tidal (stream) power plant - offshore	6915 - 8000	122 – 160	-	-	25	2
Wave energy	Wave power plant - shoreline	5340 – 5750	83 – 140	-	-	25	0.5
	Wave power plant - nearshore	5785 – 6050	90 – 145	-	-	25	1
	Wave power plant - offshore	7120 – 7450	138 – 155	-	-	25	2
Wind onshore	Wind power plant	1350 – 1685	30 – 36	-	-	25	2
Wind offshore	Wind power plant - nearshore	2850 - 2950	64 – 70	-	-	25	5
	Wind power plant - offshore: 5...30km	3150 – 3250	70 – 80	-	-	25	5
	Wind power plant - offshore: 30...50km	3490 - 3590	75 – 85	-	-	25	5
	Wind power plant - offshore: 50km...	3840 - 3940	80 – 90	-	-	25	5

While the investments costs of RES technologies as described above are suitable for an analysis at the technology level, for the comparison of technologies the generation costs are relevant. Consequently, the broad range of the resulting generation costs, due to several influences, for several RES technologies is addressed subsequently. Impacts as, variations in resource- (e.g. for photovoltaics or wind energy) or demand-specific conditions (e.g. full load hours in case of heating systems) within and between countries as well as variations in technological options such as plant sizes and/or conversion technologies are taken into account. In this context, for the calculation of the capital recovery factor a payback time of 15 years, which represents rather an investor's view than the full levelled costs over the lifetime of an installation, and weighted average cost of capital of 6.5% are used.

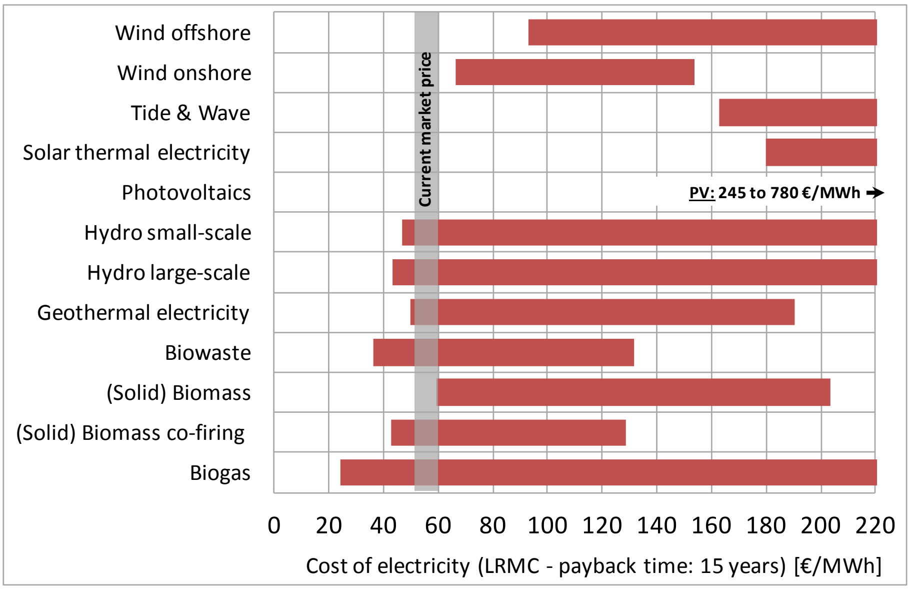

Figure 3-15. Long-run marginal generation costs (for the year 2010) for various RES-E options in EU countries

As can be observed from Figure 3-15 the general cost level as well as the magnitude of the cost ranges vary strongly between the different technologies. Looking at the different RES-E options the situation is comparatively diverse: The most conventional and cost efficient options like large hydropower and biogas can generate electricity below market prices. It is also noticeable that wind power (onshore) cannot deliver electricity at market prices even at the best sites. Of course, this proposition holds only for current market prices which have decreased substantially in the wholesale market in the near past. For most RES-E technologies the cost range at the EU level appears comparatively broad. In the case of PV or wind energy this can be to a lesser extent ascribed to (small) differences in investment costs between the Member States, but more crucial in this respect are the differences in resource conditions (i.e. the site-specific wind conditions in terms of wind speeds and roughness classes or solar irradiation and their formal interpretation as feasible full load hours) between the Member States. In the case of photovoltaics the broad cost range results also from differences in terms of application whereby the upper boundary refers to facade-integrated PV systems.

Technological change - future cost and performance expectations

Considering the assumptions of technology learning and cost reductions a brief overview is given here. For most RES-E technologies the future development of investment cost is based on technological learning. As learning is taking place on the international level the deployment of a technology on the global market must be considered. For the model runs global deployment consists of the following components:

- Deployment within the EU 27 Member States is endogenously determined, i.e. is derived within the model.
- Expected developments in the "rest of the world" are based on forecasts as presented in the IEA World Energy Outlook 2011 (IEA, 2011).

Table 3-4. **Assumed learning rates in case of moderate (default) learning expectations - exemplarily depicted for selected RES-E technologies**

Note: A cost increase (compared to 2006 levels) up to 2008 is assumed for solid biomass and wind energy (as well as for almost all other energy technologies) in line with historical observations. This increase is mainly caused by rising energy and raw material prices and in line with the assumptions on the development of energy prices (where high energy prices serve as default reference).

Assumed learning rates for selected RES-E technologies	*Geographical scope*	*Moderate learning*		
		2006 - 2010	*2011 - 2020*	*2021 - 2030*
Solid biomass - small-scale CHP	global learning system	cost increase*	10.0%	10.0%
Photovoltaics	global learning system	20.0%	20.0%	17.5%
Wind energy	global learning system	cost increase*	7.0%	7.0%

It is distinguished between a pessimistic scenario, with relatively low expectations on future cost reductions and a moderate scenario, assuming a more rapid RES deployment in Europe and at global scale. The identical assumed learning rates are depicted for both cases in Table 3-4. The consequences of the assumed RES technology diffusion and the underlying technology learning rates and efficiency improvements regarding the cost reduction of RES are depicted in Figure 3-16 (accelerated RES deployment) and Figure 3-17 (moderate RES deployment). Remarkable is the negative development in the period 2007 to 2009 for most energy technologies, but probably mostly affecting the cost of wind turbines. This increase of investment cost was largely driven by the tremendous rise of energy and raw material prices as observed in recent years and expected to prolong in the near to mid future – i.e. in line with the corresponding energy price assumptions where "high energy prices" serve as default case[16]. However, still substantial cost reductions are observable and expected for novel technology options such as photovoltaics, solar thermal electricity or ocean technologies.

16 For wind energy also an overheating of the global market was observable throughout that period, where supply could not meet demand. This lead to a higher cost increase compared to other energy technologies.

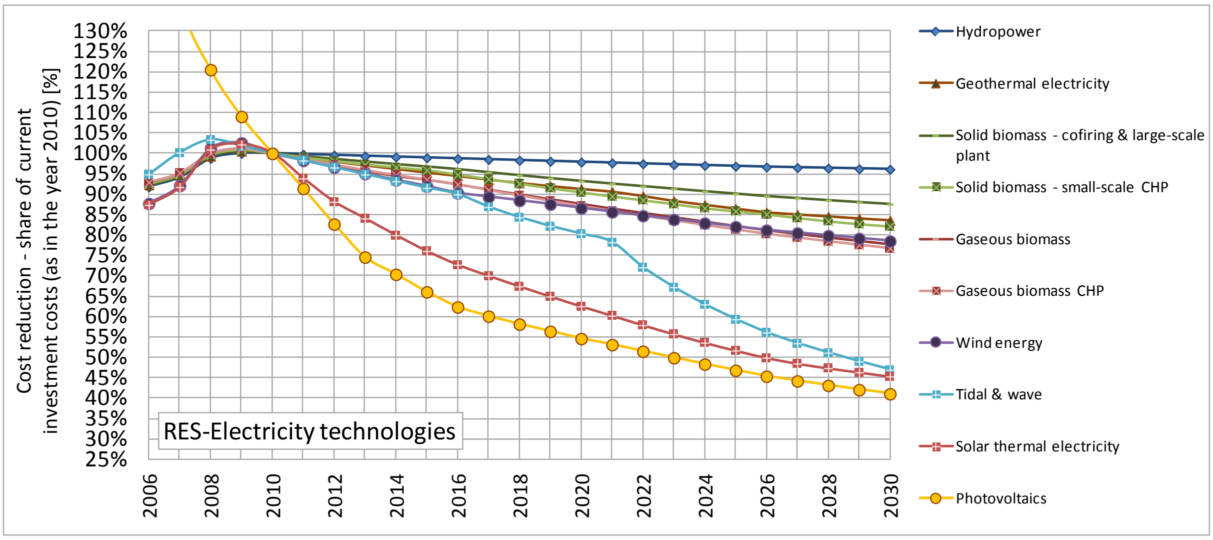

Figure 3-16. Cost reduction of RES-E investments as share of current investment costs (2010) based on moderate technological learning expectations (default) in accordance with the Green-X Advanced scenario (where a strong take-up of RES-E as required to achieve a nuclear power phase-out by 2030 is assumed)[17]. (Teske eta al. 2013b, 44-47)

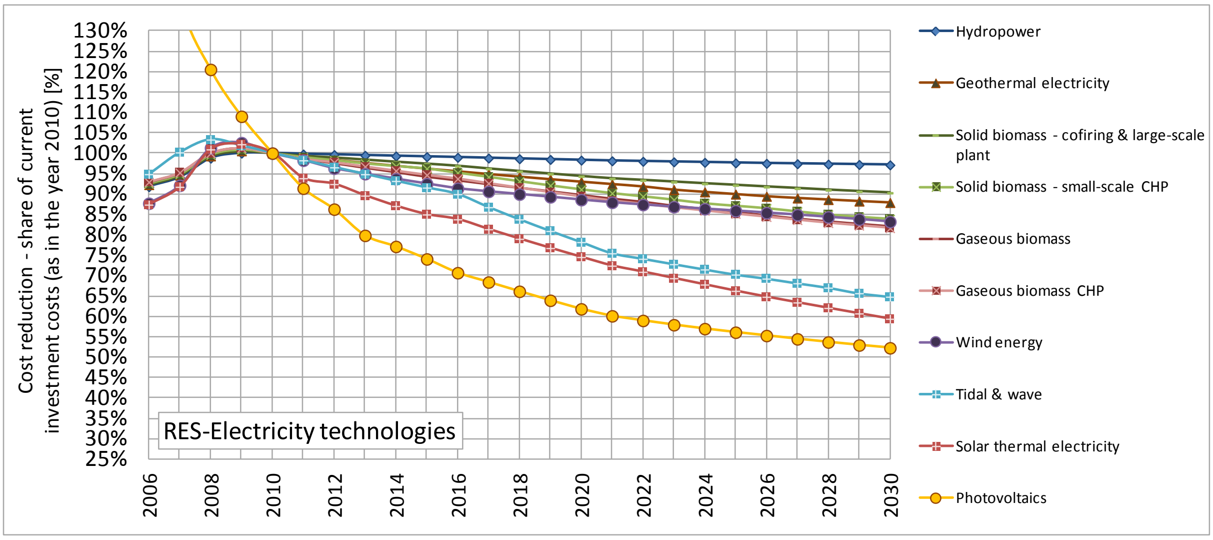

Figure 3-17. Cost reduction of RES-E investments as share of current investment costs (2010) based on moderate technological learning expectations (default) according to the assessed "business-as-usual (BAU)" case. (Resch et al., 2012)

Next, a closer look is taken on how the above discussed expected future cost trends match with the assumptions used in the energy [r]evolution study. More precisely, Box 6 offers a comparison of investment cost trends as outlined above with the expectations underlying the calculations of the energy [r]evolution Advanced scenario.

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17 Deployment of RES-E technologies within the EU 27 is taken from the Green-X Advanced scenario as illustrated in Section 3.2 of this report while for the rest of the world the IEA's WEO 2011 projection, more precisely the 450 ppm scenario, is used.

Box 6. Comparison of future expecations on RES cost (energy [r]evolution vs Green-X)

Comparing future RES cost expectations: how do the underlying assumptions of the energy [r]evolution study fit?

The energy [r]evolution study offers a comprehensive discussion on future cost trends for RES. Focussing on investment cost for RES, we undertake below a comparison of these expectations to our own analysis as outlined above. Thus, provides a summary of the cost trends derived in the energy [r]evolution study as depicted in Figure 3-18. At first glance, a downward trend is becoming apparent for almost all RES-E technologies over time – with the exception of hydropower it is expected to "ride down the learning curve" to a partly significant extent. In order to compare and contrast cost expectations in a more systematic manner, we focus on selected key RES-E technologies in the electricity sectors: solar and wind.

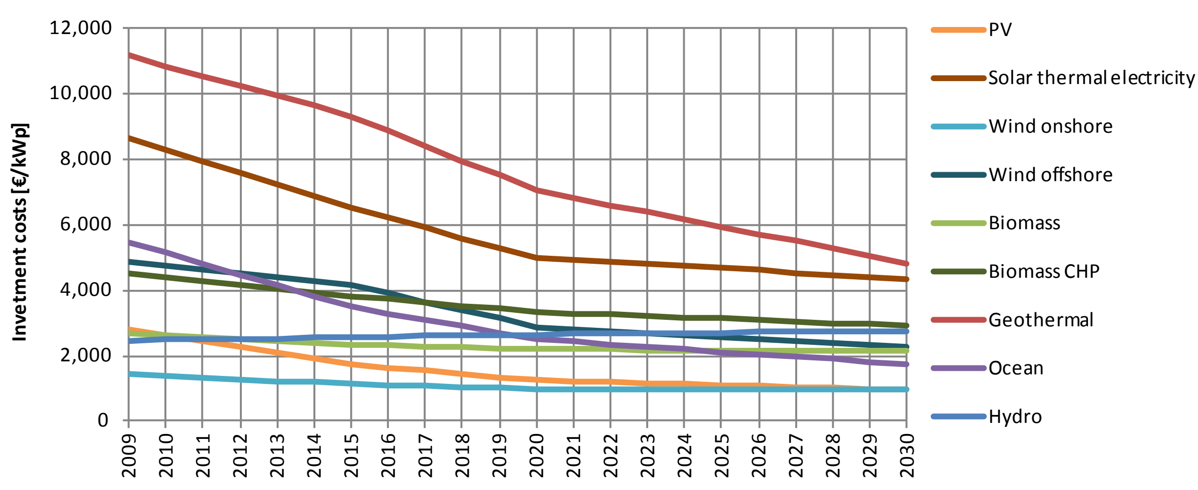

Figure 3-18. Development of investment costs of RES-E technologies according to the enegy [r]evolution study. (Teske et al., 2012a, 44-47)

As a starting point, Figure 3-19 indicates the range of cost trends for solar power technologies, i.e. PV and CSP, according to the Green-X database and related modelling of future learning (see pale green area) with the cost trend according to energy [r]evolution. PV cost trends match but energy [r]evolutions trends match with the lower boundary of the cost range indicated by Green-X. This means that a strong cost decline is assumed which matches well with expected learning trends in the case of strong market deployment (as also anticipated in the energy [r]evolution study). Moreover, the expressed investment cost trends generally seem to reflect those of large-scale (stand-alone) PV systems rather than those of small-scale household units. For CSP the opposite picture is apparent: Cost expectations of energy [r]evolution match with the upper boundary of cost trends according to Green-X. Generally, it can be concluded that for solar technologies cost expectations between these two studies / data sources are comparatively identical.

For wind technologies the match between both cost projections is lower, cf. Figure 3-20. For onshore wind in energy [r]evolution a comparatively strong cost decline is expected to take place until 2020, and thereafter a sort of stagnation. In Green-X a smoother but continuous downward trend is indicated for the period up to 2030. It has to be stated that cost expectations in Green-X are however above those used in energy [r]evolutions. In the case of offshore wind turbines energy [r]evolution indicates significantly higher investment cost for today but similar to onshore a strong decline is anticipated, specifically in the period from 2015 to 2020.

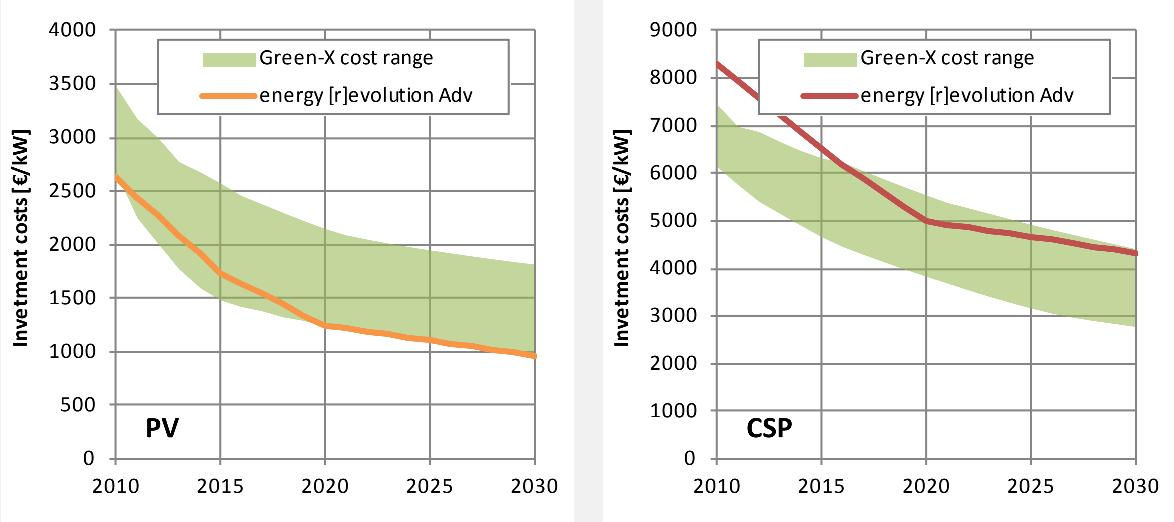

Figure 3-19. Comparison of expectations on future cost trends for solar technologies: PV (left) and CSP (right).

As in general, Green-X indicates a broad cost range for today and in future years, reflecting different site conditions (i.e. water depth, distance to shore and related cost for grid connection). Costs as of 2010 are more than 20% below those indicated in energy [r]evolution and for future years a moderate but continuous decline is expected. Of interest, from 2017 onwards both costs trend projections fit well, meaning that due to a steep decline before projections from energy [r]evolution achieve the (broader) cost range indicated by Green-X.

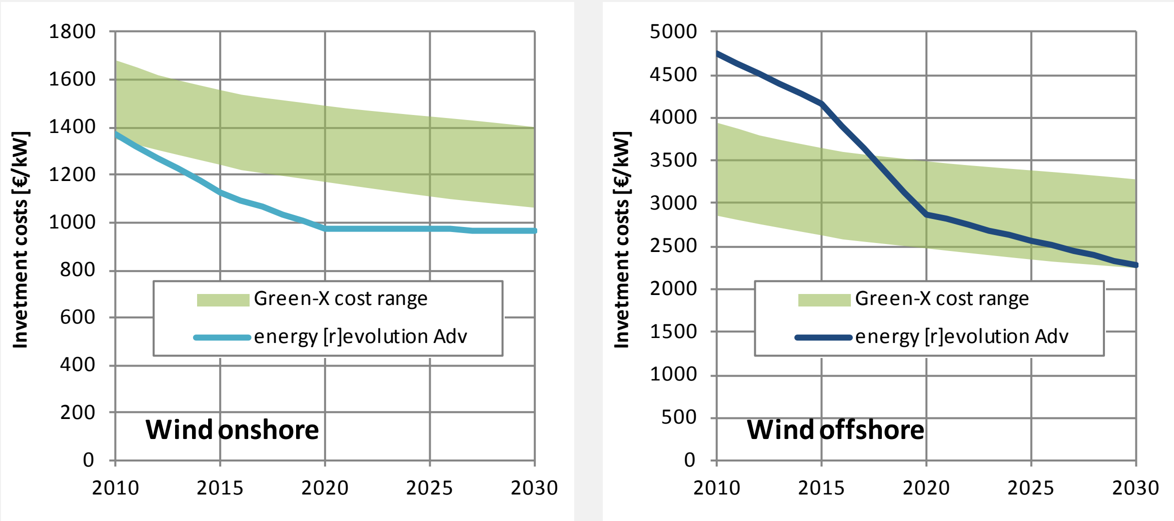

Figure 3-20. Comparison of expectations on future cost trends for wind technologies: Wind onshore (left) and wind offshore (right).

Summing up, with the exception of onshore wind and occasional differences in certain periods, a proper match between cost expectations derived from Green-X and the energy [r]evolution study is applicable. For onshore wind, the expected cost reductions as projected by energy [r]evolution can be classified as optimistic – however, the strong entrance of new market players on the manufacturing side, e.g. from Asia, may serve well as explanation.

3.2.3 Pathways and policy implications for achieving required RES targets

Complementary to energy efficiency as discussed in Section 3.1 a strong uptake of RES in the electricity sector is required to pave the way to a nuclear power-free Europe while maintaining the transition to a sustainable energy system in the mid- to long-term. How strong the RES uptake needs to be will be analysed in further detail within this subsection. Finally, we will shed light on related policy implications to safeguard the transition process. Since meeting climate commitments represents a precondition for doing so, it can be expected that the at least in parts of Europe on-going energy transition has to accelerate in speed.

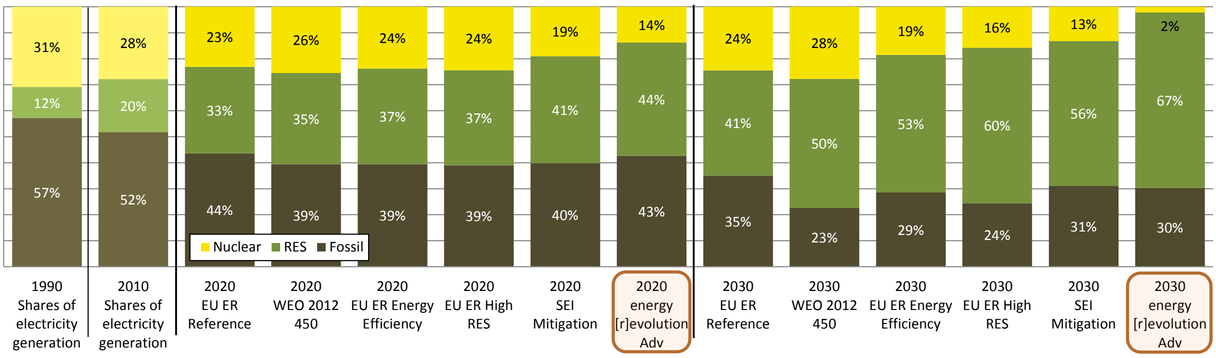

Figure 3-21. Shares of (domestic) electricity generation in 2010 and projected for 2020 and 2030 by respective scenario. (EC, 2011b, 158-175; Eurosat, 2013e; Teske et al., 2012a, 125; Heaps at al., 2009, 56; IEA, 2012, 572-575)

As a starting point for the analysis of feasible RES pathways Figure 3-21 indicates the shares of fossil, nuclear and RES on total EU's domestic electricity generation in the past (1990) as well as at present (2010). More important, this graph also compares the expected future breakdown (2020, 2030) according to the key energy scenarios assessed (cf. Chapter 2). Of highlight, among all energy scenarios assessed the energy [r]evolution Advanced scenario projects the lowest shares of nuclear power for future years. This coincides well with the strongest uptake of RES, indicating a RES share of 44% in total generation by 2020, and of 67% by 2030. In order to assess the challenges and, from a RES policy / market perspective, the feasibility of doing so, we conducted a brief complementary model-based assessment,[18] using the Green-X model – a specialised energy system model with a detailed coverage of the European RES market that has been used within various studies / assessments conducted on behalf of the European Commission, national authorities or industry partners throughout the past decade, cf. Ragwitz et al. (2005, 2009, 2012) or Resch et al. (2009, 2012, 2013). The core strength of the Green-X model lies on the detailed RES resource and technology representation accompanied by a thorough energy policy description, which allows assessing the impact of various energy policy options on RES deployment as well as on related costs and benefits. A short characterization of the model is given in Box 7, whilst for a detailed description we refer to www.green-x.at.

[18] Note that this complementary model-based assessment with the Green-X model does however not aim for an analysis of the technical feasibility or boundary conditions with respect to storage, infrastructural or other complementary options for a proactive integration of (variable) RES in the European electricity market.

Box 7. About the Green-X model

Short characterisation of the Green-X model

The model Green-X has been originally developed by the Energy Economics Group (EEG) at the Vienna University of Technology under the EU research project "Green-X–Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market" (Contract No. ENG2-CT-2002-00607) in the period 2002 to 2004. Initially focussed on the electricity sector, this modelling tool, and its database on renewable energy potentials and costs, has been extended to incorporate renewable energy technologies within all energy sectors.

Green-X covers all EU Member States as well as selected neighbouring countries like Turkey, Switzerland or Norway. It allows assessing the future deployment of RES as well as the accompanying cost (including capital expenditures, additional generation cost of RES compared to conventional options, consumer expenditures due to applied supporting policies) and benefits (for instance, avoidance of fossil fuels and corresponding carbon emission savings). Results are calculated at both a country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2030, accompanied by concise outlooks for the period beyond 2030 (up to 2050).

The Green-X model develops nationally specific dynamic cost-resource curves for all key RES technologies, including for renewable electricity, biogas, biomass, biowaste, wind on- and offshore, hydropower large- and small-scale, solar thermal electricity, photovoltaic, tidal stream and wave power, geothermal electricity; for renewable heat, biomass, sub-divided into log wood, wood chips, pellets, grid-connected heat, geothermal grid-connected heat, heat pumps and solar thermal heat; and, for renewable transport fuels, first generation biofuels (biodiesel and bioethanol), second generation biofuels (lignocellulosic bioethanol, biomass to liquid), as well as the impact of biofuel imports. Besides the formal description of RES potentials and costs, Green-X provides a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Through its in-depth energy policy representation, the Green-X model allows an assessment of the impact of applying (combinations of) different energy policy instruments (for instance, quota obligations based on tradable green certificates / guarantees of origin, (premium) feed-in tariffs, tax incentives, investment incentives, impact of emission trading on reference energy prices) at both country or European level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or technological progress (technological learning) typically complement a policy assessment.

The strong RES uptake as anticipated in the energy [r]evolution Advanced scenario up to 2030 requires launching a massive transition process within Europe's electricity sector. According to Green-X modelling, this may need more time than anticipated by energy [r]evolution. As applicable from Figure 3-22 the Advanced scenario of Green-X, implying strong proactive RES policy interventions all across Europe, does not match in the short-term (up to 2020) with those of energy [r]evolution. By 2030 however the differences between both scenarios are of negligible magnitude. Of interest, a difference between Green-X and energy [r]evolution is also apparent for the business-as-usual (BAU) and the reference case, both implying a continuation of the currently implemented energy policy measures. More precisely, the energy [r]evolution reference case indicates a 10% stronger domestic (i.e. within the EU 27) RES-E generation than Green-X. This difference can be explained by the fact that Green-X better reflects recent policy changes in selected European countries: a phase-out of support measures or retroactive changes have caused a strong destabilisation of national RES markets in countries like Spain, the Czech Republic or Bulgaria (EC, 2013). The lower RES-E deployment today as well as in forthcoming years is the reason why the Green-X Advanced scenario indicates a lower total RES-E generation in 2020 than the corresponding energy [r]evolution case. The difference in domestic RES-E generation is 14% by 2020. Besides, it can be expected that that the majority of EU countries will fail to trigger the required investments in new RES technologies needed for the 2020 RES target fulfilment with currently implemented RES support as Box 8 describes in detail. While for 2020 the projections of energy [r]evolution appear unrealistic, the 2030 perspective is largely confirmed – i.e. a negligible gap of 0.7% remains by then. As stated above, this strong RES uptake may however only be achievable if a strong commitment towards RES is taken for the period beyond 2020.

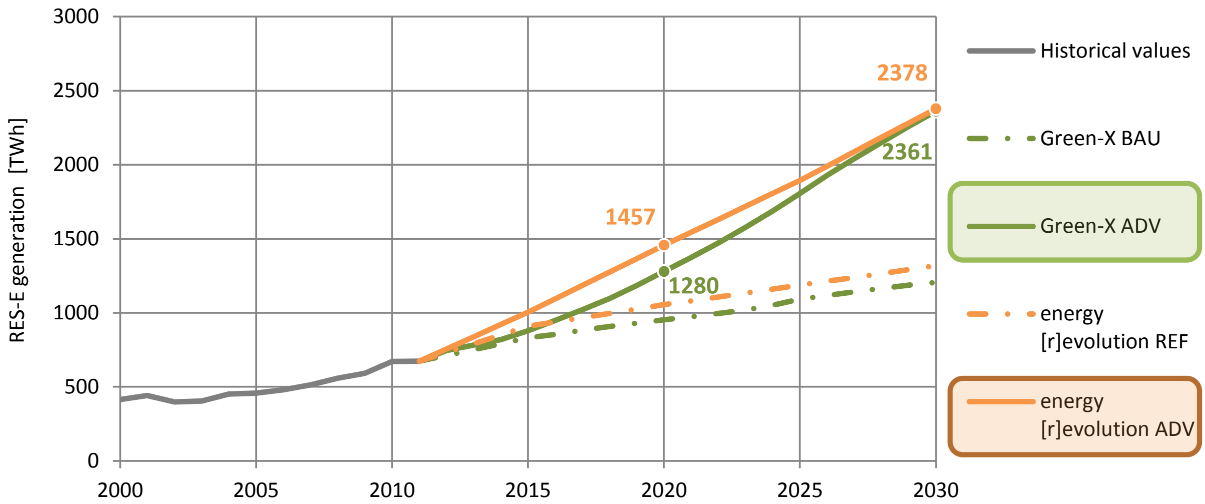

Figure 3-22. Domestic (EU 27) RES-E generation projected by energy [r]evolution and Green-X scenarios. (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

The key question remains how to speed-up RES-E deployment in forthcoming years. The economic and financial crises has sent shockwaves across European countries with negative impacts on the stability of regulatory RES support, and, in addition, debates on the, as some claim, high burden that is put on the shoulders of consumers due to rapid growth of renewables, and in particular of the former “high-cost” option photovoltaics, are occasionally gaining strong attention in several countries across the EU.

Box 8. Short term policy needs to bring RES deployment "back on track"

Towards an effective and efficient 2020 RES target (over)fulfilment – from BAU to strengthened national policies

It can be expected that with currently implemented RES support – i.e. according to our scenario definition named as "*business-as-usual" (BAU) case* – that the majority of EU countries will fail to trigger the required investments in new RES technologies needed for the 2020 RES target fulfilment. This has been highlighted by the European Commission in their recent communication on the Member States' progress for meeting 2020 RES targets (EC, 2013). Within the European project Re-Shaping (Ragwitz et al., 2012) light has been shed on how to bring RES and the Member States, respectively, "back on track". A qualitative assessment was undertaken to identify current deficits and this was complemented by a quantitative analysis, indicating the impact of individual measures required to move from BAU to a policy path where all Member States would meet their 2020 RES commitments. More precisely, within the quantitative assessment the BAU scenario, implying that all relevant energy policies and energy market structures will remain unchanged, was compared to a scenario of *"strengthened national policies" (SNP)*, considering improved financial support as well as the mitigation of non-economic barriers that hinder an enhanced RES deployment.

Within the Re-Shaping study, in accordance with the outcomes of this analysis as shown in Figure 3-22., an accelerated development of RES-E as well as RES in total can be expected with effective and efficient RES support in place while under BAU conditions a rather constant but moderate deployment is projected for the period up to 2020 and beyond. Analysing the impact of the individual key measures to move from a BAU to an enhanced RES deployment in line with 20% RES by 2020 was subject of a complementary detailed sensitivity assessment within that study. Identified key measures and related impacts can be summarised as follows:

- **Mitigation of non-economic RES barriers:**
  Non-economic barriers represent a commonly acknowledged terminology to subscribe a basket of deficits like complex and / or long-lasting administrative procedures within the permitting processes, problems or delays related to grid access, etc... All these constraints limit the (enhanced) diffusion of RES technologies, and "non-economic" shall hereby mean that they per se they are not of financial order.[19] The proactive mitigation of currently prevailing non-economic barriers has been identified by various studies, incl. Re-Shaping, as key criteria to assure a proper functioning of RES markets and for an efficient fulfilment of RES targets. Retaining current financial RES support, supplemented by a mitigation of non-economic deficits, would allow for an increase of the 2020 RES-E share by 20% (compared to default) on average at EU level. A significant impact can however be also observed on the corresponding yearly support expenditures of RES(-E).

[19] Note that these non-economic barriers may however impact the required financial support. For example the need for financial compensation through the policy intervention rises in the case of long leap times with respect to administrative procedures and / or grid access.

Required expenditures by 2020 would increase by a similar magnitude than deployment under the assumed retention of current support conditions (without any further adaptation). This indicates the need to align support conditions to the expected / observed market development, as otherwise specifically novel RES technologies would achieve significant over support under future mass deployment.

- **Improved design and implementation of RES support instruments**
  The detailed policy design has a strong impact on the RES deployment and corresponding expenditures. This is transparently demonstrated within the Re-Shaping study through a comparison of the "strengthened national policy" case with the BAU variant where similar framework conditions are implemented (i.e. mitigated (non-economic) barriers and a moderate demand development). For RES-E the direct improvement of the efficiency and effectiveness of the underlying support instruments leads to an increase of the RES-E share by another 20% (compared to the previously discussed mitigation of non-economic barriers only). With respect to support expenditures, the impact of improving RES policy design is pronounced for the electricity sector: the overall amount of support expenditures can be kept on comparatively similar level than in the BAU case while deployment increases significantly.

Thus, in accordance with Re-Shaping (Ragwitz et al., 2012) key policy recommendations targeted to enhance an effective and from an economic viewpoint efficient uptake of RES-E are:

- **Apply appropriate support levels:** If a country wishes to enhance the deployment of certain RES-E technologies, support levels should be aligned with generation costs, based on realistic assumptions for investment cost and cost of capital in case of price-based support schemes such as feed-in tariff systems. Investment support schemes and market-premium systems are other examples of price based systems that lead to a further rise in the share of renewable energies while ensuring that renewables are integrated in the market and react on price signals. In the case of demand-based support as provided through quota systems (combined with tradable green certificates), the remuneration level may also be adapted indirectly by changing the quota, banding factors, penalties or other factors, although it is more challenging to meet a desired support level.
- **Reduce barriers, apply best practice support system design and reduce investor risk:** The support level required highly depends on the existing non-economic barriers to projects, the design of the support system, and the risk involved for investors. Removal of certain barriers is not only useful to reduce support costs but is imperative to allow any new projects to be realised.
- **Learn from best practice:** Countries with immature or intermediate market deployment status for a given technology can rapidly increase policy performance by learning from the best-practice support policy designs and organisation of administrative processes of other countries. They will be able to profit from spill-over effects from the internationally available project development expertise and technology supply chain.
- **Apply technology-specific support:** When choosing support instruments and support levels, policy makers should ensure that a balance is found between developing higher-cost technologies (progressing on the learning curve) on the one hand and deploying low-cost

technology potentials at an adequate speed on the other. This compromise can be achieved more easily with technology-specific support.

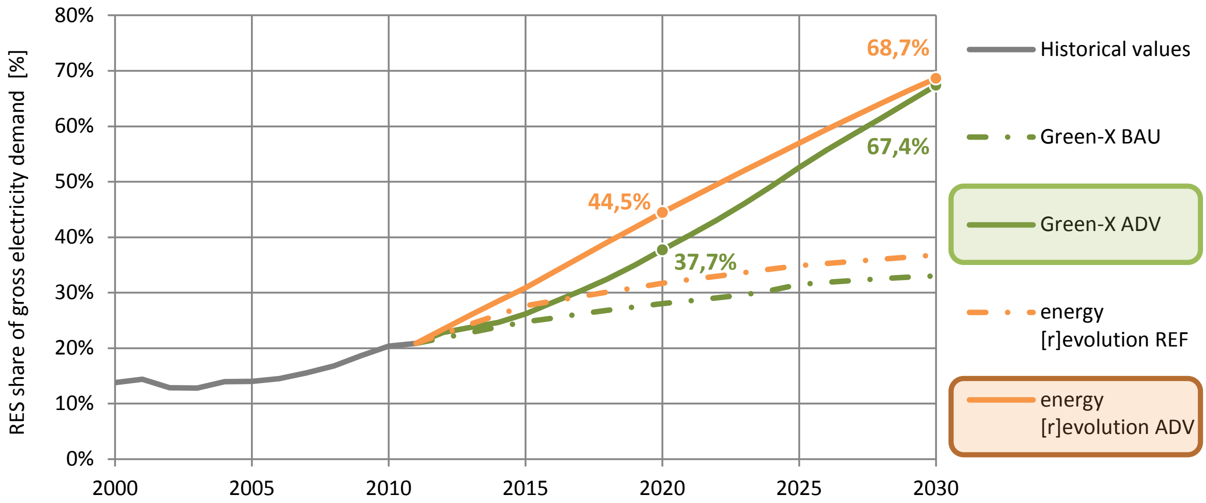

Figure 3-23. RES share in gross electricity demand projected by energy [r]evolution and Green-X scenarios. (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Complementary to Figure 3-22 showing past and projected future RES-E deployment within the European Union in absolute terms, i.e. in TWh electricity produced, Figure 3-23 illustrates RES deployment in relative terms, indicating the development of the overall RES-E share in gross electricity demand. In contrast to above, for calculating these RES-E shares both domestic RES-E generation within the EU as well as RES-E imports from non-EU countries is taken into account. Thereby, a similar trend as discussed above is applicable: short term expectations of energy [r]evolution appear too challenging while mid-term (2030) RES perspectives appear possible to achieve. A closer look on 2020 indicates an 18% higher RES-E share in the energy [r]evolution Advanced scenario than in the corresponding Green-X case, and this deviation declines to 2% by 2030 (i.e. 68.7% (energy [r]evolution compared to 67.4% (Green-X)). The reason for the remaining gap (i.e. 46 TWh by 2030 in terms of RES-E generation) is that in Green-X lower volumes of hydrogen production are anticipated for the mid future[20] while for the overall final electricity demand per se no differences are assumed.

The question arises how far the overall RES uptake needs to go in order to accelerate RES-E deployment to those anticipated volumes in the mid-term? In other words, how high is the corresponding overall RES share and/or target for 2030 that fits well to a RES-E share in gross final electricity demand in range of 67% to 69%? Thus, Box 9 will shed light on the implications, discussing the need for and the height of an overall RES target for 2030 that matches well with the assumed strong deployment of RES-E.

20 The energy [r]evolution Advanced scenario indicates hydrogen production that largely stems from variable RES-E in magnitude of 154 TWh in 2030 while Green-X assumes only assumes 108 TWh to be fed into such transformation processes. Note that hydrogen serves to meet demands in other sectors (i.e. transport and industrial processes).

Box 9. Implications for an overall 2030 RES target

2030 RES targets –how high needs the overall RES target for 2030 share to be that suits well to the anticipated strong uptake off RES in the electricity sector?

Binding national targets as defined by the RES directive (2009/28/EC) have created strong commitment for renewable energies throughout the EU and are the key driver for RES policies at the moment. Generally, they are a key element for setting up the administrative procedures, regulatory frameworks, regional planning and national infrastructure development. As these elements will also be crucial for the RES deployment after 2020 binding national targets appear an important element also for the period beyond 2020. Moreover, given the anticipated strong uptake of RES-E as necessary to compensate the supply gap arising from a nuclear power phase-out in Europe binding national 2030 RES targets are a necessity if climate constraints are taken seriously.

Within the European project “Keep on Track!” a model-based pre-assessment of future RES deployment in Europe has been undertaken throughout 2013 that illustrates in a brief manner the feasibility and impacts of striving for certain 2030 RES targets at a European level (Resch et al., 2013b). As such this analysis does neither aim for a comprehensive and complete impact assessment related to consequences of certain RES targets, nor does it aim to undertake an assessment of policy options to achieve these targets. Conducted Green-X scenarios show the country- and sector-specific RES deployment that can be expected if a certain RES share shall be met by 2030 at EU level (30%, 35%, 40% or 45%). In order to indicate the country-specific possibilities related to the required RES expansion in a fair and transparent manner the assumption is taken that all framework conditions (i.e. non-economic barriers and financial incentives for RES) would be further harmonised / aligned beyond 2020. Since energy demand (growth) is a crucial parameter for the feasibility / impacts of RES targets (defined in relative terms, as shares of demand), two variants of future demand trends are assessed – i.e. a low and a high energy demand case.

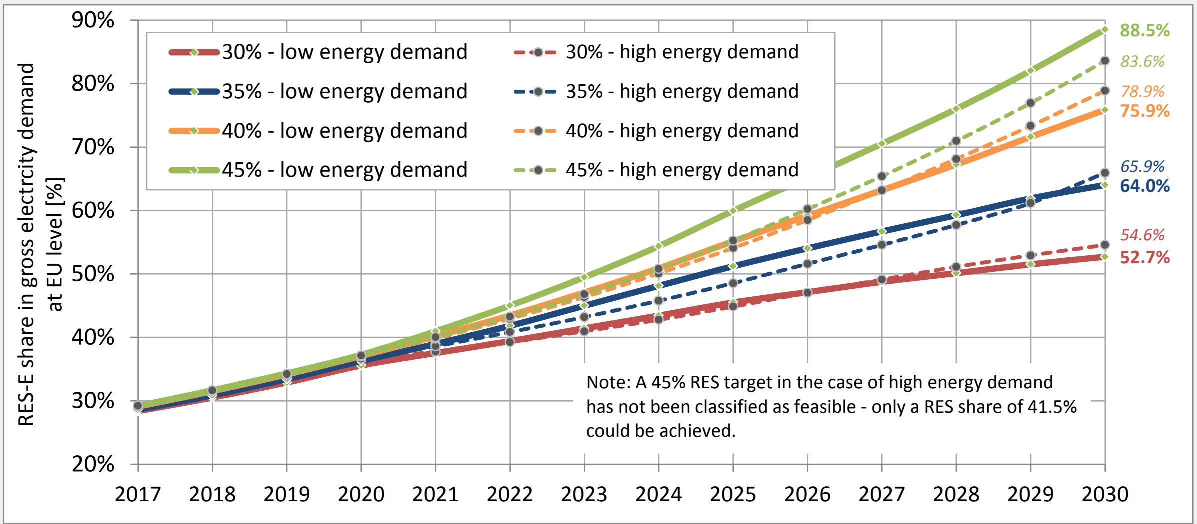

Figure 3-24. RES-E pathways up to 2030 at EU level according to different EU RES targets for 2030 depending on the future gross final energy demand. (Source: based on Resch et al., 2013b)

As shown in Figure 3-24, illustrating RES-E deployment pathways up to 2030 at EU level according to assumed overall RES targets for 2030 (and the expected future energy demand (growth)), RES in the electricity sector are expected to contribute most to the achievement of 2030 RES targets, achieving significant shares in the power sector across the EU. RES for heating and cooling may achieve a lower share in corresponding demand but deployment in absolute terms appears impressive while less significant contributions can be expected from biofuels in the forthcoming decade. Of highlight, a RES-E share in gross final electricity demand in size of 67%-69% would suit well to an overall 2030 RES target of about 36% to 37%. Such a strong uptake of RES can be classified as ambitious, requiring strong dedicated policies for RES and a rapid removal of barriers which limit the speed of RES deployment in several EU member states.

Within the study "Keep on Track!" (Resch et al., 2013b) also a closer look on the country-specific RES deployment was undertaken. Therein it was indicated that the match (or mismatch) between supply (i.e. the domestic deployment) and demand (i.e. the assumed national targets) at country level would be less affected by the ambition level of the 2030 RES target, at least for the cases of moderate RES deployment 2030 (30% or 35%). However, differences get stronger if a higher RES uptake is anticipated (i.e. 40% or 45%). In general, the observed patterns, and in particular, the partly mismatch between supply and demand for RES indicates that RES cooperation and intensified coordination between countries will be of key relevance in the period beyond 2020.

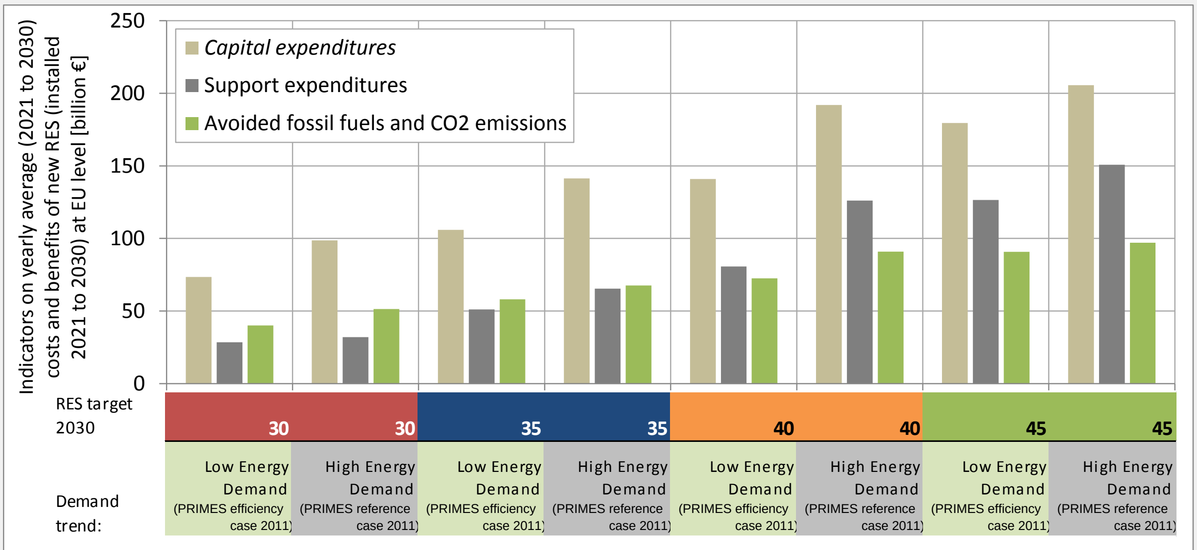

Figure 3-25. Yearly average costs and benefits of new RES installed from 2021 to 2030 at EU level. (Source: based on Resch et al., 2013b)

An accelerated RES deployment in the European Union does have a price, but this is also accompanied by increased benefits. A brief and incomplete indication of impacts on costs and benefits has been conducted, and key outcomes of that are summarised in Figure 3-25. It becomes apparent that investment needs and monetary savings related to fossil fuel avoidance match well with the required RES volumes in absolute terms. Thus, deployment and, consequently, capital expenditures and fossil fuel savings increase with the height of the RES target (i.e. moving from 30% to 35% etc.) and in the case of a higher demand growth. Similar patterns can be identified for support expenditures. This provides a first indication that striving for an ambitious RES target has to go hand in hand with the other side of the coin: a strong emphasis on energy efficiency and energy saving, respectively.

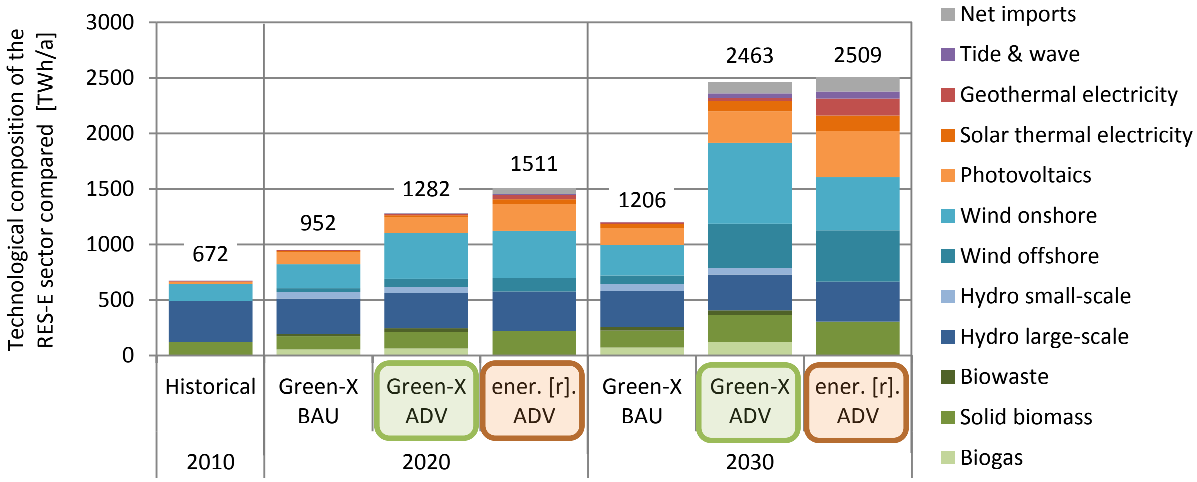

Figure 3-26. Comparison of the split of total RES-E generation into technologies for the years 2010 (historic), 2020 and 2030 according to selected scenarios (energy [r]evolution Advanced scenario compared to Green-X projections). (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Note: The electricity generation of biogas, solid biomass, and biowaste technologies is represented only by biomass in the energy [r]evolution scenario (one green bar). The same is true for the generation of small- and large-scale hydropower plants (one deep blue bar).

Further insights on the required technology-specific RES-E deployment are provided below. A first indication of the contribution of individual RES-E technologies is given by Figure 3-26. This graph lists total RES-E generation (incl. net RES-E imports from non-EU countries) as of today (2010) and for future years (2020, 2030) according to selected scenarios, i.e. the energy [r]evolution Advanced scenario, the Green-X BAU case and the Green-X Advanced scenario. Colours indicate the contribution of different technologies (incl. imports) to that.

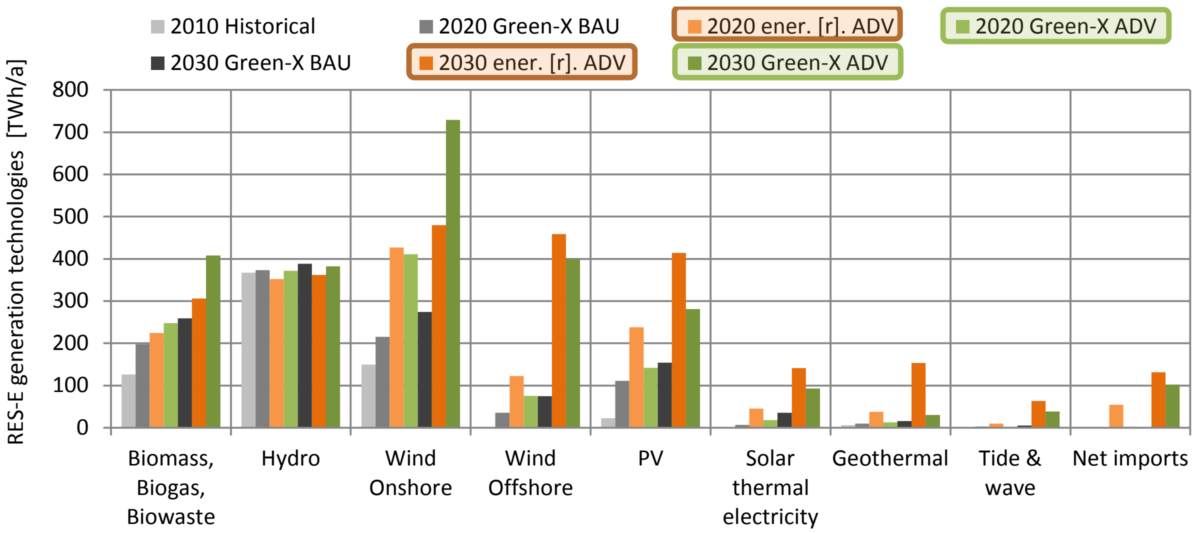

Figure 3-27. Details on RES-E generation at technology level technologies in 2010, 2020, and 2030 according to selected scenarios (energy [r]evolution Advanced scenario compared to Green-X projections). (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Further details on RES-E generation at technology level for the assessed years are shown in Figure 3-27 and, complementary to both graphs, Figure 3-28 offers an illustrative comparison of the shares of individual RES-E technologies on total RES-E generation in 2030 for the two key cases: the Advanced scenario of energy [r]evolution and of Green-X.

Accordingly, within both studies key technologies for achieving the transition to a RES-based power sector are wind (on- and offshore), photovoltaic, hydropower and biomass in the forthcoming decade. Moreover, a broad set of other RES-E technologies like biogas, solar thermal electricity, biowaste or tidal stream and wave power are contributing to power supply, but at a comparatively more limited volume. This is either a consequence of limited potentials (small hydro, biowaste) or it reflects the still comparatively early status of market maturity (solar thermal power, tidal stream and wave power). A closer look on the differences between both Advanced scenarios (where a strong RES uptake is anticipated) (energy [r]evolution versus Green-X) shows that the strongest deviations are applicable for wind onshore and geothermal electricity: while for wind onshore Green-X assumes a 50% stronger deployment by 2030 compared to energy [r]evolution the opposite trend is applicable for geothermal electricity where energy [r]evolution projects a 5 times higher generation in 2030. Differences are also apparent for other technologies, for example in the case of biomass Green-X indicates a 33% higher generation by 2030 while for tidal stream and wave power 39% lower deployment figures can be identified, but the deviations are smaller in magnitude.

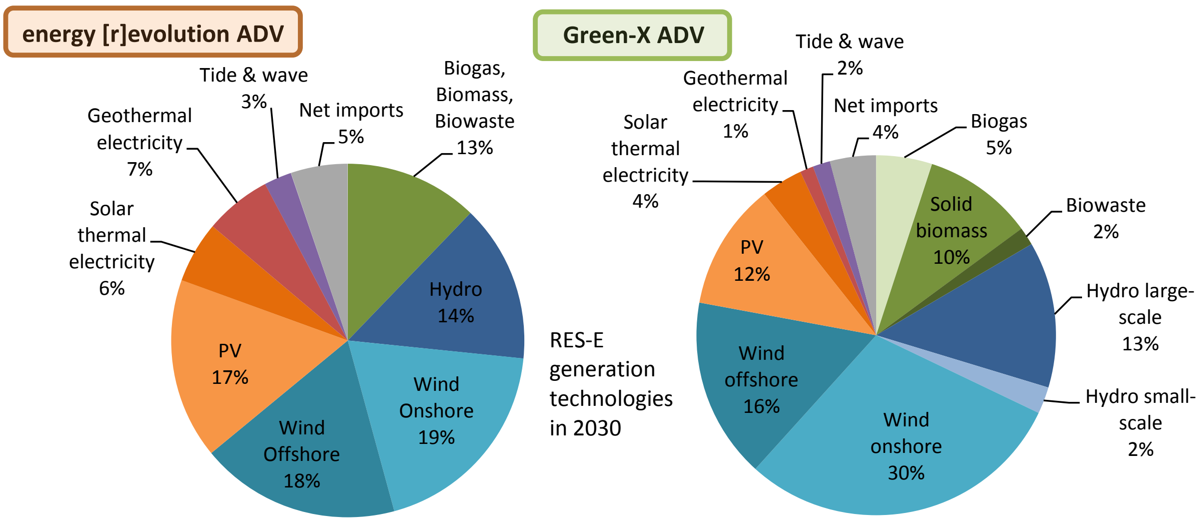

Figure 3-28. Technology-specific shares on total RES-E consumption in 2030 according to the Advanced scenario of energy [r]evolution (left) and of Green-X (right). (Greenpeace and EREC, 2012; Own calculations)

Note: The electricity generation of biogas, solid biomass, and biowaste technologies is represented only by biomass in the energy [r]evolution scenario (one green share). The same is true for the generation of small- and large-scale hydropower plants (one deep blue share).

Summing up, a strong RES uptake as anticipated by the energy [r]evolution Advanced scenario for 2030 appears feasible from a market / policy perspective – but for doing so a strong commitment towards RES needs to be taken for the period beyond 2020 all across Europe. The short-term expectations, i.e. the envisaged trend for period up to 2020, is however too optimistic considering the existence of severe barriers that hinder a proper functioning of RES markets in several countries today. Removing currently prevailing barriers requires more time than anticipated in energy [r]evolution – but doing so appears imperative to assure an effective and from an economic perspective efficient deployment of renewable electricity in the near and mid future.

Please note that the complementary model-based assessment as done within this study through applying the Green-X model does however not aim for an analysis of the technical feasibility or boundary conditions. There are important requirements complementary to the enhanced policy-driven RES-E deployment that need to be taken: Strong policy action and the implementation of related market incentives is required to provide infrastructural prerequisites – i.e. the strong extension of the electricity network and the build-up of storage facilities – as well as to assure that sufficient back-up capacities are available when needed. Another key element to allow a well-functioning integration of massive volumes of variable RES-E (wind, solar) may be the inclusion of the demand side for assuring a proper match between supply and demand in the electricity sector. That would involve smart meters aiming to switch consumption of certain electric appliances to times when supply is above (default) load occurs as well as a closer linkage and integration of the heat and electricity market. These complementary measures aim to safeguard the appropriate functioning of electricity markets to achieve similar levels of supply security as we know it today.

4 Prerequisites and implications for the European electricity sector

4.1 Can the supply gap of the energy [r]evolution scenario by 2030 (and beyond) be compensated?

The energy [r]evolution scenario takes a nuclear power phase-out until 2035 for the EU in account. The scenario projects an electricity generation of 78 TWh from nuclear power plants for the year 2030, what equates to 8.6% of nuclear generation in 2011 or 2.2% of total generation for the year 2030 according to the energy [r]evolution Advanced scenario (Eurostat, 2013c; Teske et al., 2012a, 125). This subchapter discusses in detail if this share of electricity generation of 78 TWh in 2030 can be compensated by additional energy efficiency actions or substituted by a faster deployment of RES-E technologies.

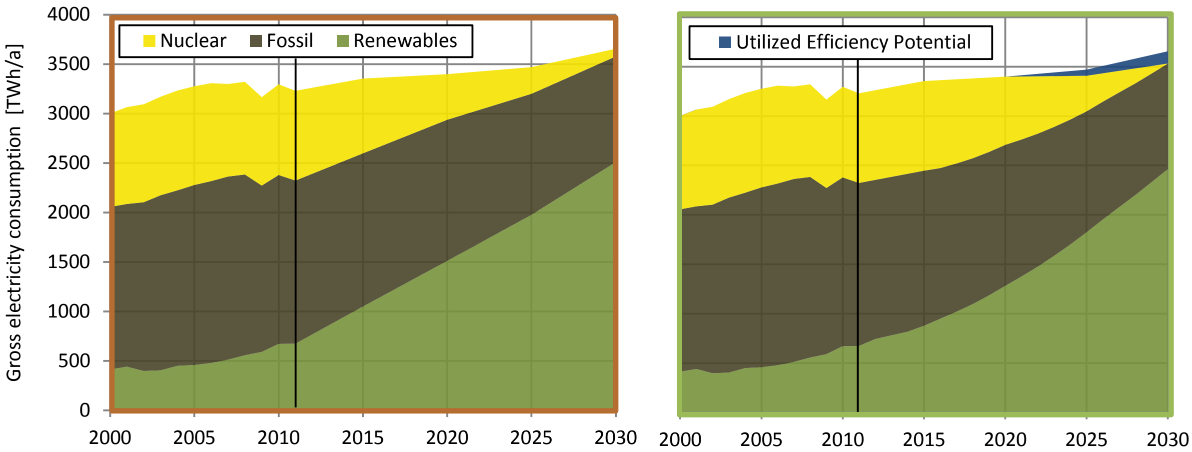

Figure 4-1. The projected gross electricity supply and consumption from 2012 to 2030 as of the energy [r]evolution scenario (left) compared to an alternative RES-E supply scenario (generation and net imports) by the Green-X model and additional efficiency measures (right), resulting in a nuclear power phase-out in the EU 27 countries by 2030. (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Note: See Chapter 3.1.3 and Figure 3-6 therein for the possible electricity saving potential.

Can the supply gap of the energy [r]evolution scenario by 2030 (and beyond) be compensated?

The simple answer to the overarching question is “Yes” – the supply gap that would arise from an earlier full phase-out of nuclear power (i.e. by 2030 instead of 2035) can be compensated according to our brief complementary assessment. The recommended option to mitigate the gap is to build on additional energy savings / efficiency measures, and as part of that we advocate to reduce the demand for hydrogen that serves as fuel for other sectors (i.e. transport and industrial processes). To frame it more comprehensible, Figure 4-1 presents the alternative RES-E supply scenario assessed with the Green-X model, combined with the fossil electricity sector and a nuclear power phase-out trajectory different to the energy [r]evolution. Therein a small wedge called "Unutilized Efficiency Potential", which amounts to 124 TWh in 2030, is added. This wedge also includes reductions in the generation of hydrogen that is projected to be used intensively already by 2030 in the energy [r]evolution Advanced scenario. Hydrogen makes sense as an option to make use of surplus supply in times when variable RES-E like wind and solar occurs, but the proposed production volumes for 2030 appear challenging to achieve from today's perspective, especially since there are cheaper alternatives applicable.

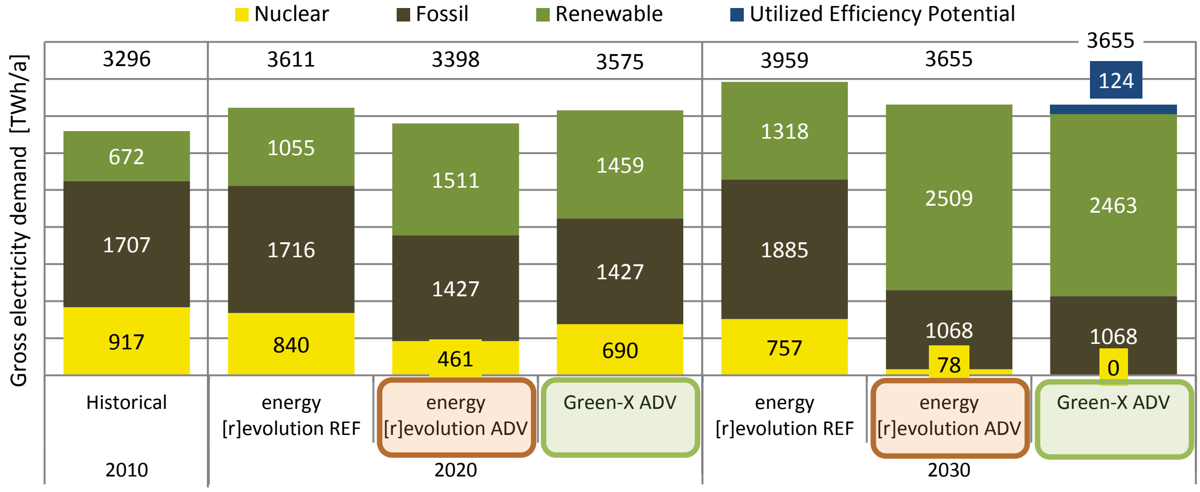

Figure 4-2. Gross electricity supply and consumption by sectors and scenarios for 2010, 2020, and 2030 in TWh. (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Figure 4-2 aims to simplify a comparison between the energy [r]evolution Advanced scenario and the newly assessed alternative advanced case as derived by the Green-X model. It offers a breakdown of gross electricity supply for the years 2020 and 2030 into key supply categories (fossil, nuclear, renewables plus RES-E imports) and depicts the additional efficiency measures as proposed.

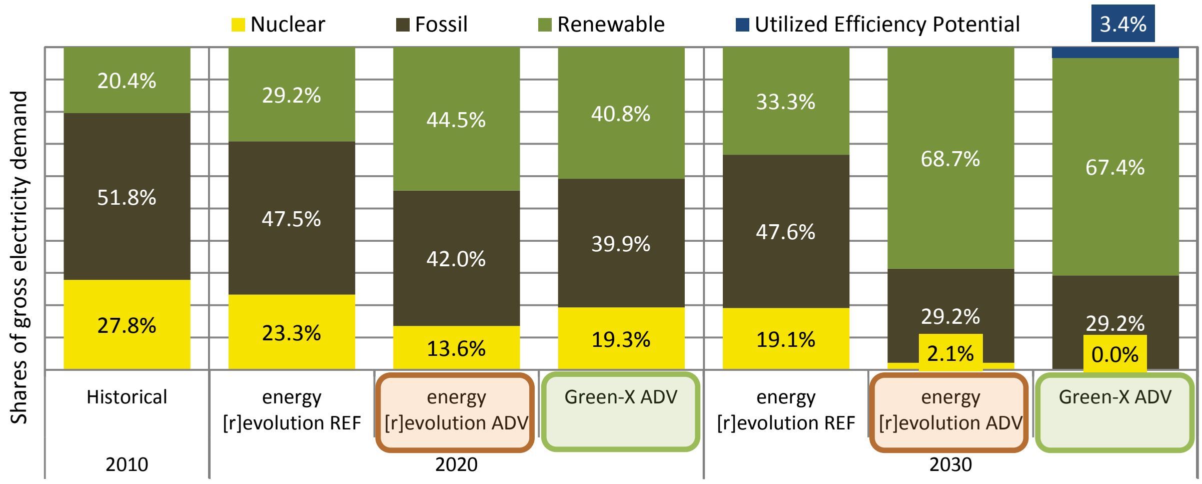

Figure 4-3. Shares of gross electricity consumption by sectors and scenarios for 2010, 2020, and 2030 in percent. (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Compared to energy [r]evolution, within Green-X less renewable electricity is imported from third countries in 2020 and 2030. The EU 27 countries will demand 124 TWh less electricity after more thoroughly adapted energy efficiency procedures and a reduced production of hydrogen in 2030.

Therefore the electricity supply infrastructure is set for all nuclear power plants to be phased-out by 2030. Finally, Figure 4-3 depicts these years in a relative manner. It seems as the included numbers present that the nuclear electricity generation share in the energy [r]evolution is linearly reduced, while the RES-E share is linearly increased. In opposition the assessed RES-E scenario in this study develops the share more progressively to virtually reach the same share in 2030 as the energy [r]evolution Advanced scenario predicts. This is the case while making a nuclear power phase-out possible, due to more extensively implemented energy saving measures and a reduced production of hydrogen. The European electricity generation of the nuclear phase-out including the newly assessed RES-E generation to the energy [r]evolution scenario is depicted in Figure 4-4. The according figures can be found in Table 7-1 in the Annex A.2.

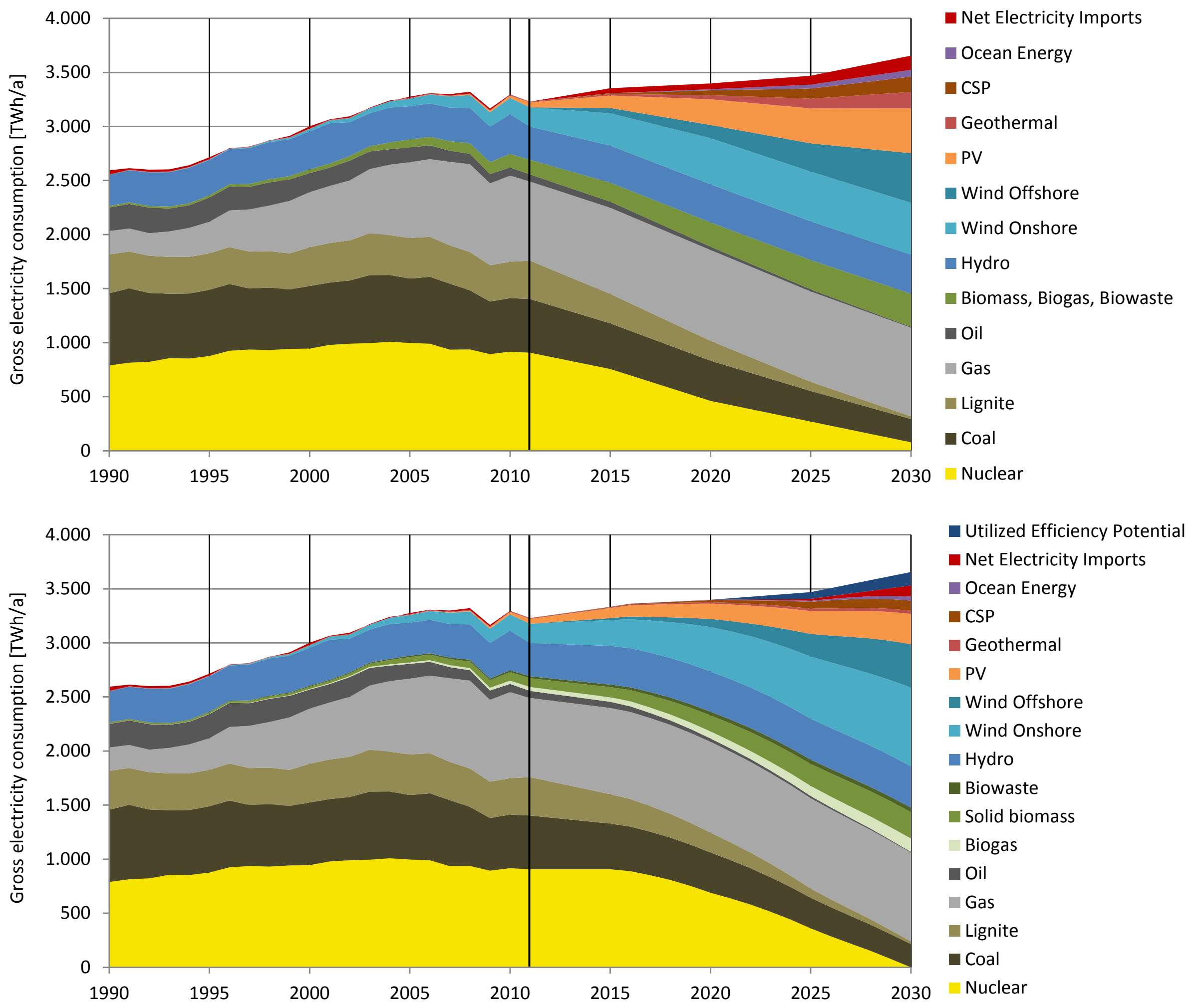

Figure 4-4. The historical (until 2011) and projected European gross electricity consumption by generation technologie up to 2030 in the energy [r]evolution Advanced scenario (top) compared to the newly assessed renewable electricity gerneration by the Green-X model combined with the generation technologies based on fossil fuels of the energy [r]evolution Advanced scenario and an European nuclear power phase-out in 2030 (bottom). (Eurostat, 2013e; Greenpeace and EREC, 2012, Own calculations)

Note: The electricity generation of biogas, solid biomass, and biowaste technologies is represented only by biomass in the energy [r]evolution scenario (one green bar). See Table 7-1 in the Annex A.2 for the statistical quantities for 2010, 2010, and 2030.

4.2 Network requirements for an enhanced RES deployment[21]

The integration of RES into power markets and networks requires investments into power networks and adjustments to the current power market design. While this statement is widely accepted, the debate over which kind of network investments are required and how power markets need to be adjusted has only just begun. It has also become clear that financing infrastructure investments is an enormous challenge. This section presents some insights into network requirements for an enhanced RES deployment as well as power market design options, summarising the outcomes of a detailed analysis undertaken within the Re-Shaping study.

4.2.1 Principle relationships between RES-E development and network infrastructure

The European Commission's Communication on energy infrastructure priorities for 2020 and beyond, adopted on 17 November 2010, called for a new EU energy infrastructure policy to achieve the European energy policy goals. More specifically, the Commission acknowledges the need to extend and upgrade the electricity network to maintain the existing levels of system security, to foster market integration, and especially to balance electricity generated from renewable sources (European Commission, 2011a). While this general formulation of the goal is widely accepted, the optimal way forward to gain a more precise picture of the long-term technical infrastructure requirements, the associated timeframe and the required regulatory measures are less clear. This section is dedicated to address the following questions:

- What are the most important parameters that define network requirements?
- Why do European network studies lead to a wide range of results?
- What are the most relevant technological options relevant for the future European transmission grid?
- What are the policy and planning steps necessary?

Important parameters for the definition of network investments

The spatial distribution of generation and load is the most important influencing factor for formulating the dimensions of the transmission network. The **spatial distribution of RES-E** plays an especially important role and the implementation of cooperation mechanisms between Member States (as discussed in the previous chapter) influences network investments. This can be illustrated with two extreme cases:

1. Transmission network extension will be minimised if Member States rely on their own resources to fulfil their renewable energy targets and the location of resources is close to centres of consumption (e.g. small photovoltaics)

[21] The topic discussed in this section is presented in full detail in the report “Network extension requirements for an enhanced RES deployment” (D13) (Nabe et al., 2011) available at www.reshaping-res-policy.eu.

2. Transmission network extension requirements will be high if cooperation mechanisms are used in order to exploit RES-E at locations with higher resource potentials (outside national borders) and with higher distance to the load centres (e.g. offshore wind).

Beyond generation and consumption patterns and their spatial allocation, several additional parameters are relevant for the calculation of transmission investment needs. These parameters can be influenced by energy policy and are discussed in the following paragraphs.

Curtailment of RES-E

The traditional planning approach for electricity infrastructure is based on the view that all generated electricity needs to be transported to the consumer at all times. Additionally, a security criterion needs to be fulfilled. This structure is based on the view that it minimises costs, which is true for conventional generation.

For RES-E, with supply-driven feed-in characteristics (wind, PV) this is not necessarily true. The maximum output power is only provided in a few hours each year, so the **economic optimum** of network extension might be below the extension required to transport the "last kWh". This results in a certain **curtailment** of the energy from RES-E. Taking the long development times and public acceptance problems of new lines into account, the realistic level of network extension is lower, and the "optimum" curtailment level of RES-E higher than the economic optimum.

Demand-side management (DSM) and electricity storage

Demand-side management (DSM) and electricity storage help to align supply with demand. Hence, these measures also influence load flows and therefore parameters for formulating dimensions of the transmission grid. In which circumstances and to what extent these options can reduce network extension requirements, remains to be shown in detail.

Backup capacities

In order to cover the load at every moment of the year, generation, storage and DSM capacities need to be available. It is a policy decision as to whether the maximum load needs to be covered regionally, nationally or within the whole system. The larger the chosen area for load coverage, the lower the required installed capacities, but the higher the required network reinforcements. A number of factors make the calculation of necessary network reinforcements a difficult exercise:

- The European transmission network is very large (about 10,000 nodes and 14,000 branches for the former UCTE[22] system). It needs to be simplified to be able to include it in larger power system models.
- In most parts of central Europe the network is heavily meshed, which creates loop-flows. These loop flows increase the computational complexities of market and network models. Therefore, models operate with very simplified assumptions on network flows.
- Framework conditions such as voltage stability, dynamic stability as well as n-1 or n-2 security is usually represented in a simplified matter.

22 Union for the Coordination of Transmission of Electricity, now ENTSO-E

- Input parameters such as long-term primary energy prices for oil, gas and coal as well as prices for future CO_2-emission rights are highly insecure.
- Investments in generation and transmission have long lead-times, a long lifetime (20-40 years), and are mostly lumpy and difficult to relocate.

The following sections give an overview of the result of recent studies of transmission extension requirements and give some interpretation of the wide range of results based on the factors previously described.

4.2.2 Review of existing studies on EU grid expansion needs

The impact of an enhanced deployment of renewables, and in particular wind energy, on the electricity network has been analysed on a European scale in a number of studies conducted through the years. Figure 4-5 provides an overview of the studies in recent years and indicates their maximum modelling horizon.

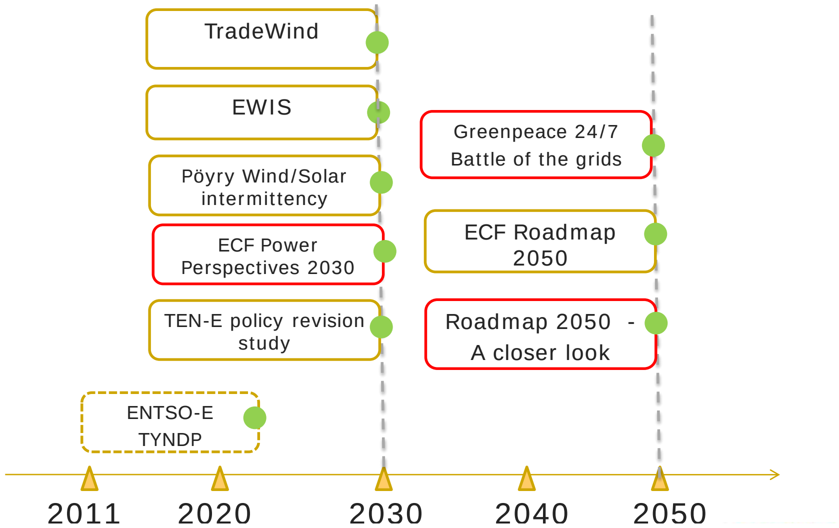

Figure 4-5. Selected European Renewables Integration studies (red) and their maximum timeframe. (Nabe et al., 2012)

Figure 4-6 shows the grid extension requirements ranging from 42,000 km - which is equal to the planned additions according to the Ten Year Network Development Plan (TYNDP) - up to 500,000 km, compared to 2010 as the most extreme case. Although there is a visible relationship between the assumed share of RES-E and the required additional grid length, the ranges of values are large and can reach a factor of two. The main driving factors for these differences are assumptions of the studies and scenarios regarding the underlying generation mix, the spatial distribution of the renewable generation units, the available back-up capacity including storages and assumptions regarding the future electricity demand. The different data points originate not only from different studies but also from various scenarios which differ among others in the assessed time period. As most studies have not reported detailed results in terms of installed technology and corresponding costs, no consistent statement concerning the costs for different RES penetrations can be derived[23].

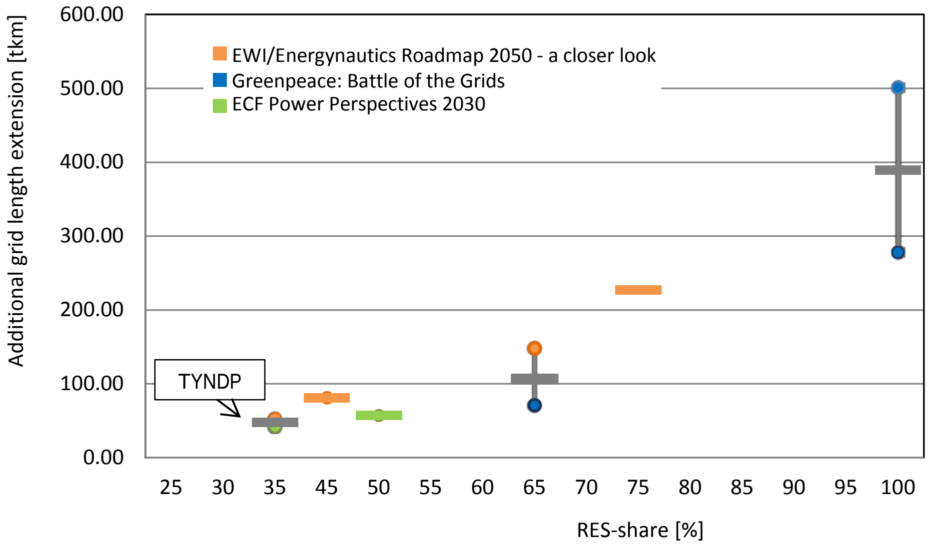

Figure 4-6. Additional grid length required as a function of the RES-E share, according to the three selected studies. (Nabe et al., 2012)

Figure 4-7 depicts the calculated extensions of net transfer capacity (NTC). As more studies report the NTC capacities rather than the total transmission line extensions, more data points are shown in this graph. It essentially confirms the message of Figure 4-6. However, it should be noted that NTC capacities cannot be translated directly into grid extension length. NTC capacities purely refer to cross-border transfer capacities and cannot be translated directly into a specific physical line. What is more, the methodology of NTC calculation leaves degrees of freedom which make it difficult to translate these figures directly into lines and cost. Related to costs it is important to be clear about the assumptions made in terms of transmission technology (High Voltage Alternating Current (HVAC) vs. High Voltage Direct Current (HVDC)) and the method of installation (Overhead Lines (OHL) or Underground Cables (UGC)). Big variations in costs could be explained for the most part by these facts. Again, the figure shows the wide ranges of necessary network capacity extensions, especially for high penetrations of RES-E.

23 Total investments costs for the TYNDP amount to € 104 billion. Total investment costs per country correlate relatively with land size and population. Still there are noticeable deviations. Ireland thus foresees as much as € 4 billion, due to mostly High Voltage Direct Current (HVDC) long-distance cables needed. With big evolutions with respect to generation location in Germany, it considers by far the highest investments, with € 30.1 billion. The investment efforts are significant for transmission system operators' financial means. It represents about 1.5 – 2 € / MWh of power consumption in Europe over the 10-year period, i.e. about 2 % of the bulk power prices or less than 1 % of the total electricity bill. (ENTSOE, 2013, 70)

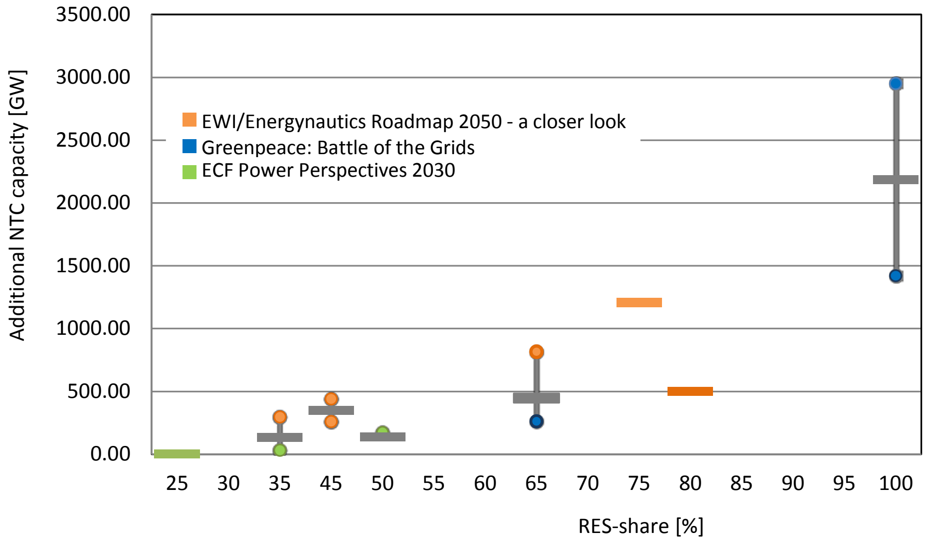

Figure 4-7. Additional Net Transfer Capacity (NTC) extension needs as a function of RES-share, according to three studies. (Nabe et al., 2012)

4.2.3 Technological options for bulk power transfer and policy implications

The high transmission expansion requirements identified in the previous chapter require appropriate technical solutions and conditions for their implementation. The factors related to the implementation of bulk power transmission can be categorised in three main areas, as presented in Figure 4-8:

1. ***Technology:*** the respective options are limited to two main transmission technologies (HVAC or HVDC) combined in two implementations (OHL or UGC).
2. ***Topology:*** two configurations are possible; either dedicated overlaying point-to-point high capacity links or overlaying meshed network structures.
3. ***Infrastructure:*** significant implications and possible synergies are introduced by existing infrastructure (such as existing electricity grid, highways, and waterways) can be decisive parameters for the realisation of new transmission projects.

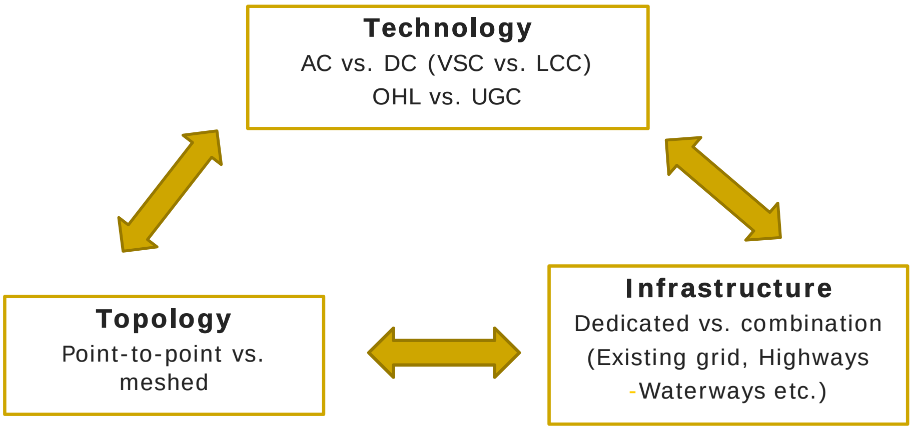

Figure 4-8. Main factors related to the planning of bulk power transmission. (Nabe et al., 2012)

Transmission technology, topology and infrastructure are interrelated choices that play a significant role in the final implementation of transmission projects. Although the techno-economic parameters of each transmission technology represent significant decision variables for the final technology choice, the **externalities** related to the implementation of the project are often the decisive factors. Based on the current state of the art, it appears that an efficient solution has the following properties:

- HVDC-VSC technology for bulk power transmission
- Mixed infrastructure use (existing towers, highways, railway tracks, new corridors)
- Mixed overhead lines and underground cables
- Meshed overlay network structures

The main policy implication is that infrastructure optimisation is a complex process affecting diverse players and large areas. High-level long-term international planning and coordination is required to achieve a gradual development towards an optimised topology. Uncoordinated gradual development may lead to sub-optimal investment allocation and transmission expansion.

4.2.4 Conclusion - Policy and planning steps

A necessary precondition for the realisation of the required network infrastructure is the adoption of a stable RES-E policy framework. EU-wide decisions on RES-E shares, mix, location and deployment timeframe will shape the network of the future. Considering the fact that network assets have a lifetime of 40 to 50 years, commitment to clear, long-term targets concerning the continental RES shares, and, if possible their spatial allocation will provide the stable framework necessary for network development, ensuring financial stability for the network manufacturing industry and for grid investments. These targets have to be sufficiently ambitious and be followed from appropriate mechanisms for the translation of the global to national targets, which is central for the localisation of the RES resources. In addition, the share of variable RES to the total RES-E mix will be of importance for the resulting network configuration since higher shares should be supported by stronger interconnections for regional balancing.

In this respect, the following steps for the planning of overlay network structures can be identified:

1. *Coordinated European overlay network planning*

   The EU should proceed to a European-wide network planning of the optimal continental network development. Since tapping of remote RES potentials translates into sheer increase in network investment costs and network development delays, the full range of options should be examined. To achieve RES-increase and climate protection in a cost-efficient way on the one hand and a foster of the transmission grid extensions on the other hand, coordinated action among the EU member states is essential. This would entail to important cost savings in the generation sector by exceeding additional costs for the transmission grid. Synergies with the existing infrastructure and the options offered by different technologies should be taken into account.

   So, beside a European regulatory framework, which stimulates the construction of new interconnection lines and guarantees the full recovery of investment, a coordinated long term European plan for grid extensions is needed. This European RES plan of action takes also advantage of the cost differences through regional benefits in the member states. This plan would be far beyond the dimension of programs like TYNDP of the ENTSO-E. In addition, there has to be a streamlined and harmonized permission process for new transmission projects across Europe and a complementary market design should be established which makes it possible to also address cross-border trading and provide a harmonized full market integration of RES generation.

2. *Extensions of the underlying HV distribution networks*

If an overlay network structure turns out to be a favourable solution, the implications on the underlying HV distribution networks need to be examined. Since the respective costs are inversely proportional to the degree of meshing of the overlay grid, these costs should be included in the comparison of the different overlay network configurations in order to reach an optimal choice.

3. *Chronological sequence of investments*

Cost-efficient achievement of RES targets implies the primary usage of mature technologies, where the pathway is characterized by early investments in onshore wind, which has already reached relatively low generation costs and investments in biomass technologies, which's potential also will help to reach the RES targets. Given the fact, that those potentials are limited, other solutions have to be found. Possible solutions are offshore wind, where installation and maintenance is crucial, or solar technologies, which have rather high generation costs at the moment, but will be a substantial solution in the long term. For this search funds are needed, to gain efficiency improvements and cost reductions.

4. *Planning reliability*

As described, huge investments in capital intensive generation and transmission grid capacities are necessary to reach the ambitious climate protection and RES targets. Therefore reliable RES targets are a precondition to achieve a cost-efficient electricity system in the EU in 2050. Otherwise investments in both types of power plants, renewable and non-renewable, would be the suboptimal consequence, also because the envisaged share of RES is unclear.

At second, reliable long term CO_2-targets are indispensable. Only if CO_2 prices are high enough to make possibilities like CCS-technologies, competitive, investments in these areas will be taken. Uncertainties about future CO_2 prices thus hinders investments in CCS plus investments in research of those technologies are needed, given the fact, that it is still in the development phase and is assumed to get commercially available by 2030.

Last, reliable returns of investments for back-up capacities are needed. This would assure security of electricity supply, which is especially in a RES-based electricity system fundamental. Large amounts of electricity are supplied by technologies which are not securely available at times of peak demand and therefore back-up capacities are needed to meet demand, in times RES are not available.

4.3 Costs for meeting energy efficiency and RES targets - Key implications on electricity prices

4.3.1 The impact of enhanced support for renewable electricity

As discussed briefly in Section 3.2.3 (cf. Box 9), an accelerated RES-E deployment within the EU does have a price, but this is also accompanied by increased benefits. The price is that consumers have to pay more for their electricity consumed, at least in the short- to mid-term. Benefits include the strong contribution of renewables to mitigate climate change, and, among others, the avoidance of fossil fuels and corresponding imports which goes hand in hand with a positive impact on Europe's trade balance.

In order to provide a first quantification of the cost impact Figure 4-9 shows the development of investment needs for new RES-E installations (left) and of overall support expenditures both for the bulk of already existing RES-E plants that receive operational support by means of feed-in tariffs, premiums or through certificates in the case of trading regimes, and for the massive volumes of new RES-E plants that have to be installed in forthcoming years. These results stem from the Green-X scenarios as described in Section 3.2.3 of this report since corresponding details are not applicable in the energy [r]evolution study or for related scenarios. More precisely, this graph shows the development of expenditures for two cases, i.e. the Green-X BAU scenario (as calculated and described in detail in the Re-Shaping study), assuming a continuation of current RES policy initiatives, and the Green-X advanced scenario as developed within this study to complement and contrast the modelling work done within the energy [r]evolution study.

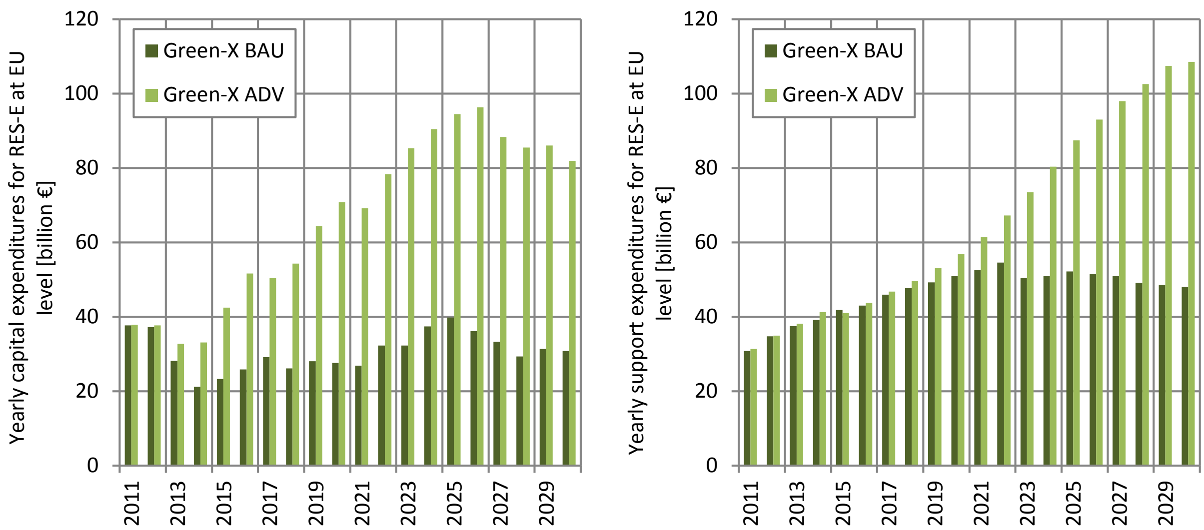

Figure 4-9. Yearly capital expenditures (left) and support expenditures (right) for RES-E at EU level. (Own calculations)

Under BAU conditions a sort of stagnation in RES-related investment activities can be expected, leading to a smooth increase of RES-E deployment from currently around 22% (as share in gross electricity consumption) to about 35% by 2030. The Green-X advanced scenario assumes a strong uptake of RES-E deployment in the forthcoming decades, achieving a RES-E share of 72% by 2030, and this requires massive investments to take place in forthcoming years. Yearly capital expenditures have to increase continuously until 2027 and thereafter decline slightly until the end of the observation period. Compared to today, this means that investments have to more than double, reaching levels of more than 95 billion € in peak years. Mobilising these massive volumes requires stable framework conditions and confidence of investors that their future revenues are assured.

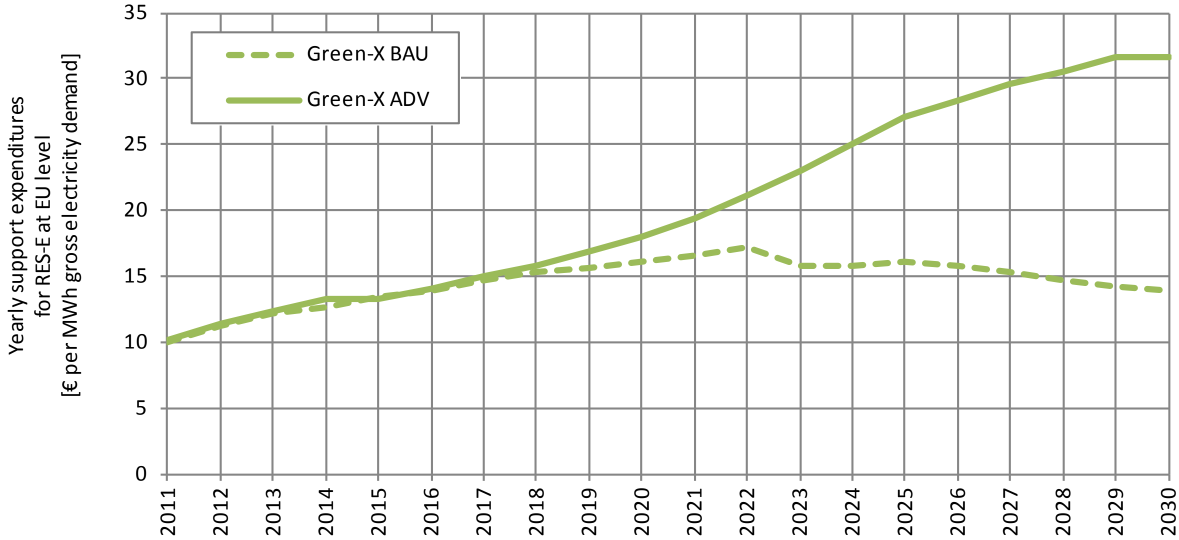

Figure 4-10. Premium on top of electricity prices due to RES-E support on average at EU level. (Own calculations)

The impact on the cost that consumers have to pay, i.e. the support expenditures remains moderate in the short-term, but for the period beyond 2020 a strong increase in required expenditures is observable. Effective and from an economic viewpoint efficiently designed support policies may help to reduce the burden for consumer but the massive policy intervention due the rapid market entrance of renewables leads to a doubling of support expenditures compared to BAU in the final years close to 2030. These expenditures finally have to be borne by the consumers or the society, either via a dedicated fee that is directly put on top of electricity prices or indirectly by the tax payers if expenditures are for example paid through governmental budgets.

To illustrate the impact on electricity prices Figure 4-10 shows the average premium on top of electricity prices that may arise if support expenditures are equally shared per MWh of electricity consumed. Obviously, a similar trend as observed in Figure 4-9 (right) is observable. In the case of a massive RES-E expansion the average premium at EU level would rise from currently around 10 €/MWh to slightly above 30 €/MWh by 2030 while in the BAU case the fee related to support expenditures would stabilise at a level of 15 €/MWh beyond 2020.

Parts of this cost burden may however be compensated by indirect effects that come along with the enhanced deployment of RES-E: From a consumer perspective a decrease of electricity prices can be expected due to the so-called "merit order effect" on the wholesale electricity (as well as on the carbon market), see Box 10 for a brief explanation of that. [24] This price erosion on the wholesale electricity market may get substantial under the assumed enhanced RES-E expansion – it can be expected that this may lead to decrease electricity prices by about 10-15 €/MWh, and as such this may compensate about 30% to 50% of the increase in prices caused by the direct support for RES-E.

Box 10. A brief recap of the "merit order effect"

The "merit order effect" that goes along with an enhanced RES-E deployment

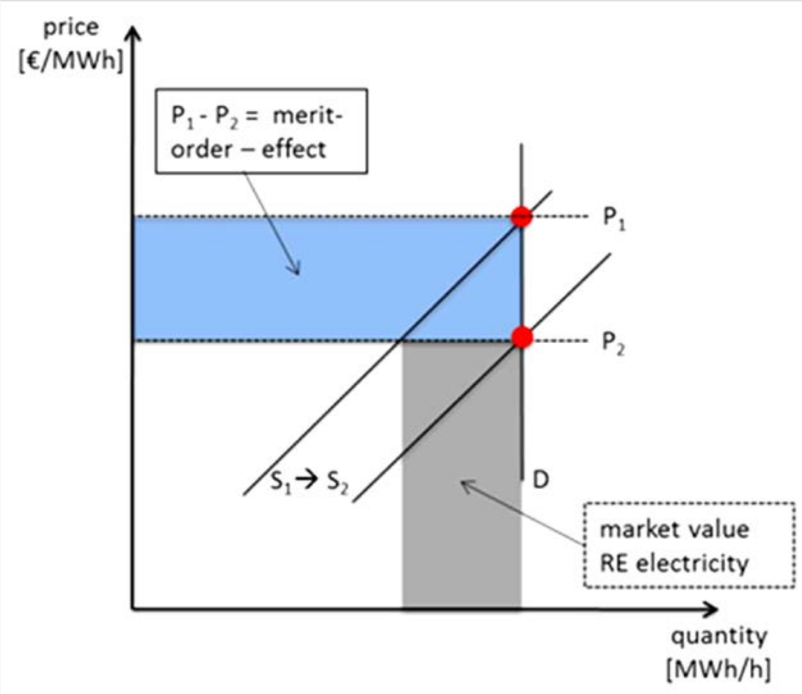

Figure 4-11. Conceptual classification of the merit-order effect and the market values of RES-E generation. (Own elaboration based on Sensfuss et al., 2008)

A stylized overview of the discussed effects of RES-E generation for a single hour is given in Figure 4-11. According to Sensfuss et al. (2008) it is assumed that the electricity demand is inelastic in the short-term perspective of a day-ahead market. If more electricity generated by RES enters the common electricity market, at least in a first approximation, the expected impact on the power system should be a decrease of total generation costs. Due to the fact that variable RES are characterized through a variable cost of production which is basically zero, the direct marketing of those technologies leads to a temporary shift of the supply curve to the right and thus displaces more expensive generation technologies. As this effect shifts market prices along the merit-order of power plants it is generally called *merit-order-effect*.

The electricity generated by RES also has a value which has to be taken into account in the public debate on costs caused by the RES policy intervention. A simplified estimation of the *market value* of RES-E generation can be calculated by multiplying the electricity production by the spot market price[25].

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[24] Note however, that both the merit order effect on electricity and CO_2 price are distributional effect between consumers and producers. These effects cause consumer profits on the one hand and losses for (conventional) producers. Therefore the benefit discussed above only exists from the consumers' point of view.

[25] Note that (decreased) market values of variable RES are taken into consideration for the calculation of (net) support expenditures in Green-X modelling.

4.3.2 The impact of energy efficiency measures

In terms of addressing climate change in a cost effective way, reducing demand for energy and improving efficiency deserves strong political attention as in most cases the supplied energy is more costly than the saved energy. As applicable in Figure 3-4 a broad set of the untapped energy efficiency potentials may come at low cost or there may even be cost savings associated with them – if evaluated from a social perspective, using generally a low discount rate. There is however an important problem or barrier to consider with respect to energy efficiency investments, referring to the up-front investments that need to be taken and the subjective (high) discount rates used in consumer's decision making process.[26] This practically means that a broad set of energy efficiency options require policy interventions to let them take shape, for example through energy saving obligations, standards, financial incentives and/or information. Moreover, this also means that there are costs/expenditures associated with them, although they might be partly classified rather as distributional effects than real macroeconomic costs.

It is however impossible to express the impact on electricity prices that arises from saving costs/expenditures that come along with the energy efficiency measures anticipated in the energy [r]evolution Advanced scenario (or additional measures that might have to be taken to fill the gap arising from an earlier nuclear phase-out than anticipated therein). The study itself provides no information on that, and also other complementary literature does hardly allow for a meaningful estimation. Moreover, costs/expenditures related to saving measures may occur at various levels and it depends on the detailed design of the policy instruments if there is any (direct or indirect) impact of them on consumer's electricity prices.

4.4 Impacts on employment through accelerated energy efficiency measures and deployment of RES

4.4.1 Employment effects according to the energy [r]evolution study

The employment in the energy sector is projected in the energy [r]evolution scenarios for the EU 27 for 2015, 2020, and 2030. This is done by using a series of employment multipliers and the projected electrical generation, electrical capacity, heat collector capacity, and the primary consumption of coal, gas and biomass (excluding gas used for transport). The results of the energy scenarios are used as inputs to the employment modelling. Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation and direct heat provision. Indirect jobs, induced jobs, and energy efficiency jobs are

[26] To summarise briefly what is explained in detail in Suna (2013): Key determinants in the (overall) economic decision process related to energy efficiency are investment costs as in general higher efficiency correlates with higher (investment) cost. From the investors' viewpoint energy efficiency investments are connected with risk (e.g. technology risks, illiquidity and irreversibility of energy efficiency investments), and consumers tend to evaluate the future benefits of their energy efficiency investment decisions by considering high discount rates for calculating the net present values of investments in order to adjust their risks from today's viewpoint. The choice of a discount rate has big impact on the cost of savings and, accordingly, also the effectiveness of a policy intervention related to energy efficiency / saving. While the social correct discount rate is generally low, reflecting the long term benefits of an investment to the society, individual discount rates are high.

not included in the calculations. Indirect jobs generally include jobs in secondary industries which supply the primary industry sector, for example, catering and accommodation. Induced jobs are those resulting from spending wages earned in the primary industries. (Teske et al., 2012a, 66)

Table 4-1. Employment in the energy sector for the energy [r]evolution reference and Advanced scenario by technology [thousand jobs]. (Teske et al., 2012a, 70)

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	165	86	84	66	307	238	216
Manufacturing	183	82	64	33	366	269	197
Operations and maintenance	210	232	237	233	240	251	253
Fuel supply (domestic)	550	517	470	395	494	441	326
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	10	12	10	11	69	212	205
Total jobs (thousands)	**1,118**	**929**	**865**	**738**	**1,475**	**1,412**	**1,196**
By technology							
Coal	261	251	208	146	210	156	80
Gas, oil & diesel	193	176	146	130	181	162	107
Nuclear	57	60	63	65	70	88	95
Renewable	**607**	**443**	**448**	**397**	**1,014**	**1,005**	**914**
Biomass	*215*	*235*	*247*	*244*	*232*	*245*	*252*
Hydro	*53*	*48*	*52*	*56*	*47*	*51*	*56*
Wind	*164*	*94*	*83*	*52*	*254*	*216*	*180*
PV	*160*	*47*	*49*	*27*	*355*	*209*	*156*
Geothermal power	*1.8*	*1.0*	*0.9*	*0.7*	*11*	*17*	*14*
Solar thermal power	*2.6*	*5.9*	*4.4*	*3.2*	*40*	*45*	*45*
Ocean	*0.3*	*0.3*	*1.1*	*3.7*	*4.7*	*10*	*6*
Solar - heat	*6*	*9*	*7*	*8*	*47*	*157*	*153*
Geothermal & heat pump	*4.0*	*2.6*	*3.0*	*3.2*	*22*	*55*	*52*
Total jobs (thousands)	**1,118**	**929**	**865**	**738**	**1,475**	**1,412**	**1,196**

The energy [r]evolution Advanced scenario results in more energy sector jobs for the EU 27 at every stage of the projection than the Reference scenario.

- There are 1.5 million energy sector jobs in the energy [r]evolution in 2015, and 0.9 million in the Reference scenario.
- In 2020, there are 1.4 million jobs in the energy [r]evolution, and 0.9 million in the Reference scenario.
- In 2030, there are 1.2 million jobs in the energy [r]evolution, and 0.7 million in the Reference scenario.

Jobs in the coal sector decline in both scenarios, leading to an overall decline of 34% in energy sector jobs in the Reference scenario. Exceptionally strong growth in renewable energy leads to an increase of 32% in total energy sector jobs in the energy [r]evolution Advanced scenario between 2010 and 2015. Renewable energy accounts for 76% of energy jobs by 2030, with biomass having the greatest share (21%), followed by solar PV, wind and solar heating. (Teske et al., 2012a, 69)

Employment in solar photovoltaics

In the energy [r]evolution Advanced scenario, solar photovoltaics would provide 12% of total electricity generation by 2030, and would employ approximately 156,000 people. Growth is much more modest in the Reference scenario, with solar photovoltaics providing 3% of generation, and employing approximately 27,000 people. (Teske et al., 2012a, 72)

Employment in solar thermal power

In the energy [r]evolution Advanced scenario, solar thermal power would provide 4% of total electricity generation by 2030, and would employ approximately 45,000 people. Growth is much lower in the Reference scenario, with solar thermal power providing only 0.4% of generation, and employing approximately 3,000 people. (Teske et al., 2012a, 72)

Employment in geothermal power

In the energy [r]evolution Advanced scenario, geothermal power would provide around 2% of total electricity generation by 2030, and would employ approximately 14,000 people. Growth is much more modest in the Reference scenario, with geothermal power providing less than 1% of generation, and employing approximately 700 people. (Teske et al., 2012a, 73)

Employment in wave and tidal power

In the energy [r]evolution Advanced scenario, wave and tidal power would provide up to 2% of total electricity generation by 2030, and would employ approximately 6,000 people. Growth is much more modest in the Reference scenario, with wave and tidal power providing less than 1% of generation, and employing approximately 4,000 people. (Teske et al., 2012a, 73)

Employment in wind energy

In the energy [r]evolution Advanced scenario, wind energy would provide 27% of total electricity generation by 2030, and would employ approximately 180,000 people. Growth is more modest in the Reference scenario, with wind energy providing 14% of generation, and employing approximately 52,000 people. (Teske et al., 2012a, 74)

Employment in biomass

In the energy [r]evolution Advanced scenario, biomass would provide up to 9% of total electricity generation by 2030, and would employ approximately 252,000 people. Growth is slightly lower in the Reference scenario, with biomass providing approximately 6% of generation, and employing approximately 244,000 people. (Teske et al., 2012a, 74)

Employment in coal

Jobs in the coal sector drop significantly in both the Reference scenario and the energy [r]evolution Advanced scenario. In the Reference scenario coal employment drops by 105,000 jobs between 2015 and 2030, despite generation from coal increasing. This is in addition to a loss of 10,000 jobs from 2010 to 2015, driven by a 5% reduction in the projected output from coal powered generation. Coal sector employment in the energy [r]evolution scenario falls even more, reflecting a 65% reduction in coal generation between 2015 and 2030. Coal jobs in both scenarios include coal used for heat supply. (Teske et al., 2012a, 75)

Employment in gas, oil & diesel

Employment in the gas sector drops by 26% in the Reference scenario between 2015 and 2030, despite the fact that gas generation increases by 21%. In the energy [r]evolution Advanced scenario employment falls by 41% while generation is reduced by only 3%. Employment losses are mainly in gas supply, as an increasing proportion is imported. Gas sector jobs in both scenarios include heat supply jobs from gas. (Teske et al., 2012a, 75)

Employment in nuclear energy

Employment in nuclear energy grows by 9% in the Reference scenario between 2015 and 2030, while generation falls by 14%. In the energy [r]evolution Advanced scenario generation is reduced by 90% between 2015 and 2030, representing a virtual phase out of nuclear power. Employment in the energy [r]evolution Advanced increases by 35% from 2015 to 2030. This is because the accelerated closure of nuclear plants results in a significant increase in nuclear decommissioning employment. It is expected these jobs will persist for 20 - 30 years. (Teske et al., 2012a, 75)

4.4.2 Employment effects according to the Employ-RES study

The impacts on economy and employment through RES and increasing energy efficiency measures in 2020 are significant. Improving current policies to achieve the 20% RES by 2020 target will provide a net effect of about 410,000 additional jobs and 0.24% additional gross domestic product (GDP). These are the key-results of the Employ-RES study, which was conducted by a consortium of EU research institutions led by Fraunhofer ISI on behalf of the European Commission’s Directorate-General Energy and Transport and finalised in 2009. (Ragwitz et al., 2009)

4.4.2.1 Background

Because of the fact, that RES have clearly shown to be an indispensable contribution to GHG-reductions and increased security of supply, the promotional effect of increased diffusion of RES in terms of ‘combating climate change‘ and ‘limiting the EU's external vulnerability to imported hydrocarbons‘ is largely undisputed. However, there is still some uncertainty about the exact contribution of RES to ’promoting growth and jobs’ in terms of the objectives of the Lisbon Strategy. As stated in the RES roadmap: ‘Studies vary in their estimates of the GDP impact of increasing the use of renewables, some suggesting a small increase,… and others a small decrease’.

> While most policy makers believe that increased use of RES and job creation can permanently go hand in hand, others assume that the distribution effects and the budget effects turn a large gross employment effect into a small or even negative net employment effect. (Ragwitz et al., 2009)

In 2008 the renewable energy Directive was agreed on by the European Parliament and the European Council with ambitious targets for each Member State which lead to reach a share of 20% renewable energy in Europe's final energy consumption by 2020. For this, further understanding and awareness of the economic and employment benefits from RES is important, which was the purpose of the Employ-RES study. Employ-RES highlights the economic effects of supporting RES, while looking not only at jobs in the RES sector itself, but also taking into account its impact on all sectors of the economy. (Ragwitz et al., 2009)

4.4.2.2 Method of Approach

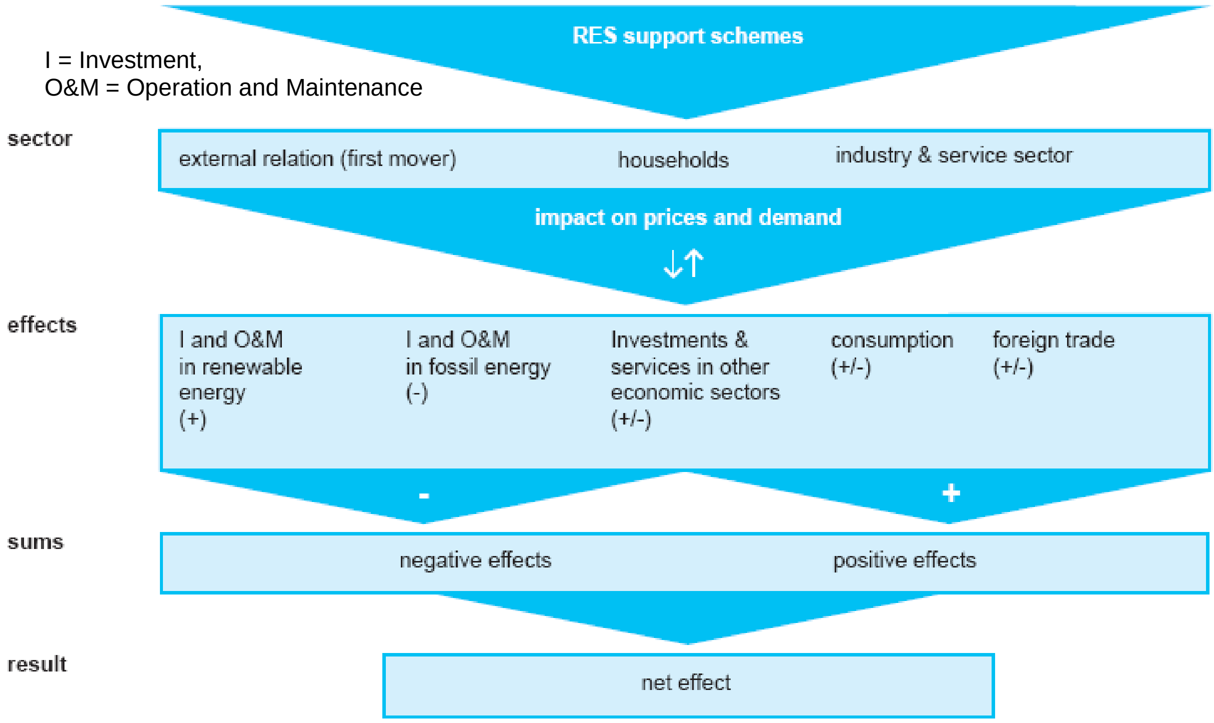

Figure 4-12. Main economic effects (a simple illustration). (Ragwitz et al, 2009)

The impact of policies, promoting a stronger growth of RES is not restricted to the energy sector; rather the whole economy and so all economic agents and sectors are directly or indirectly affected. Households, industry and services as well as external relationships are influenced by promoting RES deployment with main effects of changes in prices and demand - which moreover have consequences on the output and employment of the economy. Figure 4-12 depicts these rather complex economic mechanisms in a simplified way. A positive effect (i.e. increase in employment or GDP) is marked with a “**+**” and a negative effect (i.e. decrease in employment or GDP) with a “**-**“. An effect on *gross* employment or GDP includes all the positive effects from RES investments while the effect on *net* employment or GDP represents the difference between all positive and negative effects in the whole economy. (Ragwitz et al., 2009)

> The challenge is to capture all economic mechanisms and effects in a system of models. Furthermore, data and developments on a technological disaggregated level must be connected with economic mechanisms. (Ragwitz et al., 2009)

The study is based on an input-output model (MULTIREG) that was used to assess the effect of developments in the RES sector on other economic sectors. With regard to future developments the analysis employs a RES-sector Bottom-up model (Green-X) that was designed to simulate the effect of RES support policies to 2030. In order to calculate future economic effects, two well-established, independent macro-economic models (NEMESIS and ASTRA) were used in parallel and their results were compared for maximum reliability. Figure 4-13 shows the modelling approach and the link of the different models in a simplified way. The vertical line reflects the data transformation and model output, the horizontal line the time horizon. The figure omits the stakeholder consultation and thorough desk research on RES data, market shares in RES technologies, lead market data and further inputs of statistic historic data. (Ragwitz et al., 2009)

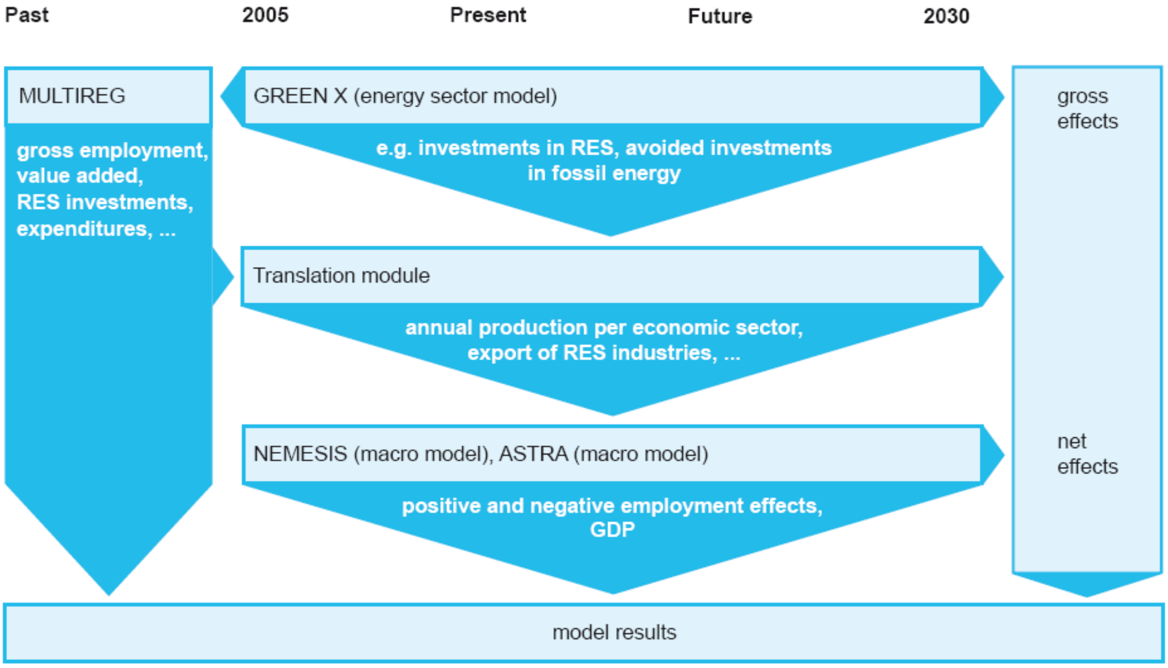

Figure 4-13. Modelling approach (linkage of models and databases). (Ragwitz et al, 2009)

4.4.3 Key results

In 2005 the RES sector employs 1.4 million people and generates €58 billion value added. The total gross value added generated by the RES industry reaches €58 billion in 2005, equal to 0.58% of EU GDP. The RES sector employs roughly 1.4 million people, equal to 0.65% of the total EU workforce. About 55% of value added and employment occurs directly in the RES sector and 45% in other sectors due to the purchase of goods and services. The impact on GDP and future employment for two key scenarios are as follows:

- Current RES support policies (Business as usual (BAU-ME) scenario) lead to a EU-wide share of RES in final energy consumption of 14% by 2020 and 17% by 2030
- Stronger RES support policies (Accelerated deployment policies (ADP-ME) scenario) lead to a share of RES in final energy consumption of 20% by 2020 and 30% by 2030.

Achieving the 2020 RES target leads to about 1.1% total gross value added to the GDP (of the RES sector). Assuming business as usual (BAU) polices, the total gross value added of the RES sector in the EU 27 in 2020 would amount to €99 billion (0.8% of total GDP). Based on the accelerated deployment policy (ADP) scenario the value would amount to €129 billion (1.1% of total GDP). This is in comparison with a hypothetical scenario in which all RES support policies are abandoned after 2006. Achieving the 2020 RES target likely leads to a net increase in GDP by about 0.24%. The total net GDP change due to RES policies in 2020, depending on the used model, is expected between amounts of 0.11% to 0.14% under the BAU scenario and 0.23% up to 0.25% under the ADP scenario for the EU 27. Again this is in comparison with the no-RES-support scenario. Achieving the 2020 RES target likely leads to 2.8 Million jobs in the RES sector in total. Total gross employment in the RES sector in the EU 27 in 2020 will amount to 2.3 million people under the BAU scenario and 2.8 million under the ADP scenario. Compared to the hypothetical scenario in which all RES support policies are abandoned, the additional gross employment due to RES policies amounts to 0.6 million people for the BAU scenario and 1.1 million people for the ADP scenario. Achieving the 2020 RES target likely generates about 410,000 net additional jobs. The total net increase in employment in the RES sector in the EU 27 in 2020 compared to the hypothetical scenario will amount to about 115 - 200 thousand people under the BAU scenario and to 396 - 417 thousand people under the ADP scenario, depending on the used model. (Ragwitz et al., 2009)

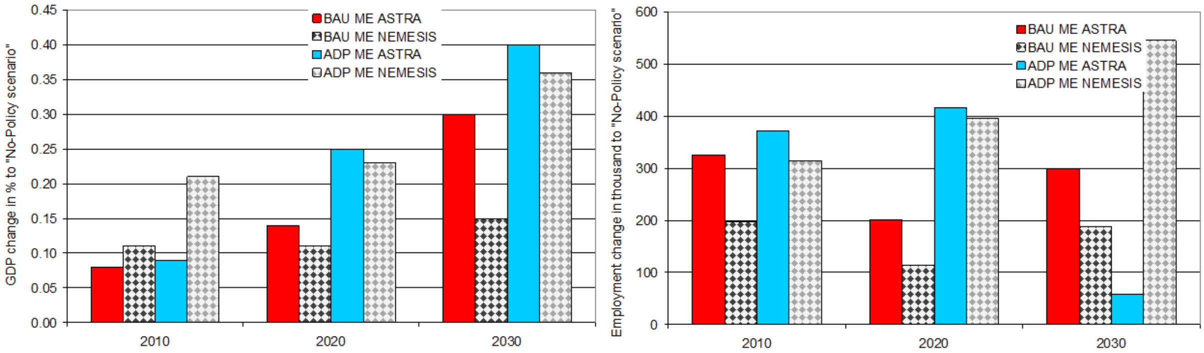

Figure 4-14. GDP- and Employment-change to "No-policy"-scenario of the two macro-economic models ASTRA and NEMESIS (Ragwitz et al., 2009) The impact of RES-promoting policies would be to slightly stimulate EU´s GDP development.

Figure 4-14 presents the results of the two macro-economic models ASTRA and NEMESIS used in the Employ-RES study. For EU 27 employment the conclusion can be drawn, that it would be also slightly stimulated by these policies, but the effects would be more moderate as for GDP. Beside the successive increase of GDP in 2010 – 2030 it is interesting, that there will be indeed a positive employment change in 2010 and 2020, but also a negative in 2030. (Ragwitz et al., 2009)

4.4.4 Conclusions

The Employ-RES study draws the following conclusions: As the strong growth of biomass and onshore wind lead to a bulk of positive trends in RES production, employment and economic growth in the last years, this way has to be sustained in the future and enhanced with stronger policies to reap maximum economic benefits from RES.

Although innovative technologies such as photovoltaic, offshore wind, solar thermal electricity and second-generation biofuels require more financial support in the short-term, it is precisely these technologies that are additionally needed to achieve the substantial growth of renewables until 2030. If policy interventions are properly designed and coordinated, a positive economic impact does not appear unlikely. This will contribute to strengthen the EU's competiveness and to increase employment and GDP in the mid-term. Innovation policy is therefore essential to strengthen the first-mover advantage of Europe's RES industries. If successful, these technologies can help the EU maintain a higher world market share in RES and a high net GDP increase. (cf. Ragwitz et al., 2009)

The energy [r]evolution study projects higher employment effects, which cannot be directly compared to the Employ-RES study. The much higher gross employment effects of 550,000 additional jobs in 2020 and 460,000 additional jobs in 2030 compared to the reference scenario are partly a result of higher RES-E developments compared to Employ-RES. Furthermore energy [r]evolution calculates employment effects only for the electricity sector, and ignores indirect effects, as job losses due to less consumer spending in other sectors.

4.5 Country specifics to be considered

Today, nuclear power is a commonly used option for electricity generation within the EU, and nuclear power is holding a share of 28% on total electricity generation at EU level. 14 Member States have nuclear reactors in operation, and for nine countries with currently (as of 2010) the highest total production of nuclear electricity Figure 4-15 illustrates their generation mix, indicating the shares of nuclear, fossil and renewables on total domestic generation in 2010.

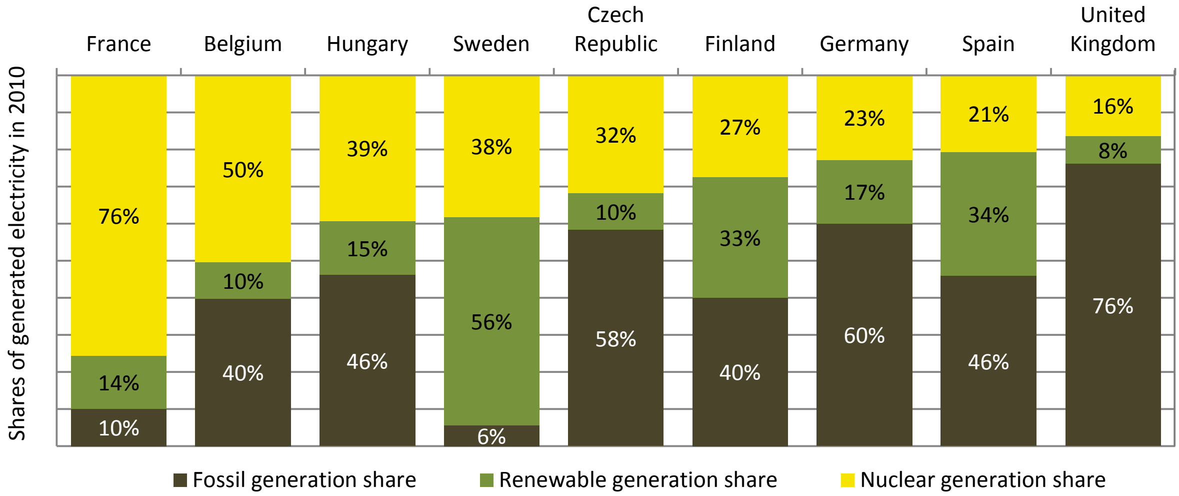

Figure 4-15. Generated electricity shares in 2010 by the nuclear, fossil and renewable sectors for nine EU27 countries with (currently) the highest total production of nuclear electricity. (Eurostat, 2013e)

Complementary to this, Figure 4-16 depicts a breakdown of total electricity generation into these categories, now expressed in absolute terms (i.e. TWh produced) but again referring to 2010.

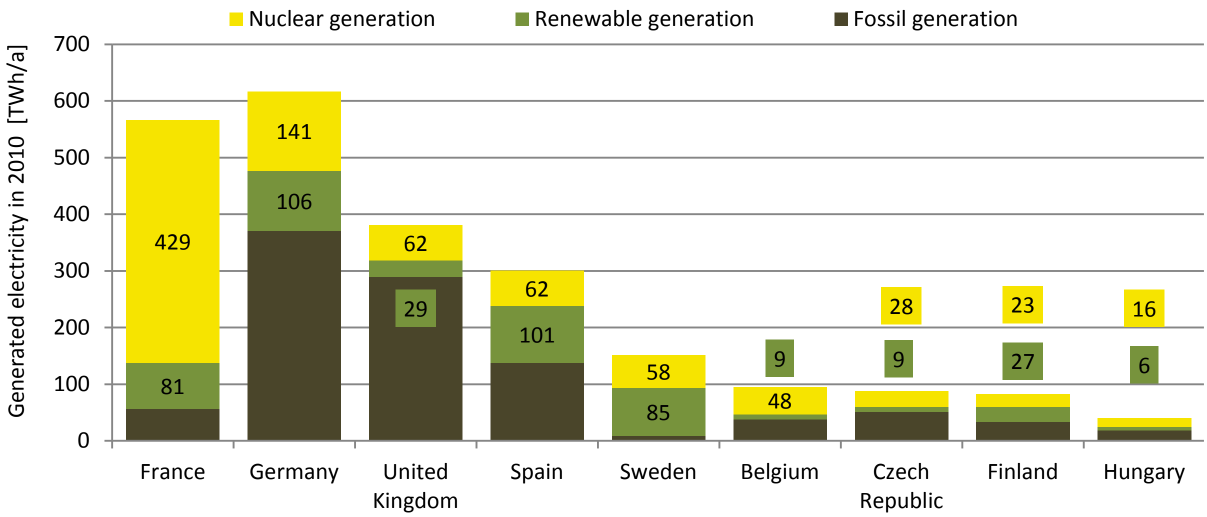

Figure 4-16. Generated electricity in 2010 by the nuclear, fossil and renewable sectors for nine EU27 countries with (currently) the highest total production of nuclear electricity. (Eurostat, 2013e)

Remarkably, in countries like France, Belgium, Hungary or Sweden, nuclear power is responsible for more than one third of total domestic electricity supply, and partly this is significantly more, compare e.g. France (76% nuclear share) or Belgium (50%). At first glance, these countries appear most significantly affected by a possible phase-out of nuclear power as assumed to take shape in the mid-term (by 2030). Notably, also other countries with a lower nuclear share may face a significant challenge in the transition process towards a low carbon energy system, in particular if fossil fuels are responsible for their majority or at least a large part of their power supply today, cf. Germany, Spain or the UK.

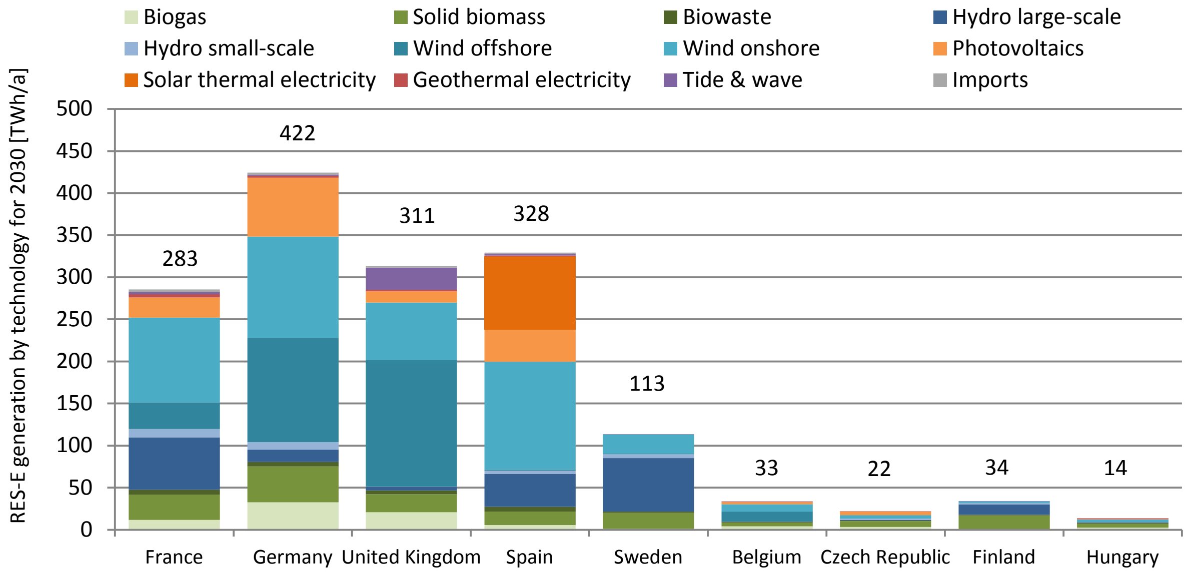

Figure 4-17. Technology-specific breakdown of RES-E generation in 2030 according to the Green-X advanced scenario for nine EU27 countries with (currently) the highest total production of nuclear electricity. (Own calculations)

As discussed above (cf. Chapter 2 or Section 3.2), the supply gap that would arise from a nuclear power phase-out together with the on-going combat against climate change needs to be filled to a large extent by renewables in the short to mid-term. In this context, Figure 4-17 shows a technology-specific breakdown of total RES-E generation in 2030 according to the Green-X advanced scenario for the nine countries discussed above.

The increase of RES-E generation compared to 2010 is in magnitude of 1100 TWh for the nine countries in focus while a phase-out of nuclear means to take about 850 TWh out of the system.[27] Thus, the simple comparison of these two figures may point out that additions from renewables overcompensate the arising supply gap, but additional challenges have to be taken into account: first, climate action may require to also substantially reduce fossil generation, and, secondly, at country level, there is a occasionally a large discrepancy between gap and additions. For example, France would have to take 429 TWh of nuclear electricity out of operation while additional renewable generation is in magnitude of about 202 TWh. In contrast to that, its southern neighbour Spain may well end up with a surplus in power supply that is waiting to be consumed elsewhere. This exemplifies to need for intensified coordination and cooperation in the (renewable) energy sector, an issue that Europe, or at least the European Commission, is addressing in several of its energy-related publica-

[27] Corresponding figures for the EU level appear more impressive: additions in RES generation are in magnitude of 1800 TWh while a shut-down of nuclear power means a decrease in generation by about 900 TWh.

tions and statements (cf. EC, 2013). Furthermore, this nicely indicates the need for further network extensions to tackle the challenges arising from a massive uptake of (variable) renewables in the electricity sector.

4.6 Complementary activities are of need to safeguard the transition process

Complementary to energy efficiency a strong uptake of RES in the electricity sector is required to pave the way to a nuclear power-free Europe, while maintaining the transition to a sustainable energy system in the mid- to long-term. Since meeting climate commitments represents a precondition for doing so, this already in parts of Europe on-going transition process has to accelerate in speed. It can be expected that this puts the stable functioning of the EU's internal electricity market(s) as of today under challenge, and requires clear commitments across all societal levels. Strong and proactive policy action are ultimately required to define a level playing field for both RES and energy efficiency. As derived from the analysis undertaken in Chapter 3 of this report, ambitious binding European (and probably also accompanying national) 2030 targets for both energy efficiency and RES can be seen as first step to tackle and initiate this process – but the list of policy action is significantly longer and has to challenge all areas and levels of the energy system and the society. Below we provide an incomplete list of complementary activities that are of need.

4.6.1 A well-established carbon price to safeguard that climate commitments can be held

A well-established carbon price is the key element to safeguard that climate commitment can be held as otherwise dirty fossil fuels like lignite or coal are preferred against less carbon intensive sources. Mainly as a consequence of the economic crisis and the decrease of energy demand and industrial production, carbon prices in the European Emission Trading System as of today are at such a low level that no redirecting of energy-related investments towards more sustainability occurs. There is an ongoing debate on how to reform the ETS and how to define the appropriate energy and climate framework for 2030. Thereby, the introduction of price-stabilising elements in the carbon market deserves key attention but also alternatives to an emission trading regime like the introduction of carbon taxes should be taken into consideration. Moreover, some critics argue that the coexistence of separate EU targets and policies for renewable energy, energy efficiency and greenhouse gas emissions reduction is undesirable and even counter-productive, and should therefore be discontinued after 2020.

Within European project beyond2020 (cf. Resch et al. (2013a) or www.res-policy-beyond2020.eu), the conclusion is drawn that the coexistence of GHG and RES policies and targets is clearly justified but coordination has to deserve key attention. Well-coordinated targets and policies will be capable of reaching both the GHG emissions reduction target and the RES deployment targets in an effective and efficient manner. As pointed out in that study, supporting a strong RES-E deployment, trough dedicated RES-E support, instruments is clearly more cost-effective than promoting it through the ETS only.

The question arises how to make GHG and RES targets more coherent? Appropriate solutions are analysed in del Rio et al. (2013) and it was concluded:

> In principle, ETS and RES-E trajectories can be coordinated ex ante or ex post. From the ETS perspective, ex ante coordination is clearly preferable, as ex post adjustments will reduce the credibility of the ETS. However, one might consider transparent dynamic adjustment mechanisms that would become effective in cases where there are major deviations from the original projections. Adjustments for coordinating RES-E deployment and the ETS cap can be implemented both within the ETS and within the RES-E support instruments through specific design elements. Some flexibility in the RES-E growth trajectory is important, however, as a strict yearly trajectory would be difficult to achieve and could obstruct RES-E market growth patterns. (del Rio et al., 2013)

This discussion has also a key relevance for renewables and energy efficiency, as stabilising carbon prices is crucial for the effectiveness and efficiency of dedicated support for both. Low carbon prices will increase the need for support and lead either to high support payments or to reduced RES growth and energy savings, respectively.

4.6.2 Less carbon intensive fossil fuels are required (in the transition phase)

Fossil fuels are of need to complement renewables in power supply, at least in the transition phase they are an important contributor in both base load and peak supply. More precisely, from a climate perspective, the assumed phase-out of nuclear power requires less carbon intensive fossil fuel power, e.g. gas-fired combined heat and power production.

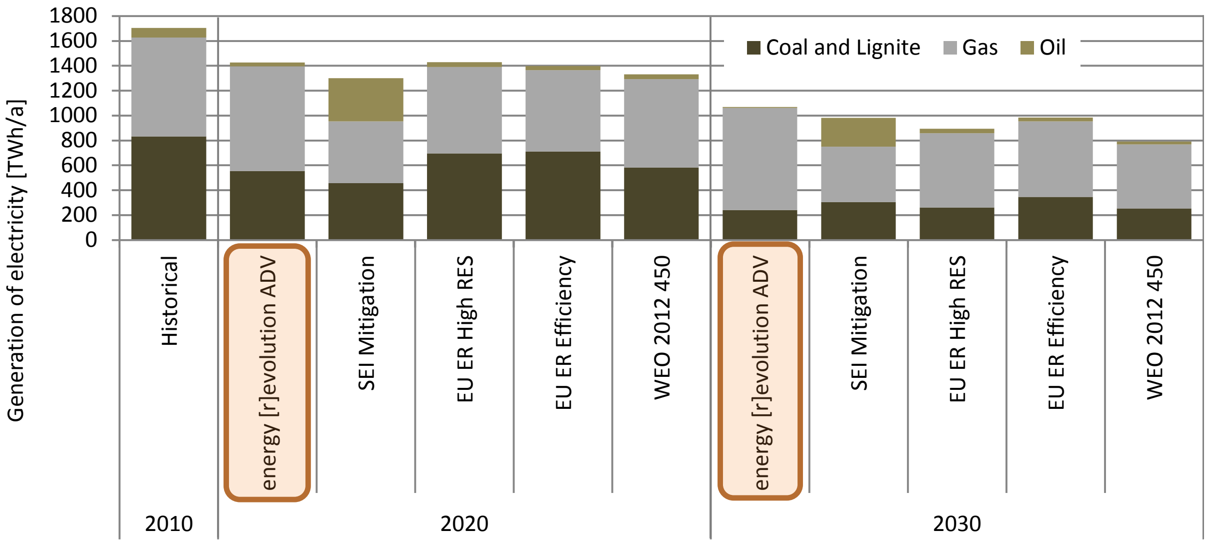

Figure 4-18. Generation of electricity by fossil fuels for 2010 and of all included mitigation scenarios for 2020 and 2030. (EC, 2011b, 158-175; Eurostat, 2013e; Greenpeace and EREC, 2012; Heaps at al., 2009, 56; IEA, 2012, 572-575)

In accordance with assessed climate mitigation scenarios (cf. Section 2.3) in the short- (2020) to mid-term (2030) there will be still electricity generated from fossil fuels. As Figure 4-18 shows, the fossil part will be based on coal, lignite and natural gas.[28] Coal and lignite will however have to phase-out by mid-century to fulfil the decarbonisation target of the electricity sector. To accomplish this necessity in Europe, a CO_2 price should be established that ensures that less carbon intensive fossil fuels gain sufficient competitiveness against more carbon intensive sources such as coal or lignite. The competition between gas and coal-fired power plants is currently dominated by coal as can be seen in the statistics of Eurostat (2013e). The production of electricity by coal and lignite grew from the lowest level of production on record since 1990 from 823 TWh in 2009 to 852 TWh in 2011. The opposite is true for the electricity production by natural gas in the EU. The production decreased from its highest level on record since 1990 of 813 TWh in 2008 to 732 TWh in 2011. Moreover, a solution for another key challenge of the electricity market that affects all forms of (conventional) power production needs to be provided: the price depression on the wholesale market due to the merit order effect (cf. Box 10) that goes hand in hand with the increased deployment of (variable) RES. This can be seen as positive effect from a consumer perspective (if the decrease in wholesale prices is well reflected in end-user prices) but, on the other hand, as several studies pointed out (Frias et al., 2013) additional capacity will be required to back-up RES. According to Frias et al. (2013) "[this] raises the issue of whether this capacity will come online if prices are depressed (and therefore the investment signal is reduced). Currently, the European electricity market is characterized by a situation of overcapacity, so this should not be an issue in the medium term, and will anyway depend on the strength of the incentive for new investments (be them in the generation or demand side)." As part of an appropriate solution to handle this, new pricing and bidding rules have to be developed. As Frias et al. (2013) concluded: "Possibly, complex instead of simple bids could be beneficial for systems with a high renewables penetration. Also, joint bids for energy production and balancing services could be useful. Non-discriminatory pricing could be used to internalize non-convex-cost related components of the actual value of electricity market prices."

[28] The SEI study poses an exception with a significant part of electricity in the 27 EU countries generated by oil.

5 Legal aspects of a nuclear power phase-out

The work within work package 3 of the project and under Chapter 5 of this report involves two complementary tasks, both related to nuclear energy policy in the European Union and juridical aspects.

The first part deals with the question which legal aspects have to be considered when Member States want to promote the operation of nuclear energy plants through national support schemes. The focus will be laid on the provisions of the prohibition of state aids and its exemptions. The analysis is made against the background of the actual state aid modernization process, which was initialized by the EU Commission in May 2012[29]. In summer 2013, some drafts of documents by the Commission on this matter came to the attention of the public although they were not published officially. They had shown that for the first time it was considered to integrate nuclear energy into the design of a new state aid framework for environmental protection and energy for the next years. Though the Commission meanwhile declined that there will be a codification of exact conditions under which state aid could be granted for nuclear power projects.

The description on the general principles of state aid made in the first part will serve as a basis for the analysis carried out in the second part which will highlight the ongoing Electricity Market Reform in the UK. As part of the reform it is foreseen that a new system will be introduced which establishes feed-in tariffs with contracts for difference for “low carbon technologies”. This system shall also be applied to nuclear energy in the UK. This promotion scheme will be analysed and shown that it is not compatible with EU law on state aid.

This report will focus on possible national support schemes for the generation of electricity based on nuclear energy. Other aspects of aid granted for nuclear energy especially related to decommissioning costs, nuclear waste management and disposal costs as well as liability costs will not be considered. The legal assessment of schemes for operating aid for nuclear energy will lie primarily on the European state aid rules according to Article 107-109 of the Treaty on the Functioning of the European Union (TFEU)[30] due to its general importance for policy implications regarding a nuclear phase-out in Europe.

[29] Commission, Communication, EU State Aid Modernisation (SAM), COM(2012) 209 final.
[30] OJEU, C 115/47, 9.5.2008.

5.1 Interaction between the Euratom Treaty and the Treaties of the European Union

5.1.1 General aspects

In the field of nuclear energy the Treaty establishing the European Atomic Energy Community (Euratom Treaty)[31] constitutes binding Primary law for all Member States of the European Union[32]. Since the Lisbon Treaty entered into force in December 2009, the European Union itself is based on the Treaty on European Union (the TEU) and the Treaty on the Functioning of the European Union (the TFEU). How and where the EU treaties could be applied in the nuclear energy sector has been a relevant question already for a long time. The analysis of the interaction between the Euratom Treaty and the TFEU is of high relevance in various fields, but especially decisive when it comes to aspects of the common market, e.g. state aid law.

Before the Lisbon Treaty entered into force, the general relation between the Euratom Treaty and the Treaty establishing the European Community (TEC)[33], which was valid at the time, was characterized by Article 305 (II) TEC:

> The provisions of this Treaty [establishing the European Community] shall not derogate from those of the Treaty establishing the European Atomic Energy Community.

With the Lisbon Treaty, two changes were made which are relevant for the relation between the Euratom Treaty and the other European treaties forming the Primary law. First, Article 305 (II) TEC was abolished; second, the following Article 106a was introduced into the Euratom Treaty:

> 1. Article 7, Articles 13 to 19, Article 48(2) to (5), and Articles 49 and 50 of the Treaty on European Union, and Article 15, Articles 223 to 236, Articles 237 to 244, Article 245, Articles 246 to 270, Article 272, 273 and 274, Articles 277 to 281, Articles 285 to 304, Articles 310 to 320, Articles 322 to 325 and Articles 336, 342 and 344 of the Treaty on the Functioning of the European Union, and the Protocol on Transitional Provisions, shall apply to this Treaty. (…)
>
> 3. The provisions of the Treaty on European Union and of the Treaty on the Functioning of the European Union shall not derogate from the provisions of this Treaty.

In general, this regulation means that the Euratom Treaty adopts its own rules for the predefined scope. So the legal area is not determined primarily by the other European Treaties. But as will be shown in the following, the Euratom Treaty does not constitute a totally separated framework for the material regulated.

[31] OJEU C 84/1, 30.3.2010.

[32] See e.g. *Ptasekaite*, The Euratom Treaty v. Treaties of the European Union: limits of competence and interaction, 2011, page 2, available at www.stralsakerhetsmyndigheten.se

[33] OJEC C 325/33, 24.12.2002.

5.1.2 The Euratom treaty and state aid law

5.1.2.1 Subsidiarity of state aid provisions

The interactions between the different treaties and the consequences for their practical application have long been debated by the scientific literature and the Commission[34]. Especially the application of state aid rules on nuclear energy aspects is discussed. However, there is no explicit verdict by the European Court of Justice (ECJ) on this matter[35]. It can be seen as widely agreed, that the Euratom Treaty is not a completely closed, isolated area in itself, but open to certain restrictions and provisions formulated by other EU Primary law[36]. So in relation to the European treaties, the Euratom Treaty can be determined as lex specialis. That means: where the Euratom Treaty governs a specific subject matter (lex specialis)[37], the TEC (at that time) and now the TFEU are overridden as they only govern general matters in this case (lex generalis)[38]. In other words: the European treaties are only applicable in nuclear energy matters as far as the Euratom Treaty does not contain a concrete regulation on a specific aspect[39].

When it comes to the applicability of the EU State aid law in particular it has to be stated, that the Euratom Treaty contains no provisions analogous to Article 107-109 TFEU. The application of these articles for the benefit of undertakings active in the nuclear energy sector is therefore accepted by the Commission[40] and a wide range of the scientific literature[41]. Therefore when state aid in the scope of the Euratom Treaty is concerned, the provisions of the Euratom Treaty are not exhaustive.

[34] *Heidenhain*, European State Aid Law, 2010, § 1, recital 14; *Ehricke/Hackländer*, Europäische Energiepolitik auf der Grundlage der neuen Bestimmungen des Vertrages von Lissabon, ZEuS 2008, S. 579 (584 f.).

[35] See *Kreuschitz/Wernicke* in: Lenz/Borchardt, EU-Verträge, Kommentar, 2012, Introduction to Art. 107-109, recital 13; see also opinion of the ECJ related to Euratom Treaty and external trade, Opinion 1/94, ECR 1994, Page I-05267, recital 24: "Article 232(2) of the EC Treaty states that the provisions of that Treaty 'shall not derogate from those of the Treaty establishing the European Atomic Energy Community'. Since the Euratom Treaty contains no provisions relating to external trade, there is nothing to prevent agreements concluded pursuant to Article 113 of the EC Treaty from extending to international trade in Euratom products."

[36] See *Pechstein*, Elektrizitätsbinnenmarkt und Beihilfenkontrolle im Anwendungsbereich des Euratom-Vertrags, EuZW 2001, S. 301 (309); opposed: *Grunwald*, Das Energierecht der Europäischen Gemeinschaften, Berlin 2003, S. 234 ff.

[37] *Kühling*, in: Streinz, EUV/AEUV, Kommentar, Art. 107, recital 16; *Cremer* in: Calliess/Ruffert, EUV/AEUV, Kommentar, 2011, Art. 107, recital 8.

[38] *Kokott*, in: Streinz, EUV/EGV, Kommentar, 2003, Art. 305, recital 11.

[39] *Schärf*, Europäisches Nuklearrecht, Berlin, 2008, S. 168 ff; *Bär-Bouyssiere*, in: Schwarze, EU-Kommentar, 2012, Art. 107, recital 9.; *Frenz*, Beihilfe- und Vergaberecht, 2007, § 6, recital 151; *Papenkort*, Der Euratom-Vertrag im Lichte des Vertrags über eine Verfassung für Europa, 2007, S. 99 f.; *Schlömer*, Der beschleunigte Ausstieg aus der friedlichen Nutzung der Kernenergie, 2012, S. 198 f.; *Pelzer*, Die EU und der europäische Atomhaftungs-Flickenteppich, in: Koch, 14. Deutsches Atomrechtssymposium, 2013, S. 101.

[40] See e.g. Commission, Invitation to submit comments pursuant to Article 88(2) of the EC Treaty, concerning aid C 52/03 (ex NN 45/03) — Restructuring aid in favour of British Energy plc, O.J. C 180/5 and Decision of 22 September 2004 on the State aid which the United Kingdom is planning to implement for British Energy plc., COM 2005/407/EC; O.J. L 142/06, page 42.

[41] *Heidenhain*, European State Aid Law, 2010, § 1, recital 14, referring to opinion of AG Reischl, ECJ, 188/80, ECR 1982, 2545, 2583, para 11 – *France/Commission*; *Bungenberg* in: Birnstiel/Bungenberg/Heinrich, Europäisches Beihilferecht, Introduction, recital 107.

Thus the provisions of Articles 107 -109 TFEU are applicable on state aid subjects, as far as the Euratom treaty does not contain specific provision on the matter[42].

5.1.2.2 Interaction with Euratom treaty objectives

The objective of the European Atomic Energy Community (Euratom) is stated in Article 1 (II) Euratom Treaty:

> It shall be the task of the Community to contribute to the raising of the standard of living in the Member States and to the development of relations with the other countries by creating the conditions necessary for the speedy establishment and growth of nuclear industries.

In order to perform this task, Article 2 Euratom Treaty includes several activities which shall be exercised by the Community. Inter alia, the Community shall:

- "promote research and ensure the dissemination of technical information" (Article 2 lit. a) Euratom Treaty);
- "facilitate investment and ensure, particularly by encouraging ventures on the part of undertakings, the establishment of the basic installations necessary for the development of nuclear energy in the Community" (Article 2 lit. c) Euratom Treaty);

Additionally, Chapter 4 of the Euratom Treaty is titled "Investments" and contains, especially in Articles 40-44, regulations which might be seen as relevant in the discussed context.

Article 40 (I) states:

> In order to stimulate action by persons and undertakings and to facilitate coordinated development of their investment in the nuclear field, the Commission shall periodically publish illustrative programmes indicating in particular nuclear energy production targets and all the types of investment required for their attainment.

Article 41 (I) Euratom Treaty states:

> Persons and undertakings engaged in the industrial activities listed in Annex II to this Treaty shall communicate to the Commission investment projects relating to new installations and also to replacements or conversions which fulfil the criteria as to type and size laid down by the Council on a proposal from the Commission.

Some authors argue that the provisions of the Euratom Treaty on investments (see Article 2 lit. c) and Article 40, 41 Euratom Treaty) are so detailed that the general rules on state aid in the TFEU cannot be applied in the nuclear sector[43]. This opinion is mainly based on the following argumentation: Point 1.7 of the Annex of the COM Regulation 1209/2000/EC determining procedures for ef-

[42] *Kühling*, in: Streinz, EUV/AEUV Kommentar, Art. 107 AEUV recital 16.

[43] See *Ptasekaite*, The Euratom Treaty v. Treaties of the European Union: limits of competence and interaction, 2011, page 91-95, available at www.stralsakerhetsmyndigheten.se; this opinion is based on the following argumentation: Point 1.7 of the Annex of the, states that the undertakings have to provide information on "Methods of financing" (inter alia); the author deducts from this provision that investments can be in general be financed by Member States.

fecting the communications prescribed under Article 41 Euratom Treaty[44] states that the undertakings have to provide information on "Methods of financing" (inter alia); from this provision it is deducted that investments can in general be financed by Member States. Therefore, a general prohibition of state aid in the nuclear sector would not apply here[45]. This opinion neglects two aspects: First, the addressees of Article 41 Euratom Treaty are not the Member States and their possible support schemes for nuclear energy, but "persons and undertakings engaged in the industrial activities listed in Annex II to this Treaty"[46]. Second, the possibility of the financial promotion of projects by the Member States is neither mentioned in the Euratom Treaty nor in other legal acts like the above cited COM regulation 1209/2000/EC. The mere term "Methods of financing" in the Annex of the Euratom Regulation 1209/2000/EC cannot imply a general decision on the question if a financial promotion is publicly financed or not. Such an interpretation cannot be based on the wording of the named Regulation.

5.1.2.3 Conclusions

As a result it can be stated that financial aid by Member States to promote the further deployment of nuclear energy, e.g. in form of operating aid for the generation of electricity based on nuclear energy, is not regulated by the Euratom Treaty and therefore falls under the general EU state aid rules.

[44] COMMISSION REGULATION (EC) No 1209/2000 of 8 June 2000 determining procedures for effecting the communications prescribed under Article 41 of the Treaty establishing the European Atomic Energy Community

[45] Report by Working group III on "Legal Certainty in International Nuclear Trade", Nuclear Inter Jura 2001, p. 298, cited by *Ptasekaite*, The Euratom Treaty v. Treaties of the European Union: limits of competence and interaction, 2011, page 92.

[46] *Pechstein*, Elektrizitätsbinnenmarkt und Beihilfenkontrolle im Anwendungsbereich des Euratom-Vertrags, EuZW 2001, S. 301 (310).

5.2 The possible compatibility of the promotion of nuclear energy with state aid law

As seen before, the financial promotion of nuclear energy plants by the Member States, e.g. through operating aid, is not solely subject to the provisions of the Euratom-Treaty, but falls also under the scope of the TFEU. One of the key provisions of the TFEU, which aims at defending a fair competition between all market participants without non-justified state interventions, is the European state aid law. In the following, the general framework for the prohibition of state aid and its possible exemptions will be set out.

5.2.1 The legal framework of state aid in general

When defining the concept of state aid from a very general point of view, two questions have to be answered:

- Is there a state aid?
- If yes, is there an exemption from the general incompatibility of state aids with the common market?

In order to answer these questions in a reliable way, a well elaborated and detailed scheme of assessment has to be considered. This scheme is set out by the rules on state aid contained in Article 107 to 109 of the Treaty on the Functioning of the European Union (TFEU) and was developed further by the EU Commission and the European Court of Justice.

The most important steps can be summarized as follows:

- Article 107 (I) TFEU: Does the national measure fulfil the requirements of a state aid? Are the *Altmark*-criteria considered and fulfilled? Is the scope of Article 107 (I) TFEU limited by Article 106 (II) TFEU which regulates the operation of “services of general economic interest”?
- If there is a state aid pursuant to Article 107 (I) TFEU, it has to be examined whether the state aid can be exempted from the general prohibition of state aids:
    - Is the state aid compatible with the internal market pursuant to Article 107 (II) TFEU (“legal exemptions”)?
    - If no: Is the state aid compatible with the internal market pursuant to Article 107 (III) TFEU (“facultative exemptions”)?
        - Does the measure fall into the scope of the General Block Exemption Regulation?
        - If no: Is the measure subject of Guidelines set out by the Commission?
        - If no: Is the measure compatible with the internal market pursuant to one of the alternatives of Article 107 (III) TFEU (examined by the Commission on the basis of the so called balancing test)?
    - If no: National measure qualified as state aid which is not compatible with the internal market and therefore prohibited.

5.2.2 Prohibition of state aid pursuant to Article 107 (I) TFEU

5.2.2.1 National measure as a state aid

Article 107 TFEU is the key provision to determine whether or not a measure taken by the Member States constitutes state aid. If so, Article 107 (I) TFEU contains a general prohibition of state aid due to its distorting effect on the internal market.

Article 107 (I) TFEU reads as follows:

> Save as otherwise provided in the Treaties, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market.

According to this regulation, the assessment, whether a national measure is to be classified as a state aid and therefore prohibited, includes the examination of the possible fulfilment of all of the following criteria:

- Transfer of state resources
- Granting of an economic advantage
- Selectivity: Favouring of certain undertakings or the production of certain goods
- Distortion of competition with adverse effects on trade between Member States

Member States have to inform the Commission in advance about measures which may be considered as state aid[47]. The Commission then opens a procedure and in the end issues reasoning whether or not the respective measure can be seen as consistent with state aid rules. If the measure is not compatible with state aid law, no subsidy can be paid and any payments already made by the Member State have to be paid back to the Member State.

5.2.2.2 Scope of Article 107 TFEU is limited by Article 106 II TFEU/ Conditions of *Altmark*-Judgement by the ECJ

Article 106 (II) TFEU states:

> Undertakings entrusted with the operation of services of general economic interest or having the character of a revenue-producing monopoly shall be subject to the rules contained in the Treaties, in particular to the rules on competition, in so far as the application of such rules does not obstruct the performance, in law or in fact, of the particular tasks assigned to them.

The definition of the term “*services of general economic interest”* lies within the discretion of the Member States. Regarding energy law several services of general interests have been recognized by the ECJ or the Commission, for example: dispatching service for grid security and consumer protection[48].

[47] In case, a measure falls into the scope of the GBER, see below.
[48] ECJ (Enel) C-242/10,para 51.

Closely connected to the question of “services of general economic interest” is the assessment of national measures on the basis of the so called “*Altmark*-criteria”[49]. When the four *Altmark*-criteria are met, the national measure is not considered to be a state aid:

- **First condition:** the recipient´s undertaking is actually required to discharge public service obligations and those obligations have been clearly defined.
- **Second condition**: the parameters on the basis of which the compensation is calculated have been established beforehand in an objective and transparent manner.
- **Third condition**: the compensation does not exceed what is necessary to cover all or part of the costs incurred in discharging the public service obligations, taking into account the relevant receipts and a reasonable profit for discharging those obligations.
- **Fourth condition**: where the undertaking which is to discharge public service obligations, in a specific case, is not chosen pursuant to a public procurement procedure which would allow for the selection of the tenderer capable of providing those services at the least cost to the community, the level of compensation needed must be determined on the basis of an analysis of the costs which a typical undertaking, well run and adequately provided with means of transport so as to be able to meet the necessary public service requirements, would have incurred in discharging those obligations, taking into account the relevant receipts and a reasonable profit for discharging the obligations.

5.2.2.3 Conclusions

If a Member State plans to introduce a support scheme which provides financial support for the operation of nuclear power plants, any intervention by the state has to be proven with scrutiny. Especially when direct state means are involved or state control on private means is established, the criterion of “transfer of state resources” will be met. So in a first step any national measure which has to be qualified as a state aid is prohibited.

5.2.3 General aspects of exemptions from state aid prohibition

Though, the prohibition of state aid does not apply unconditionally and without exceptions. The TFEU knows two forms of exemptions:

The first ones are the so called “legal exemptions”, regulated in Article 107 (II) TFEU. This article declares compatible with the common market certain aid granted by Member States, which is social in character, makes good certain damage, or compensates for disadvantages[50]. According to established case law, the Commission does not have any discretion in applying Article 107 (II) TFEU. If the conditions of Article 107 (II) TFEU are met, the Commission must declare such state aid compatible with the common market, unless such aid violates other provisions of the Treaty[51].

[49] ECJ (Altmark), C-280/00.

[50] *Heidenhain*, European State Aid Law, 2010, § 10, recital 1.

[51] *Heidenhain*, European State Aid Law, § 10, recital 3.

Legal exemptions pursuant to Article 107 (II) TFEU only play a minor role in the every day's application practice. Far greater importance is given to the complex criteria of so called "facultative exemptions", stated in Article 107 (III) TFEU, which will be analysed in detail in the following.

5.2.4 In detail: Article 107 (III) TFEU ("Facultative exemptions")

It can be stated that Article 107 (III) TFEU is one of the key provisions of the European competition law. If a national measure is qualified as state aid and cannot be exempted on the basis of Article 107 (III) TFEU it will be prohibited and the Member States are not allowed to put these measures into effect.

In the following it will be shown, how the Commission exercises its strong position in state aid issues and how the assessment of the compatibility of any measure with the common market is exercised. Further, it is analysed how the framework for state aid evaluation is formed, especially looking at the so called "Guidelines" and the implications the state aid modernization process had so far.

5.2.4.1 Wide discretion of the Commission

While measures, which fall into the scope of Article 107 (II) TFEU are automatically exempted, Article 107 (III) TFEU requires an in depth assessment of the compatibility with the internal market and gives the Commission a wide discretion[52]. This includes:

- The competence of the Commission to decide, whether an aid can be exempted pursuant to Article 107 (III) TFEU, is exclusive.
- The Commission enjoys a broad but not unlimited discretion in making rulings in the context of its regulation of state aid and must respect certain legal "guide rails".
- The Commission's discretion is generally exercised on the basis of economic and social assessments whereby the interests of the Community as a whole are to be taken into consideration.
- The entire primary and secondary European law is binding on the Commission and may thus stipulate limitations on its discretion in particular cases.
- The Courts recognize a broad scope of discretion in the Commission's application of the conditions for exemption. The extensive freedom enjoyed by the Commission when applying Article 107 (III) TFEU must not be undermined by the Courts, by replacing the judgments made by the Commission with their own when reviewing the legality of approval rulings.
- The Court´s review is limited to whether these judgments are clearly erroneous or involve an abuse of discretion.

5.2.4.2 The balancing test

In the case of environmental protection and incentives for the use of renewable energies especially Article 107 (III) lit. c) TFEU may be applicable. The rule states that "aid to facilitate the development of certain economic activities or of certain economic areas, where such aid does not adversely affect trading conditions to an extent contrary to the common interest" may be considered to be

[52] See for the following explanations: *Heidenhain*, European State Aid Law, 2010, § 10, recital 4.

compatible with the internal market. Thus, the European Commission can decide upon whether or not a measure of a Member State can be seen as applicable to the internal market rules or not.

Commission practice shows that measures may be declared compatible directly under Article 107(3)(c) TFEU if they are necessary and proportionate and if the positive effects for the common objective outweigh the negative effects on competition and trade[53].

In assessing whether an aid measure can be deemed compatible with the common market, the Commission balances the positive impact of the aid measure in reaching an objective of common interest against its potentially negative side effects by distortion of trade on competition. The State Aid Action Plan[54], building on existing practice, has formalized this balancing exercise in what has been termed a “balancing test”. It operates in three steps to decide upon the approval of a state aid measure; the first two steps are addressing the positive effects of the state aid and the third is addressing the negative effects and results in balancing of the positive and negative effects.

The steps are[55]:

1. Is the aid measure aimed at a well-defined objective of common interest (growth, employment, cohesion and environment)?
2. Is the aid well designed to deliver the objective of common interest; does the proposed aid address the market failure or other objective?
    a) Is State aid an appropriate policy instrument?
    b) Is there an incentive effect – does the aid change the behaviour of market players?
    c) Is the aid measure proportional – could the same change in behaviour be obtained with less aid?
3. Are the distortions of competition and effect on trade limited, so that the overall balance is positive? The balancing test is applicable to the design of state aid rules as well as for the assessment of cases.[56]

The balancing test is always to be examined when a measure shall be exempted pursuant to Article 107 (III) TFEU. It is also applicable to measures which fall into the scope of Commission Guidelines (see below).

5.2.4.3 Scope of the Commission’s discretion

The question on how to weigh the aspects that have to be considered and thus also the results of the weighing lie within the discretion of the Commission[57]. However, there are certain limits to the wide discretion of the Commission.

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[53] Compare Commission decision C(2011) 1363 final of 8 March 2011 on State aid measure No C 24/2009 (ex N 446/2008), recital 152.

[54] Commission, STATE AID ACTION PLAN, Less and better targeted state aid: a roadmap for state aid reform 2005–2009, COM(2005) 107 final.

[55] See e.g. Beschluss der Kommission in Sachen Österreich (Staatliche Beihilfe für energieintensive Unternehmen, Ökostromgesetz, Österreich), C-24/2009, KOM(2011) 1363 final, S. 35.

Firstly, the reasoning followed by the Commission "must remain consistent"[58]. When it comes to judicial review, as laid down by the ECJ, "[…] the courts cannot substitute their own evaluation of the matter for that of the competent authority but must restrict themselves to examining whether the evaluation of the competent authority contains a patent error or constitutes a misuse of power"[59]. As a consequence the ECJ restrains itself in case of complex economic situations and bestows on the Commission a wide discretion[60].

Taking this in consideration, the ECJ has confirmed the Commission's position that an exemption pursuant to Article 107 (III) TFEU for state aid to companies can only be granted, if it "[…] can establish that the aid will contribute to the attainment of one of the objectives specified in the derogations, which under normal market conditions the recipient firms would not attain by their own actions"[61]. The ECJ also confirms that "the compatibility with the treaty of the aid in question must be determined in the context of the community and not of a single member state"[62].

Examinations of the Court may only be based on the information that the Commission had at the time when taking its decision on the respective state aid. Subsequent actual changes may not be taking into consideration[63].

5.2.4.4 Provision of transparency and legal certainty: General block exemption regulation and Guidelines by the Commission

In the last years, the Commission has developed several guidelines, notices, communications etc. to provide a certain kind of transparency of its acting and to provide a certain form of legal certainty. The issued regulations specify in advance how the wide discretion of the Commission will be exercised. In the area of environment and energy state aid, the General Block Exemption Regulation and the Community Guidelines on state aid for environmental protection[64] are the most important acts to be considered, although they have totally different legal effects.

a) General block exemption regulation

First, there is the block exemption regulation (EC) No 800/2008 of 6 August 2008 declaring certain categories of aid compatible with the common market in application of Articles 107 and 108 TFEU (General block exemption regulation). The general block exemption regulation was adopted on the basis of Regulation 994/1998. Therewith, the commission made use of the authority granted by the

[56] Commission decision C(2011) 1363 final of 8 March 2011 on State aid measure No C 24/2009 (ex N 446/2008), recital 152.

[57] *Cremer* in: Calliess/Ruffert, EUV/AEUV, Kommentar, 2011, Art. 107, recital 49; *Kühling*, in: Streinz, EUV/AEUV, Kommentar, Art. 107, recital 109.

[58] ECJ joined cases C-278/92, C-279/92 and C-280/92, recital 51.

[59] ECJ case 57/72, recital 14; see also ECJ case C-456/00, recital 41; ECJ C-310/99, recital 46.

[60] Compare e.g. ECJ case 55/75, recital 8, ECJ case 29/77, recital 19/20

[61] ECJ case 730/79, recital 16; see also ECJ 296, 318/82, recital 9.

[62] ECJ case 730/79, recital 26.

[63] ECJ case C-333/07, recital 80 f.

[64] Commission, Community Guidelines on state aid for environmental protection, Official Journal C 82 of 1.4.2008.

Council to declare specific groups of horizontal aid as compatible with the common market and as exempted from the notification requirement of Article 108 (III) TFEU. In order to be exempted from the obligation to notify, the categories of aid concerned must conform to all the conditions in Chapter I of this regulation (specifically they must have an incentive effect and conform to transparency criteria) and the relevant provisions of Chapter II (intensity of the aid, eligible costs, maximum amount of aid). They must, moreover, expressly refer to the provisions of the latter.

b) Community guidelines on state aid for environmental protection

The function and impact of guidelines

The Commission applies self-inflicted guidelines on how to use its wide discretion. Guidelines may be used if they contain rules indicating the approach which the institution is going to take and if they do not depart from the rules of the Treaties[65]. The guidelines reflect the Commission's desire to publish directions on the approach it intends to follow, in the light of its individual decisions in the field concerned[66]. Those rules, setting out the approach which the Commission proposes to follow, help to ensure that it acts in a manner which is transparent, foreseeable and consistent with legal certainty. The guidelines cannot bind the Court. However, they may provide a useful point of reference[67]. As stated above, the Court can only examine whether the measure contains a patent error or constitutes a misuse of power.

The Commission has to follow the guidelines when taking an individual decision[68], since these guidelines put the Commission's discretion of Art. 107 (III) TFEU into concrete terms[69]. As stated in the case T-214/95 recital 89 "… [the Commission] can specify the criteria it intends to apply in guidelines which are consistent with the Treaty (see paragraph 79 above). The adoption of such guidelines by the Commission is an instance of the exercise of its discretion and requires only a self-imposed limitation of that power when considering the aids to which the guidelines apply, in accordance with the principle of equal treatment. By assessing specific aid in the light of such guidelines, previously adopted by it, the Commission cannot be considered to exceed the limits of its discretion or to waive that discretion."

Community Guidelines on state aid for environmental protection

In the case of environmental protection, the Community guidelines of 1 April 2008 on State aid for environmental protection[70] regulate whether financial aid can be used by Member States as an incentive for companies to reach a level of environmental protection that is higher than the one they

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[65] ECJ case C-278/00, recital 98; ECJ case C-310/99, recital 52; CFI case T-17/03 recital 42; CFI case T-214/95 recital 79.

[66] CFI case T-187/99, recital 56, CFI case T-17/03, recital 42.

[67] ECJ case C-310/99, recital 52; ECJ case C-387/97 recital 87,89.

[68] *Jestaedt/Häsemeyer*, Die Bindungswirkung von Gemeinschaftsrahmen und Leitlinien, EuZW 1995, S. 787 ff (790); Heidenhain, Handbuch des Europäischen Beihilfenrechts, § 14, Rn. 26

[69] *Birnstiel* in: Birnstiel/Bungenberg/Heinrich, Europäisches Beihilfenrecht, 2013, Kap. 1, Rn. 1061; Heidenhain, Handbuch des Europäischen Beihilfenrechts, § 14, Rn. 18.

[70] Official Journal C 82 of 1.4.2008.

would aim for in the absence of binding standards. The Commission determines the conditions under which this aid can be allocated to undertakings without this aid interfering in the proper functioning of the common market.

The Community guidelines apply to all environmental protection aid measures notified to the Commission (including those notified before the guidelines were published) as well as measures which have not been notified. The Guidelines have no direct external legal effect, but they are binding for the Commission as the provision has been laid down by itself.

Every year, Member States must submit a report to the Commission on environmental aid measures. For each authorised scheme, the report must list information about large undertakings and particularly the amount of aid per beneficiary, aid intensity, a description of the measure and the type of environmental protection being promoted. State Members must also maintain a detailed register of all aid which is granted.

The balancing test and its application to aid for environmental protection

As shown above, measures may be declared compatible with the common market if they are necessary and proportionate and if the positive effects for the common objective outweigh the negative effects on competition and trade. This so called balancing test is addressed by the Commission in its Guidelines and further explained in detail. In a schematic way, the criteria of the balancing test can be named as follows:

- Objective of common interest
- Appropriate instrument
- Incentive effect and necessity of aid
- Proportionality of the aid
- Negative effects of environmental aid must be limited so that the overall balance is positive

5.2.4.5 The actual process of state aid modernisation and its implications on the promotion of nuclear energy

The framework for state aids for environmental protection and energy shall be modernised[71]. The Commission has named three main, closely linked objectives for modernisation:

- Foster growth in a strengthened, dynamic and competitive internal market,
- Focus enforcement on cases with the biggest impact on the internal market,
- Streamlined rules and faster decisions.

Meanwhile, the Commission has published a draft for a new Regulation of the Commission declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty[72]. This draft does not contain any explicit regulation on nuclear energy. In case of

[71] COM(2012) 209 final.

[72] Draft: COMMISSION REGULATION (EU) N° …/… of 18.12.2013 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, C(2013) 9256, available at: http://ec.europa.eu/competition/consultations/2013_consolidated_gber/gber_regulation_en.pdf.

electricity generation, it addresses investment aid for the promotion of energy from renewable sources or high-efficiency cogeneration.

In its consultation paper of March 2013 the Commission recognizes that "[t]he wish of some Member States to widen support also to other low-carbon energy sources including nuclear merits an in-depth discussion in order to analyse whether market failures justify intervention and whether it is possible to establish ex-ante rules in the framework of Guidelines while ensuring cost transparency and the internalisation of external costs."[73] Although not published officially, another document of the Commission became public in summer 2013, which contained draft Guidelines on environmental and energy aid for 2014-2020[74]. After becoming public, the Commission was confronted with a noticeable headwind to its plans to integrate state aid for nuclear energy into the Guidelines. The Commission finally gave up the plans to address nuclear energy in the ongoing drafting of new Guidelines.

The first Draft Guidelines on environmental and energy aid will be analysed subsequently. Although not an official document, the guidelines may indicate the Commission's general views on state aid for nuclear energy and thus can also be of importance for individual decisions in case the guidelines will not be applied in the future.

a) General structure of the Draft Guidelines on environmental and energy aid for 2014-2020

The draft Guidelines are divided into an introduction and eleven chapters. The introduction of the draft Guidelines sets out the background of state aid law and addresses general considerations. As to the justification of aid for energy and environment it is set out (rec. 5), that

> [it] will primarily be justified on the basis of Article 107(3)(c) of the TFEU or Article 107(3)b of the TFEU, according to which the Commission may consider compatible with the internal market State aid to facilitate the development of certain economic activities within the European Union, where such aid does not adversely affect trading conditions to an extent contrary to the common interest.

Related to nuclear energy it is stated, that (rec. 6)

> [insofar] as these Guidelines set out rules on state aid for nuclear, the assessment under the TFEU will take due account the objectives of the Euratom Treaty.

Chapter 1 contains the "Scope and definitions". The scope of the Guidelines is determined as follows (rec. 13):

> These Guidelines apply to State aid for environmental protection, including CO2 capture, transport and storage (CCS)6, energy infrastructure, capacity mechanisms and nuclear energy.[…]

Chapter 2 is titled "Notifiable environmental and energy aid" and defines for which kind of state aid the Guidelines apply for.

[73] COM, Environmental and Energy Aid Guidelines 2014 – 2020, Consultation paper, 11 March 2013, http://ec.europa.eu/competition/state_aid/legislation/environmental_aid_issues_paper_en.pdf, recital 51.

[74] Paper of the Commission Services containing draft Guidelines on environmental and energy aid for 2014-2020.

> These Guidelines provide the compatibility criteria for the following categories of aid which are subject to the notification obligation pursuant to Article 108(3) of the TFEU: (1) aid schemes involving large total amounts of public spending and aid schemes not covered by General Block Exemption Regulation (GBER); (2) ad hoc aid granted to large undertakings and ad hoc aid not covered by GBER and (3) individual aid granted on the basis of an existing aid scheme but exceeding the notification thresholds laid down in in the GBER.

Chapters 3 to 6 of the Guidelines contain all the provisions which have to be considered when examining a prohibited state aid and when balancing whether it can be declared compatible with the internal market by the Commission. Contrary to its known practice and known balancing test (see above), the Commission presents a "new" approach. When setting out its "Common Assessment Principles" in Chapter 3, the Commission describes first its normal assessment procedure (rec. 33):

> To assess whether a notified aid measure can be considered compatible with the internal market, the Commission generally analyses whether the design of the aid measure ensures that the positive impact of the aid towards an objective of common interest exceeds its potential negative effects on trade and competition.

Then, the Commission refers to its Communication on state aid modernisation and states that it

> (…) will consider an aid measure compatible with the Treaty only if it satisfies each of the following criteria.
>
> **(a) Contribution to a well-defined objective of common interest**: a State aid measure must aim at an objective of common interest in accordance with Article 107(3) TFEU;
>
> **(b) Need for state intervention:** a State aid measure must be targeted towards a situation where aid can bring about a material improvement that the market cannot deliver itself, by remedying a well-defined market failure;
>
> **(c) Appropriateness of the aid measure:** the proposed aid measure must be an appropriate policy instrument to address the objective of common interest;
>
> **(d) Incentive effect:** the aid must change the behaviour of the undertaking(s) concerned in such a way that it engages in additional activity which it would not carry out without the aid or it would carry out in a restricted or different manner;
>
> **(e) Proportionality of the aid (aid to the minimum):** the aid amount must be limited to the minimum needed to incentivise the environmental behaviour or strengthen the development of the internal energy market:
>
> **(f) Avoidance of major undue negative effects on competition and trade between Member States:** the negative effects of aid must be sufficiently limited, so that the overall balance of the measure is positive;
>
> **(g) Transparency of aid:** Member States, the Commission, economic operators, and the public, must have easy access to all relevant acts and to pertinent information about the aid awarded thereunder. [75]

[75] COM, Environmental and Energy Aid Guidelines 2014 – 2020, Consultation paper, 11 March 2013, http://ec.europa.eu/competition/state_aid/legislation/environmental_aid_issues_paper_en.pdf, recital 51.

b) Overview on compatibility principles related to the promotion of nuclear energy

In Chapter 6, where the aid for nuclear energy is addressed, the Commission determines (rec. 164):

> In assessing state aid measures in support of nuclear energy the Commission will apply the compatibility principles set out below on the basis of common compatibility principles set out in section 3.

But the Commission reserves to itself to take into account other elements which are deemed necessary for the assessment of the specific support measure for nuclear energy (rec. 165).

Thus, the situation for assessing whether an aid for nuclear energy can be exempted from state aid prohibition remains rather unclear: the general principles are set out in Chapter 3, the explanation and characterization of these principles follow in Chapter 5 and nuclear energy specific elements are named in Chapter 6.

A clarification of these provisions will be made below, where the plan of the UK for a future promotion of nuclear energy strategies are analysed.

c) Limitation of Commission`s acting on state aid law

As it seems until this very moment, the Commission did not realise its plans to integrate nuclear energy in the scope of the Guidelines on environmental and energy state aid. The Commission did not comment on the reasons as no official Draft was ever presented. But it was obvious that the Commission´s discretion in state aid matters (see also above) would have been misused in the case of addressing nuclear energy in state aid Guidelines which are meant to reflect the Commission´s continuous practice on certain issues.

5.2.5 Conclusions

The financial promotion of nuclear energy plants by the Member States, e.g. through operating aid, is not solely subject to the provisions of the Euratom-Treaty. It falls also under the scope of the TFEU, especially under the provisions of state aid which aims to defend a fair competition between all market participants without non-justified state interventions.

In a first step, it has to be analysed if the national measure constitutes state aid. This is the case, when direct state means are involved or state control on private means is established. When besides the criterion of “transfer of state resources” all other criteria of Article 107 (III) TFEU are met, the national measure which aims to promote the operation of nuclear power plants have to be qualified as a state aid, which is prohibited.

In a second step, the general framework on the exemptions from the prohibition of state aid comes into the focus. Based on Article 107 (III) TFEU, the Commission has developed several provisions and criteria in the past, set out in Regulations and Guidelines, which help to identify the possible compatibility of national measures, qualified as state aid. In the first draft of the Guidelines, which was not published, but became public, it was foreseen to integrate nuclear energy into the new Guidelines on environmental and energy state aid. As it it is clear now, the Commission will no longer pursue these plans, so that any compatibility assessment of state aids regarding the promotion of nuclear energy has to be carried on the basis of Article 107 (III) TFEU directly.

5.3 The plans for a future promotion of nuclear energy in the UK: a possible master plan for other Member States?

At the moment, the UK Government is planning the so called Electricity Market Reform laid down by the Energy Bill. Part of this reform shall be the mechanism of Feed-in Tariffs with Contracts for Difference (CfD), serving to promote "low carbon technologies". Before it can be assessed if the CfD mechanism constitutes state aid and may fall or not under the aforementioned derogations of the general state aid prohibition, the general structure of the CfD scheme, as far as it is known at the moment, shall be considered.

5.3.1 Structure of the CfD mechanism

The UK mechanism of Contracts for Difference is part of the planned Electricity Market Reform[76] laid down by the Energy Bill. The Energy Bill is still in the legislation process[77]. The Energy Bill follows the purposes of decarbonisation and of encouraging low carbon electricity generation or ensuring security of supply[78]. As a key element Feed-in Tariffs with Contracts for Difference (CfD) will be introduced. CfDs are contracts which shall provide long term electricity price stability to developers and investors in low carbon generation (e.g. carbon capture & storage, renewable and nuclear energy). Generators will receive the price they achieve in the electricity market plus a 'top up' from the market price to an agreed level (the "*strike price*"). Where the market price is above the agreed level, the generator would be required to pay back and thus ensure value for money and greater price stability for consumers[79].

In the case of renewables, the CfD mechanism will replace the so called Renewables Obligation[80]. But the low carbon approach means as well that CfD will be a measure to support new nuclear power generation.

5.3.1.1 General provisions of the proposed Energy Bill

In Chapter 2 of the proposed Energy Bill high level details about the mechanism are set out. This includes:

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[76] Compare the White Paper for secure, affordable and low carbon electricity, July 2011: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48129/2176-emr-white-paper.pdf.

[77] Final amendments were made to the Bill during the third reading of the House of Lords on 19 November 2013. The Bill will now go to the Commons on 4 December 2013 for consideration of Lords amendments. The process can be followed here: http://services.parliament.uk/bills/2013-14/energy.html.

[78] http://www.publications.parliament.uk/pa/bills/lbill/2013-2014/0030/20140030.pdf.

[79] Compare for a brief overview over CdF: https://www.gov.uk/government/uploads/mechanism/uploads/attachment_data/file/204813/contracts_for_difference_policy_brief.pdf.

[80] See Chapter 7 of the Energy Bill Draft: http://services.parliament.uk/bills/2013-14/energy.html. For a look at the draft strike prices for renewables see: https://www.gov.uk/government/uploads/mechanism/uploads/attachment_data/file/209276/EMR_Spending_Review_Announcement_-_FINAL_PDF.pdf, Appendix A.

- Provision to enable the Secretary of State to designate a body to act as counterparty to CfDs (known as the CfD counterparty). That body will have powers to collect money from suppliers to meet its obligations to generators under the CfD;
- Identifying the national Mechanism Operator and the Secretary of State as responsible for determining eligibility and allocating contracts. The CfD counterparty will be under a duty to offer (and therefore enter into) those contracts;
- Setting out a duty to make regulations obliging electricity suppliers to make payments to the counterparty body, to enable it to make payments under CfDs;
- Providing for changes to transmission licenses to enable the national Mechanism Operator to carry out its functions in relation to CFDs; and
- Powers to set maximum costs and targets that have to be adhered to in delivering the mechanism.

In conclusion, one key element of the CfD mechanism is, that the power generators will receive long term guaranteed payments by the CfD-counterparty[81]. A stable revenue level should in turn reduce investment risk and financing costs, and therefore drive innovation and development of low-carbon technologies[82].

5.3.1.2 Details on the CfD-counterparty and funding

According to a government document from November 2012[83] the CfD counterparty will be a limited liability company owned by the Government. It will be considered a public sector body as it will be set up and owned by the Government, delivering a Government policy through the signing and management of CfD contracts. Additionally, it will have an ongoing relationship with the Government[84]. As the signatory to these contracts, the CfD counterparty is bound by the terms of the CfD[85].

To fund the payments that are due under the CfD to generators the Government intends to introduce a statutory obligation on suppliers to make payments to the CfD counterparty[86]. The suppliers´ obligation is a compulsory levy and is likely to be classified as a direct tax[87].

5.3.1.3 Process for determining CfD strike prices

While moving towards a decarbonised electricity market, the two core objectives of minimising costs to consumers and reducing uncertainty for investors have to be taken into consideration when

81 This can be a private company or a public authority designated by the Secretary of State, see Chapter 2.7. Energy Bill Draft.

82 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/204813/contracts_for_difference_policy_brief.pdf.

83 This information is seen as still valuable as no other document was released on this issue since.

84 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 252.

85 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 254.

86 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 269.

87 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 273.

determining the level of support. The UK Government holds the view that the best way to do this in the long term is through competitive price setting. However, in Stage 1 (to 2017) the initial process for renewable technologies will be similar to that used for the most recent Renewables Obligation banding review, giving visibility of prices for a five-year period to enable planning, i.e. will be set administratively. For early stage CCS projects (including those supported under the UK CCS Commercialisation Programme) and nuclear projects the strike price will be determined through cost, risk and price discovery processes and negotiation. In Stage 2 (2017 – 2020s) it is planned to move to a competitive price discovery for specific technologies.

In Stage 3 (2020s) when technologies and the market have matured sufficiently, the Government intends to move to technology-neutral competitive price setting.

Stage 4 (late 2020s and beyond) will be reached when CfDs are no longer needed as the market will be sufficient to drive competition[88].

5.3.1.4 Details of initial agreement on new nuclear power station at Hinkley C

On 21st of October 2013 the UK Government and EDF group published details on their commercial agreement on the key terms of a proposed investment contract for the Hinkley Point C nuclear power station in Somerset, which would be the first nuclear power station to be built under the new system of 'Contracts for Difference' (CfD) being put in place by the Energy Bill[89]. The Strike Price of £89,50/MWh is fully indexed into the Consumer Price Index. This Strike Price benefits from an up-front reduction of £3 per MWh on the basis that EDF's subsidiary NNB Generation Company Limited would share "first of kind" costs of the EPR reactors across Hinkley Point C and Sizewell C sites. If there is no final investment decision on Sizewell C, the Strike Prize for Hinkley would be £ 92,50 (around € 109)[90]. The duration of the Contract for difference payment will be 35 years[91]. The plant is expected to have a life-span of 60 years and to create 25.000 jobs in the course of construction as well as 900 long-term jobs[92]. Next to EDF Group, AREVA and two Chinese companies (CGN and CNNC) will be partners in the project[93]. As mentioned in the respective documents one further requirement for a final investment decision is the decision from the European Commisison on state aid[94] and the Royal Assent of the Energy Bill[95].

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88 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48373/5358-annex-b-feedin-tariff-with-contracts-for-differe.pdf, p. 8;
see also https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 104.

89 https://www.gov.uk/government/speeches/agreement-reached-on-new-nuclear-power-station-at-hinkley.

90 https://www.gov.uk/government/speeches/agreement-reached-on-new-nuclear-power-station-at-hinkley.

91 https://www.gov.uk/government/news/initial-agreement-reached-on-new-nuclear-power-station-at-hinkley.

92 https://www.gov.uk/government/speeches/agreement-reached-on-new-nuclear-power-station-at-hinkley.

93 http://edfenergy.presscentre.com/News-Releases/Agreement-reached-on-commercial-terms-for-the-planned-Hinkley-Point-C-nuclear-power-station-82.aspx.

94 http://edfenergy.presscentre.com/News-Releases/Agreement-reached-on-commercial-terms-for-the-planned-Hinkley-Point-C-nuclear-power-station-82.aspx.

95 https://www.gov.uk/government/speeches/agreement-reached-on-new-nuclear-power-station-at-hinkley.

5.3.2 State aid assessment

As shown above, the assessment of a national measure by a Member State before the background of state aid law includes two questions which have to be answered: (1) Is there a state aid? (2) If yes, is there an exemption from the general incompatibility of state aids with the common market?

5.3.2.1 The assessment of the CfD scheme as a state aid

Article 107 (I) TFEU contains the conditions which have to be fulfilled by a measure cumulatively: Transfer of state resources, granting of an economic advantage, Favouring of certain undertakings or the production of certain goods (Selectivity) and distortion of competition with adverse effects on trade between Member States. The approach of state aid is limited in a certain way in case of the existence of so called services of general economic interest (SGEI) pursuant to Article 106 (II) TFEU and the cases which meet the Altmark-criteria (see above).

a) Article 107 (I) TFEU

The payments by the suppliers to the low carbon generators are administered by the “CfD counterparty”. According to Chapter 2.7 Energy Bill Draft, this can be a private company or a public authority, designated by the Secretary of State.

- If the CfD counterparty will be a public authority:

In the case, that the counterbody is a public authority, the aid is granted directly by the state, because the money flow has a direct impact on the state budget.

If the CfD-counterparty will be a private company, it has to be differentiated: the state is not directly involved in the money transfer, but decisions by the COM[96] and the ECJ[97] state strongly suggest, that the payments made by the CfD-counterparty would nonetheless be attributable to the Member State. The main criteria in this case is the level of control exercised by the Member State over the CfD-counterparty. In case of the CfD mechanism the level of control is very strong, as can be shown by the following examples:

- The Energy Bill enables the Secretary of State to designate the CfD counterparty. This body will have powers to collect money from suppliers to meet its obligations to generators under the CfD, which means that the money cannot be used for other purposes;
- A duty will be set out to make regulations obliging electricity suppliers to make payments to the counterparty body, in order to enable it to make payments under CfDs;
- The CfD counterparty will be under a duty to offer (and therefore enter into) the CfD.

According to the above cited Government plans, the CfD counterparty will be a limited liability company owned by the Government and it will be considered a public sector body, set up and owned by the Government, delivering a Government policy through the signing and management of CfD contracts, with an ongoing relationship with the Government[98]. If these plans become reality,

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[96] Compare for the Austrian *Ökostromgesetz*: COM NN 162/A/2003 und N 317/A/2006.

[97] See for example: ECJ C-206/06 – *Essent Netwerk Noord*, para. 66.

[98] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 252.

the CfD counterparty would be a public sector body. Thus, the aid would be granted directly by the state, because the money flow has a direct impact on the state budget. The supplier obligation, which is supposed to finance the payments to generators due under the CfD[99], is intended to be a compulsory levy and therefore is likely to be classified as a direct tax[100].

Likewise, the CfD differs from the measure referred to in Case C-379/98 (Preussen Elektra)[101], in which the Court held, at paragraph 59, that the obligation imposed on private electricity supply undertakings to purchase electricity produced from renewable energy sources at fixed minimum prices did not involve any direct or indirect transfer of State resources to undertakings which produced that type of electricity. In the latter case, the undertakings had not been appointed by the State to manage a State resource, but were bound by an obligation to purchase by means of their own financial resources.

The CfD mechanism aims at reducing investment costs and financing risks for low-carbon technologies. The fact that, in case of the market price being below the strike price, the difference between the strike price and the market price is paid to the low-carbon electricity generators constitutes an advantage according to Article 107 TFEU. Furthermore it is quite clear that the CfD mechanism favours certain undertakings in the sense of Article 107 (I) TFEU. This support will finally lead to a market distortion because the position of the low carbon generators is strengthened in relation to its competitors.

b) Limitation of state aid approach by Article 106 (II) TFEU or Altmark-criteria?

As set out in the first part of this report, the effect of prohibition of state aid can be limited in the cases of so called "services of general economic interest" or where the Altmark-criteria are met, respectively. As far as the UK Government has presented its plans, there is no indication why the comprehensive state aid approach pursuant to Article 107 (II) TFEU could be limited for reasons related to "public interest". Especially when analysing the Altmark-criteria it becomes obvious that the support of nuclear power generation under the CfD scheme cannot be subsumed as being in or treated as a public interest. In its justification for the proposed implementation of the CfD scheme for nuclear energy, the UK Government fails to point out why the generation of electricity should be of "public interest" and should be delivered by nuclear energy. As the Commission has stated out before, it would not be appropriate to attach specific public service obligations to an activity which is already provided or can be provided satisfactorily and under conditions, such as price, objective quality characteristics, continuity and access to the service, consistent with the public interest, as defined by the State, by undertakings operating under normal market conditions[102].

[99] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 269.

[100] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65635/7077-electricity-market-reform-annex-a.pdf, recital 273.

[101] ECR I-2099/01The German feed-in tariff according to the former Stromeinspeisungsgesetz (StrEG), predecessor to the Renewable Energies Act (Erneuerbare Energien Gesetz – EEG).

[102] Commission, Communication from the Commission on the application of the European Union State aid rules to compensation granted for the provision of services of general economic interest, OCJ C 8/4, Nr. 48.

Further, the compensation for EDF as sole competitor at the moment is not calculated beforehand in an objective and transparent manner. In contrast to the decided cases by the ECJ, the compensation is not determined by a tender procedure, but by non-public negotiations between the UK government and EDF. This assessment is confirmed by the current events regarding the commercial agreement for the new nuclear power station Hinkley Point C. So far, only the decisions but not the underlying negotiating process details have been made public.

Due to this non transparent negotiation process it is insofar not yet possible to assess whether or not the compensation does or does not exceed what is necessary to cover all or part of the costs incurred in discharging a presumed public service obligations.

The negotiations lack of an objective and transparent tendering procedure. In so far it would have been necessary that the level of compensation granted to EDF was determined on the basis of an analysis of the costs which a typical undertaking, well run and adequately provided, would have incurred in discharging those obligations, taking into account the relevant receipts and a reasonable profit for discharging the obligations.

c) Conclusions

It appears that the CfD scheme constitutes a state aid according to Article 107 (I) TFEU. It cannot be concluded that the CfD scheme fulfils the requisites of a service of general economic interest or the Altmark-criteria.

5.3.2.2 CfD scheme compatible with internal market?

Article 107 TFEU contains in its paragraphs 2 and 3 exemptions from the prohibition of state aid. Article 107 (II) TFEU contains mandatory legal exemptions, which are not applicable in the case of the CfD scheme, whereas Article 107 (III) TFEU contains optional or “facultative” exemptions (see above).

As already explained above, the Commission has developed several guidelines, notices, communications etc. on state aid issues. The aim was and is to provide a certain kind of transparency of its acting and to a certain form of legal certainty. When assessing the compatibility of the CfD scheme with the common market, it has first to be analysed if the mechanism falls under the scope of the General Block Exemption Regulation or the Community Guidelines on state aid for environmental protection. If this is not the case, the CfD scheme has to be evaluated on the general provisions in Article 107 (III) TFEU.

a) Does the CfD scheme fall into the scope of the General Block Exemption Regulation

The existing General Block Exemption Regulation (GBER)[103] defines state aid measures which do not have to be notified and therefore are considered in advance to be compatible with the internal market. Articles 17 to 25 GBER are dealing with state aid for environmental protection. As it is stated in the block exemption, it is applicable on energy from high-efficiency cogeneration (Art. 22 GBER) and from renewable sources (Art. 23 GBER) if certain conditions are fulfilled. The GBER only

[103] Regulation 800/2008/EC, OJ L 214/3.

applies to aid under certain thresholds (7.5 Mio € per undertaking per investment project). Furthermore the aid must not exceed 45% of the eligible costs. But the eligible costs may be raised by 10-20 % in the case of SME. Nuclear energy and its support is not addressed. Furthermore, the threshold would be reached in any case as the operation of nuclear power plants is far more expensive than 7.5 Mio € a year.

The Commission launched a draft proposal for the new GBER on May 8th 2013[104]. On October 11th 2013 the consultation on the prolongation of the period of application of the General block exemption Regulation ('GBER prolongation') was opened in order to ensure a consistent approach across all State aid instruments. The parallel revision of interdependent State aid instruments in the context of EU State Aid Modernisation cannot be finalised before the GBER expires[105].

In case of CfD for nuclear power generation there will be no changes to the assessment made under the scope of the current GBER. The GBER will still not be applicable to nuclear power generation. This states recital 34 Draft-GBER:

> Investments in assisted regions in favour of energy from renewable sources, co-generation and efficient district heating and cooling shall be allowed under the conditions laid down in the environmental section of this Regulation; this shall minimise their high distortive impact on the internal energy market and shall ensure an increased focus on cost efficiency. In view of their high distortive potential impact on the internal energy market, *state aid to electricity generation from non-renewable sources and energy infrastructures shall not be exempt from the notification requirement of Article 108(3) of the Treaty.*

b) Is the measure subject of Guidelines on environmental protection (and energy) set out by the Commission?

The facultative exemptions according to Article 107 (III) TFEU are partly specified by Commission Guidelines (Community Guidelines on environmental protection[106]). Contrary to energy produced from renewable energies, nuclear energy does not fall under the scope of the existing Community Guidelines on environmental protection. Although the CfD mechanism per se aims at the promotion of low-carbon technologies and therefore includes nuclear energy, nuclear power generation has different negative effects on the environment, such as nuclear waste problems or the danger for the environment in case of a nuclear accident. This cannot be seen as an environmental friendly technology.

As seen above, the first Draft Guidelines set out a complex system for the examination of the compatibility of nuclear state aids with the internal market (“Compatibility assessment principles”). But the Commission has stated in the meantime, that nuclear energy will not be considered in the ongoing process anymore.

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[104] http://ec.europa.eu/competition/consultations/2013_gber/index_en.html.
[105] http://ec.europa.eu/competition/consultations/2013_gber_prolongation/index_en.html.
[106] Community guidelines on State aid for environmental protection, OJ C 82/1, 1.4.2008.

c) Facultative exemption pursuant to Article 107 (III) TFEU

General structure

If neither the Block Exemption Regulation nor the specific Guidelines apply, the possible compatibility of the state aid for nuclear power generation with the internal market has to be assessed due to a direct application of one of the criteria of Article 107 III a)-e) TFEU. Thus, Article 107 III c) TFEU reads as follows:

> The following may be considered to be compatible with the internal market:
>
> (…) c) aid to facilitate the development of certain economic activities or of certain economic areas, where such aid does not adversely affect trading conditions to an extent contrary to the common interest.

As shown above, the Commission and the ECJ check regularly in its decisions several points according to Article 107 III TFEU:

1. Does the state aid measure contribute to one of the aims mentioned in Article 107 III TFEU?
2. Is the state aid measure necessary in order to reach the aim? In this case, it has to be clear that without the aid the supported measure would not have been conducted.
3. Is the state aid proportionate and does not exceed what is absolutely necessary?

In its Draft Guidelines, the Commission structured these aspects under the headline "Compatibility assessment under Article 107(3)c of the Treaty of environmental and energy aid" and named the following general compatibility principles:

- Contribution to a well-defined objective of common interest
- Need for state intervention
- Appropriateness of the aid measure
- Incentive effect
- Proportionality of the aid (aid to the minimum)
- Avoidance of major undue negative effects on competition and trade between Member States
- Transparency of aid

The compatibility of the CfD scheme with the internal market

According to these rules, the CfD scheme as a state aid for nuclear energy would have to consider all the principles mentioned above to be exempted from the general prohibition of state aid. Still, not all the aspects of the CfD scheme for nuclear energy in the UK are known so the assessment can only be based on today´s knowledge.

- **The "common interest"**

First, the state aid would have to contribute to a well-defined objective of common interest.

The general principles request for the existence of a common interest that the "primary objective of environmental aid is to increase the level of environmental protection compared to the level that would be achieved absent the aid. These measures in particular contribute to the Europe 2020 targets for sustainable growth to support climate change and energy sustainability." A global reference to the Euratom Treaty and its Article 2 c) of the Euratom Treaty cannot be made without bearing in mind other objectives which are part of the overall European treaty architecture. Although it is stated in Article 2 c) of the Euratom Treaty that its objective is to "facilitate investment and ensure, particularly by encouraging ventures on the part of undertakings, the establishment of the basic installations necessary for the development of nuclear energy in the Community", this objective has to be balanced with other objectives. It would have been a wrong understanding of the relation between the European Treaties if Member States had not to show that their national measure, which is supposed to serve for the promotion of nuclear energy, can be considered automatically as an objective of common interest in accordance with Article 107 (III) TFEU. Correctly, the criterion of a "common interest" has to be seen in the context of Euratom Treaty and the European Treaties (TEU and TFEU): the "spirit" of the Euratom Treaty should still be recognized, but other aspects as the European Union's objectives set in Articles 3 – 6 TFEU (environment and improvement of human health) and the protection of the competition and the internal market and cannot be neglected in an absolute way.

- **Need for state aid (market failure)**

Another key issue of the assessment of the compatibility principles for nuclear energy is the need for state aid, or, in different words: "a State aid measure must be targeted towards a situation where aid can bring about a material improvement that the market cannot deliver itself, by remedying a well-defined market failure". But a state intervention cannot be justified alone on the mere existence of market failures in a certain context. As the Commission has stated before, other policies and measures may already be in place precisely to address some of the market failures addressed. So in case of the CfD scheme, it cannot be seen isolated but in the context of all advantages and benefits granted to the nuclear as a whole in the UK.

- **Appropriateness of the aid measure and proportionality of the aid**

Neither the appropriateness nor the proportionality of the aid can be finally assessed as long as the details of the compensation scheme are not known. But bearing in mind that it has to be demonstrated by the Member State that the instrument chosen is the least distortive way of granting the aid and that generally the aid amount must be limited and cannot compensate more than a reasonable rate of return, it has to be stated: Already the long period of support of 35 years and the total lack of a process of determining the remuneration in a clear and transparent way, raise serious doubts on the appropriateness and proportionality of the aid.

d) In-depth investigation into UK measures supporting nuclear energy

After the notification of the CfD scheme for nuclear energy by the UK Government in autumn 2013, the European Commission opened an in-depth investigation on 18Th of December 2013 to examine whether the UK plans are in line with EU state aid rules. As it was announced by the Commission, there are in particular doubts that the project suffers from a genuine market failure[107].

[107] See Press release by the Commission: http://europa.eu/rapid/press-release_IP-13-1277_en.htm.

5.3.2.3 Conclusions

The CfD scheme constitutes a state aid measure. Whereas the CfD mechanism for renewables is likely to be compatible with the internal market if the payment conditions meet the criteria according to the Community guidelines on environmental protection, the assessment of the CfD mechanism for nuclear power comes to a different result: it can be stated that the CfD scheme can hardly be seen as compatible with the internal market. Beside the fact that a common interest cannot be identified and the fact of a total lack of a need of state aid, another problem in this respect is the non-transparent determination of the payments. As said before, the objective and transparent determination of state aid payments is a very important criterion for the Commission in order to consider a state aid measure as appropriate and proportionate.

6 Summary and conclusions

The aim of this meta-study is to analyse the possibilities and impacts of a gradual exit from nuclear power up to 2030 within the European Union, assuming that long-term climate targets shall be met, as well as to identify the related energy-political requirements. This meta-study builds on related existing modelling work, i.e. the study “energy [r]evolution, a sustainable EU 27 energy outlook” (Teske et al., 2012a), complemented by brief own quantitative assessments to contrast the derived outcomes and to fill identified knowledge gaps. The central part of this analysis is an extensive literature-review in which prestigious European studies on meeting long-term climate, RES, or energy efficiency targets and related aspects (RES, energy efficiency, infrastructural prerequisites) focusing on the electricity sector, are examined for derivable implications at European level. Furthermore legal aspects of a nuclear power phase-out until 2030 in the EU are analysed.

This report concludes with a summary of key findings, conclusions and recommendations, discussed in topical order.

6.1 Scenario Assessment

A comprehensive literature review and scenario analysis sets the scene and discloses first peculiarities of the analyzed studies

The literature review on energy scenarios[108] for the EU in Chapter 2 reveals a broad spectrum of possible future developments for the European energy supply infrastructure. All non-policy assumptions compared in Section 2.1.5 appear comprehensible and within “commonly acknowledged boundaries”. An exception to this general match is the SEI study “Europe’s Share of the Climate Challenge” where the projected population development seems to underestimate population growth within the EU, in particular in comparison to other studies. Additionally the lower economic growth assumptions do not fit within the picture drawn by the other studies assessed. The SEI study clearly states these differences which in the end widen the focus for possible developments for the EU.

The scenario results, compared in Section 2.2, disclose the energy [r]evolution Advanced and SEI mitigation scenario as two ambitions developments with regard to their GHG reduction pathways. The opposite is true for the European Commission’s “Energy Roadmap 2050” (EC, 2011b) and the climate mitigation scenarios published therein, which fulfil the long-term GHG reduction targets (proposed by the European Commission itself) precisely on the lower-end. Section 2.3 focuses on the European electricity sector and the high level of ambition of the energy [r]evolution Advanced scenario with respect to the role of renewables in electricity supply. Particular attention is drawn to the short- to mid-term where a, compared to other studies, massive uptake of RES-E is assumed to take shape. This appears unrealistic compared to current trends and recent market assessments for the near future. Peculiarities of other studies also become apparent. For example, within the EU High Renewables scenario – i.e. one of the climate mitigation scenarios included in the Energy Roadmap 2050 – the long-term needs for storage and generation capacities appear to be overestimated. This, in turn, makes this scenario comparatively costly as shown in the cost evaluation undertaken within Section 2.4. The projected specific costs for generated electricity rise in all scenarios by 20 to 40% until 2030. The energy [r]evolution Advanced scenario and the EU High Energy Efficiency scenario project falling total costs for generation and supply in the long-term. The energy [r]evolution trajectory for electricity prices actually foresees lower prices after 2040 than today. This assumed positive trend from a consumer / societal perspective may however get compensated by higher costs for energy efficiency measures that are needed to realize the lower demand for energy.

6.2 The role of energy efficiency and RES

Energy saving / efficiency potentials are sufficient to meet anticipated savings. Whether or not the comprehensive policy package as of today is sufficient to trigger the required developments remains to be seen.

Estimating the energy saving potentials by sector and the corresponding energy use areas are essential to identify where policy priorities can be set and which results can be expected. This is subject of Section 3.1 of this report, offering a comparison between the mid- and long-term savings anticipated by the energy [r]evolution study and the potentials identified for Europe by other key studies. Thus, it can be concluded that the technical saving potentials are sufficient to meet the envisaged demand trajectory. To realise these potentials, barriers in the energy market have to be removed, and market failures in regards to the use of energy have to be overcome or compensated by corrective energy policy measures. As discussed in Section 3.1 in a detailed manner, a comprehensive package of energy efficiency policy measures has been implemented at the EU level in recent years that directly address these deficits and failures. One of the key pillars in this respect is the EU's Energy Efficiency Directive (2012/27/EU) containing legally binding measures to step up Member States' efforts to use energy more efficiently at all stages of the energy chain. It also provides for the establishment of national energy efficiency targets until 2020. Meeting the enacted energy efficiency target by the European Commission of a 20% reduction of primary energy consumption compared to a reference development by 2020 seems still out of reach from today's perspective. Yet it might be too early to evaluate whether or not the new legislation is sufficient to speed up the process in this respect.

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108 Aside from the study "energy [r]evolution – A sustainable EU 27 energy outlook" (Teske et al., 2012a) as conducted by (and on behalf of) Greenpeace and EREC, the European Commission's "Energy Roadmap 2050" and the related "Impact assessment and scenario analysis" (EC, 2011b), "Europe's Share of the Climate Challenge" published by the Stockholm Environmental Institute (SEI) (Heaps et al., 2009), and the International Energy Agency (IEA)'s "World Energy Outlook 2012" (IEA, 2012) form the central scenario literature for this comparative assessment.

Realisable potentials for renewable electricity stay in general higher than the anticipated deployment, and cost assumptions taken, appear reasonable.

Complementary to energy efficiency a strong uptake of RES in the electricity sector is required to pave the way to a nuclear power-free Europe while maintaining the transition to a sustainable energy system in the mid- to long-term. As a starting point in the assessment of the feasibility of such a rapid RES-E expansion within Section 3.2.2 of this report a comparison of the projected deployment (according to energy [r]evolution) with the identified realisable potentials is undertaken. As key source for doing so, a profound data source with respect to potentials and costs for RES in Europe was used: the Green-X database. In addition to the mid-term (2030) potentials according to the Green-X database also long-term potentials (up to 2050) are taken into consideration, summarising the outcomes of a literature survey. Generally, a proper match between the projections on technology-specific RES deployment according to the Advanced scenario of the energy [r]evolution study and the identified realisable potentials for 2030 can be seen. In other words, expected deployment is (well) below applicable resources[109]. The overall up-take of renewables appears ambitious and it can be anticipated that proactive policy action is required to tackle current deficits and problems related to RES-E deployment well in time.

Complementary to potentials, cost assumptions for RES-E technologies as used in the energy [r]evolution study are also compared with and contrasted to those applicable in the Green-X database and model. With the exception of onshore wind and occasional differences in certain periods, a proper match between cost expectations derived from Green-X and the energy [r]evolution study is applicable. For onshore wind, the expected cost reductions as projected by energy [r]evolution can be classified as optimistic – however, the strong entrance of new market players on the manufacturing side, e.g. from Asia, may serve as explanation.

The RES-E policy / market assessment discloses the need for corrective actions to bring RES "back on track" for meeting 2020 RES targets

In order to assess the challenges and, from a RES policy / market perspective, the feasibility of the anticipated strong RES uptake, we conducted a brief complementary model-based assessment,[110] using the Green-X model – a specialised energy system model with a detailed coverage of the European RES market. The model has been used within various studies conducted on behalf of the European Commission, national authorities or industry partners throughout the past decade.

It can be concluded that the short-term expectations of the energy [r]evolution study, i.e. the envisaged trend with respect to the RES-E uptake for the period up to 2020, appears too optimistic considering the existence of severe barriers that hinder a proper functioning of RES markets in several countries today. Removing currently prevailing barriers requires more time than anticipated in

109 An exception to this general observation (i.e. geothermal electricity) is apparent, however, since the magnitude of expected deployment by 2030 is small this does not imply to put the whole scenario projection under question.

110 Note that this complementary model-based assessment with the Green-X model does however not aim for an analysis of the technical feasibility or boundary conditions with respect to storage, infrastructural or other complementary options for a proactive integration of (variable) RES in the European electricity market.

energy [r]evolution study – but doing so appears imperative to assure an effective and economically efficient deployment of renewable electricity in the near and mid future.

Therefore, in accordance with the Re-Shaping study (Ragwitz et al., 2012) key policy recommendations to enhance an uptake of RES-E in the 2020 time horizon are:

- *Apply appropriate support levels:* If countries wish to enhance the deployment of certain RES-E technologies, support levels should be aligned with generation costs, based on realistic assumptions for investment cost and cost of capital in case of price-based support schemes such as feed-in systems. In the case of demand-based support as provided through quota systems (combined with tradable green certificates), the remuneration level may also be adapted indirectly by changing the quota, banding factors, penalties or other factors, although it is more challenging to meet a desired support level.
- *Reduce barriers, apply best practice support system design and reduce investor risk:* The required support level highly depends on the existing non-economic barriers to projects, the design of the support system, and the risk involved for investors. Removal of certain barriers is not only useful to reduce support costs but is also imperative to the realization of new projects.
- *Learn from best practice:* Countries with immature or intermediate market deployment status for a given technology can rapidly increase policy performance by learning from the best-practice support policy designs and organisation of administrative processes of other countries. They will be able to profit from spill-over effects from the internationally available project development expertise and technology supply chain.
- *Apply technology-specific support:* When choosing support instruments and support levels, policy makers should ensure a balance between developing higher-cost technologies (progressing on the learning curve) on the one hand and deploying low-cost technology potentials at an adequate speed on the other. This compromise can be achieved more easily with technology-specific support.

A clear commitment towards RES and ambitious binding RES targets are a necessity to achieve the ambitious 2030 RES-E deployment as anticipated

Binding national targets as defined by the RES directive (2009/28/EC) have created strong commitment for renewable energies throughout the EU and they are the key driver for RES policies at the moment. Generally, they are key elements for setting up the administrative procedures, regulatory frameworks, regional planning and national infrastructure development. As these elements will also be crucial for the RES deployment after 2020, binding national targets also appear to be an important element for the period beyond 2020. Moreover, given the anticipated strong uptake of RES-E as necessary to compensate the supply gap arising from a nuclear power phase-out in Europe, binding (national) 2030 RES targets are a necessity if climate constraints are taken seriously. A closer look on the recent quantitative assessment undertaken in the European “Keep on Track!” project discloses that a RES-E share in gross final electricity demand in size of 67%-69% (as anticipated by energy [r]evolution and Green-X modelling for 2030) would suit well to an overall 2030 RES target of about 37% to 38%.

6.3 Prerequisites and implications for the European electricity sector

An alternative “advanced scenario” to allow an earlier nuclear phase-out (as anticipated in energy [r]evolution)

The energy [r]evolution scenario takes a nuclear power phase-out until 2035 for the EU into account. The scenario projects an electricity generation of 78 TWh from nuclear power plants for the year 2030, what equates to 8.6% of nuclear generation in 2011 or 2.2% of total generation for the year 2030 according to the energy [r]evolution Advanced scenario (Eurostat, 2013c; Teske et al., 2012a, 125).

The simple answer to the overarching question whether or not the supply gap that would arise in the case of an earlier nuclear phase out (i.e. by 2030 instead of 2035) can be compensated is “Yes” – according to our brief complementary assessment it appears feasible to compensate this gap. The recommended option to mitigate the gap is to build on additional energy savings / efficiency measures, and as part of that we advocate to reduce the demand for hydrogen that serves as fuel for other sectors (i.e. transport and industrial processes). To frame it more comprehensible, Figure 6-1 presents the alternative RES-E supply scenario assessed with the Green-X model, combined with the fossil electricity sector and a nuclear power phase-out trajectory different to the energy [r]evolution. Therein a small wedge called “Unutilized Efficiency Potential”, which amounts to 124 TWh in 2030, is added. This wedge also includes reductions in the generation of hydrogen that is projected to be used intensively already by 2030 in the energy [r]evolution Advanced scenario. Hydrogen makes sense as an option to make use of surplus supply in times when variable RES-E like wind and solar occurs, but the proposed production volumes for 2030 appear challenging to achieve from today’s perspective, especially since there are cheaper alternatives applicable.

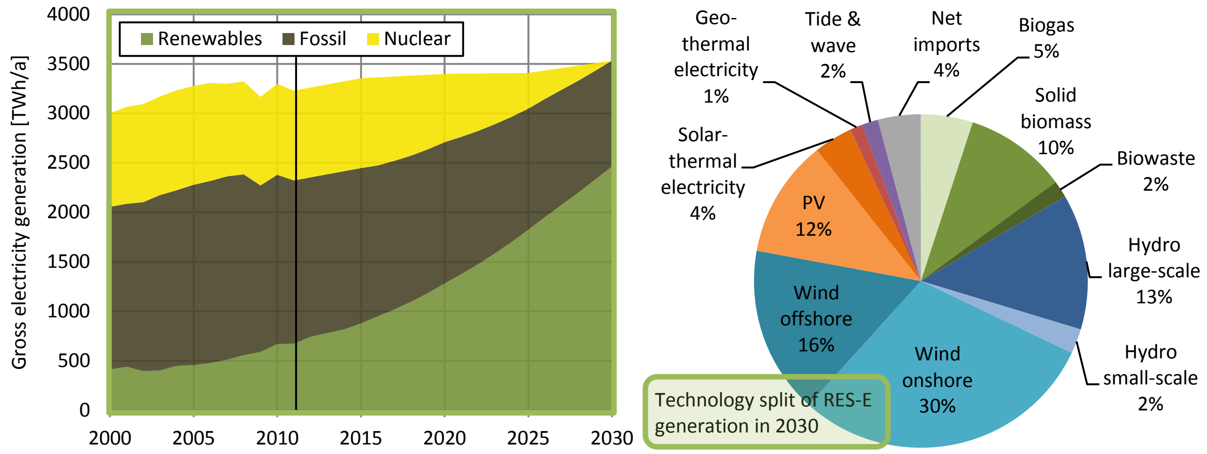

Figure 6-1. The projected gross electricity supply and consumption from 2012 to 2030 as of the energy [r]evolution scenario coupled with an alternative RES-E supply scenario (generation and net imports) assessed with the Green-X model and additional efficiency measures, resulting in a nuclear power phase-out in the EU27 countries by 2030 (left). The corresponding technology split of the RES-E supply scenario in 2030 (right). (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Note: See Chapter 3.1.3 and Figure 3-6 therein for the possible electricity saving potential.

Figure 6-2 provides a brief comparison between the energy [r]evolution Advanced scenario and the newly assessed alternative advanced case as derived by the Green-X model. It offers a breakdown of gross electricity supply for the years 2020 and 2030 into key supply categories (fossil, nuclear, renewables plus RES-E imports) and depicts the additional efficiency measures as proposed. Compared to energy [r]evolution, within Green-X less renewable electricity is imported from third countries in 2020 and 2030. The EU 27 countries will demand 124 TWh less electricity after more thoroughly adapted energy efficiency procedures and a reduced production of hydrogen in 2030. Therefore the electricity supply infrastructure is set for all nuclear power plants to be phased-out by 2030.

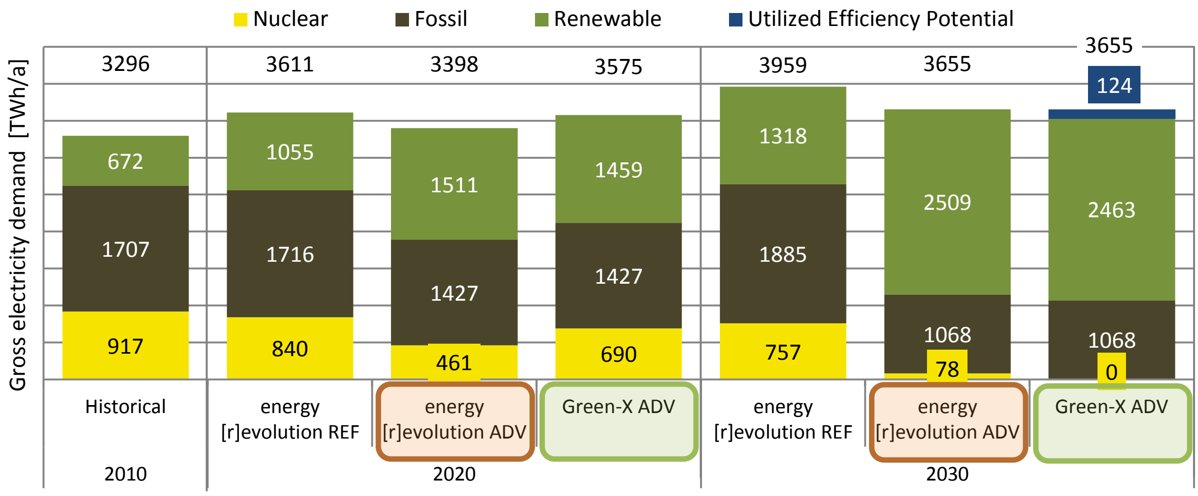

Figure 6-2. Gross electricity supply and consumption by sectors and scenarios for 2010, 2020, and 2030 in TWh. (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Finally, Figure 6-3 depicts these years in a relative manner. It seems as the included numbers present that the nuclear electricity generation share in the energy [r]evolution is linearly reduced, while the RES-E share is linearly increased. In opposition the assessed RES-E scenario in this study develops the share more progressively to virtually reach the same share in 2030 as the energy [r]evolution Advanced scenario predicts. This is the case while making a nuclear power phase-out possible, due to more extensively implemented energy saving measures and a reduced production of hydrogen.

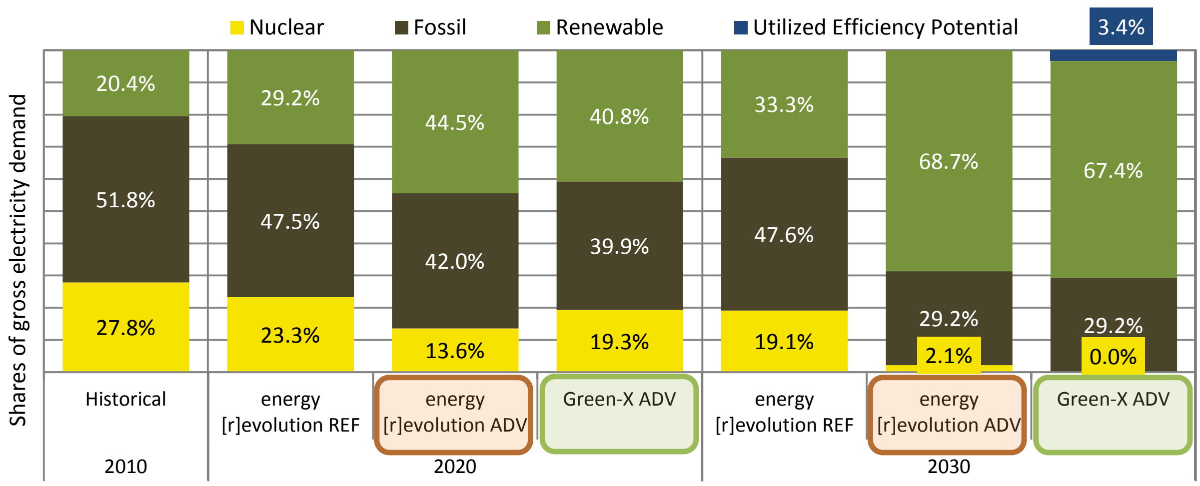

Figure 6-3. Shares of gross electricity consumption by sectors and scenarios for 2010, 2020, and 2030 in percent. (Eurostat, 2013e; Greenpeace and EREC, 2012; Own calculations)

Planning of network extensions has to appropriately incorporate the strong RES uptake

The integration of RES into power markets and networks requires investments into power networks and adjustments to the current power market design. While this statement is widely accepted, the debate over which kind of network investments are required and how power markets need to be adjusted has only just begun.

A necessary precondition for the realisation of the required network infrastructure is the adoption of a stable RES-E policy framework. EU-wide decisions on RES-E shares, mix, location and deployment timeframe will shape the network of the future. Considering the fact that network assets have a lifetime of 40 to 50 years, commitment to clear, long-term targets concerning the continental RES shares, and, if possible their spatial allocation will provide the stable framework necessary for network development, ensuring financial stability for the network manufacturing industry and for grid investments.

An accelerated RES-E deployment and the achievement of real energy savings within the EU do have a price…

An accelerated RES-E deployment and the achievement of real energy savings within the EU do have a price that comes with increased benefits. The price is that, compared to today, consumers will have to pay more for their electricity consumed in the short- to mid-term.[111] Benefits include the strong contribution of renewables and energy efficiency to mitigate climate change, and the avoidance of fossil fuels and corresponding imports which goes hand in hand with a positive impact on Europe's trade balance.

In order to provide a first quantification of the cost impact that stems from the strong deployment of renewable electricity, investment needs and support expenditures have been estimated. These results are taken from the Green-X scenarios conducted within the RES market / policy assessment as described above, since corresponding details are not applicable in the energy [r]evolution study. The impacts on the cost that consumers have to pay, i.e. the support expenditures, remain moderate in the short-term. But for the period beyond 2020 a strong increase in required expenditures is observable. Effective and from an economic viewpoint efficiently designed support policies may help to reduce the burden for the consumer, but the massive policy intervention due to the rapid market entrance of renewables leads to a doubling of support expenditures compared to a "business-as-usual" development in the final years close to 2030. These expenditures finally have to be borne by the consumers or the society, either via a dedicated fee that is directly put on top of electricity prices or indirectly by the tax payers if expenditures are for example paid through governmental budgets.

Parts of this cost burden may however be compensated by indirect effects that come along with the enhanced deployment of RES-E: From a consumer perspective a decrease of electricity prices can be

[111] A cost increase in the short- to mid-term is expected to come along with any type of climate mitigation measure. For example, as the recent discussions in the UK indicate, the build-up of new nuclear power plants that fulfil more stringent safety standards may be well in magnitude to offshore wind power – i.e. one of the more costly RES options as of today.

expected due to the so-called "merit order effect" on the wholesale electricity market (as well as on the carbon market).[112]

In addition to RES, it remains however impossible to express the impact on electricity prices that arises from saving costs/expenditures that come along with the energy efficiency measures anticipated in the energy [r]evolution study. The study itself provides no information on that, and also other complementary literature hardly allows for a meaningful estimation.

... but employment effects may remain positive

The European job market seems to be positively impacted by a substantial increase of renewable technologies in the electricity sector. While the assessment by the energy revolution study only includes gross employment effects and shows positive developments of plus 550,000 jobs for the year 2020 and plus 450,000 jobs for 2030, also the extensive economic assessment of the Employ-RES study, to which is referred to in Section 4.4, confirms this conclusion. In case a BAU scenario is compared to a scenario with substantial RES-E implementation, the two included economic modelling approaches of Employ-RES project positive GDP effects for 2020 and 2030 for the EU.

The strong RES uptake puts the stable functioning of the EU's internal electricity market under challenge - complementary activities are of need to safeguard the process

Complementary to energy efficiency a strong uptake of RES in the electricity sector is required to pave the way to a nuclear power-free Europe, while maintaining the transition to a sustainable energy system in the mid- to long-term. Since meeting climate commitments represents a precondition for doing so, this already on-going transition process in parts of Europe has to accelerate in speed. It can be expected that this challenges the stable functioning of the EU's internal electricity market(s) as of today, and requires clear commitments across all societal levels. Strong and proactive policy action are ultimately required to define a level playing field for both RES and energy efficiency. Ambitious binding European (and probably also accompanying national) 2030 targets for both energy efficiency and RES can be seen as a first step to tackle and initiate this process – but the list of policy actions has to tackle all areas and levels of the energy system and the society:

- Fossil fuels are of need to complement renewables in power supply, at least in the transition phase they are an important contributor in both base load and peak supply. More precisely, from a climate perspective, the assumed phase-out of nuclear power requires less carbon intensive fossil fuel power, e.g. gas-fired combined heat and power production. A well-established carbon price is the key element to safeguard that climate commitment can be held as otherwise dirty fossil fuels like lignite or coal are preferred against less carbon intensive sources. Mainly as a consequence of the economic crisis and the decrease of energy demand and industrial production, carbon prices as of today are at such a low level that no redirecting of energy-related investments towards more sustainability occurs. There is an ongoing debate on how to reform the ETS and how to define the appropriate energy and climate framework for 2030. Thereby, the introduction of price-stabilising elements in the carbon market deserves key attention but also al-

[112] Note however, that both the merit order effect on electricity and CO_2 price are distributional effects between consumers and producers. These effects cause consumer profits on the one hand and losses for (conventional) producers. Therefore the benefit discussed above only exists from the consumers' point of view.

ternatives to an emission trading regime like the introduction of carbon taxes should be taken into consideration.

- An appropriate coordination of future targets for GHG, RES and energy efficiency has to deserve key attention: A clear incorporation of expected complementary GHG savings coming from meeting future RES and energy efficiency targets in the elaboration of a GHG target trajectory is required. Preferably this incorporation has to be made ex-ante rather than ex-post.
- The anticipated strong uptake of RES and the mobilisation of energy savings is also a contribution to supply security, since building on domestic resources and consuming less more efficient decreases import dependencies and related political risks. Supply security also has other dimensions, involving a well-functioning power supply that builds on a proper match of supply and demand at all times of operation. In this respect the volatile nature of various key renewable sources imposes a challenge that needs to be tackled through new operational concepts that assure the efficient functioning of the EU's internal electricity market and complementary side-markets for balancing etc… Moreover, new market rules and appropriate incentives need to be provided to assure that investments in complementary options like (fossil) back-up and storage capacities as well as network extensions are taken.
- Improved cross-border transmission policies will facilitate the efficient operation of the grid under increased RES penetration. Grid extension will dampen price volatility and numbers of hours with negative market prices. Current regulations should be adapted if the foreseen extensions (TYNDP) are not able to be realized. The costs and need for balancing can be reduced by more frequent and shorter scheduling intervals. Balancing markets should be made more flexible, so that renewables and demand-side sources can participate more easily. The coordination of balancing areas is also important to reduce balancing costs. Increased RES penetration leads to a greater need for flexibility in system operation. Therefore, incentives for demand response or other flexibility options could be considered after an in-depth analysis of all of their strengths and weaknesses.

6.4 Legal aspects of a nuclear power phase-out

The legal part of this report addresses two complementary tasks, both related to nuclear energy policy in the European Union and juridical aspects. It focusses on possible national support schemes for the generation of electricity based on nuclear energy. Other aspects of aid granted for nuclear energy especially related to decommissioning costs, nuclear waste management and disposal costs as well as liability costs will not be considered.

First, the question is answered which legal aspects have to be considered when Member States want to promote the operation of nuclear energy plants through national support schemes. The focus will be laid on the provisions of the prohibition of state aids and its exemptions. The analysis is made against the background of the actual state aid modernization process, which was initialized by the EU Commission in May 2012.

Based on the description of the general principles of state aid, an analysis is carried out which will highlight the ongoing Electricity Market Reform in the UK. As part of the reform it is foreseen that a new system will be introduced which establishes feed-in tariffs with contracts for difference for "low carbon technologies". It is shown that the planned aid scheme is not compatible with EU law on state aid.

Euratom Treaty

In the field of nuclear energy the Treaty establishing the European Atomic Energy Community (Euratom Treaty) constitutes binding Primary law for all Member States of the European Union. Since the Lisbon Treaty entered into force in December 2009, the European Union itself is based on the Treaty on European Union (the TEU) and the Treaty on the Functioning of the European Union (the TFEU). How and where the EU treaties could be applied in the nuclear energy sector has been a relevant question already for a long time. The analysis of the interaction between the Euratom Treaty and the TFEU is of high relevance in various fields, but especially decisive when it comes to aspects of the common market, e.g. state aid law. When it comes to the applicability of the EU State it has to be stated, that the Euratom Treaty contains no provisions analogous to Article 107-109 TFEU. The application of these articles for the benefit of undertakings active in the nuclear energy sector is therefore generally accepted. Therefore when state aid in the scope of the Euratom Treaty is concerned, the provisions of the Euratom Treaty are not exhaustive. Thus the provisions of Articles 107 -109 TFEU are applicable on state aid subjects, as far as the Euratom treaty does not contain specific provision on the matter. So it can be stated that financial aid by Member States to promote the further deployment of nuclear energy, e.g. in form of operating aid for the generation of electricity based on nuclear energy, is not regulated by the Euratom Treaty and therefore falls under the general EU state aid rules.

State aid

One of the key provisions of the TFEU, which aims at defending a fair competition between all market participants without non-justified state interventions, is the European state aid law. When defining the concept of state aid from a very general point of view, two questions have to be answered: Is there a state aid? If yes, is there an exemption from the general incompatibility of state aids with the common market? In order to answer these questions in a reliable way, a well elaborated and detailed scheme of assessment has to be considered. This scheme is set out by the rules on state aid contained in Article 107 to 109 TFEU and was developed further by the EU Commission and the European Court of Justice. If a Member State plans to introduce a support scheme which provides financial support for the operation of nuclear power plants, any intervention by the state has to be proven with scrutiny. Especially when direct state means are involved or state control on private means is established, the criterion of "transfer of state resources" will be met. In a first step, any national measure which has to be qualified as a state aid is prohibited.

Though, the prohibition of state aid does not apply unconditionally and without exceptions. The TFEU knows two forms of exemptions: Legal exemptions pursuant to Article 107 (II) TFEU only play a minor role in the every day's application practice. Far greater importance is given to the complex criteria of so called "facultative exemptions", stated in Article 107 (III) TFEU. This article requires an in depth assessment of the compatibility of any state aid with the internal market and gives the Commission a wide discretion. This includes e.g. the competence to decide, whether an aid can be exempted pursuant to Article 107 (III) TFEU, is exclusive; a broad but not unlimited discretion in making rulings in the context of its regulation of state aid; the exercise of the discretion is generally exercised on the basis of economic and social assessments whereby the interests of the Community as a whole are to be taken into consideration. In the last years, the Commission has developed several guidelines, notices, communications etc. to provide a certain kind of transparency of its acting and to provide a certain form of legal certainty. The issued regulations specify in advance how the wide discretion of the Commission will be exercised. In the area of environment and energy state aid, the General Block Exemption Regulation and the Community Guidelines on state aid for environmental protection are the most important acts to be considered. Measures may be declared compatible with the common market if they are necessary and proportionate and if the positive effects for the common objective outweigh the negative effects on competition and trade (so called balancing test). The following criteria are part of the balancing test: objective of common interest, appropriate instrument, incentive effect and necessity of aid, proportionality of the aid, and negative effects of the aid must be limited so that the overall balance is positive.

UK plans for a CfD scheme for nuclear energy

At the moment, the UK Government is planning the so called Electricity Market Reform laid down by the Energy Bill. Part of this reform shall be the mechanism of Feed-in Tariffs with Contracts for Difference (CfD), serving to promote “low carbon technologies”. As it is shown, the CfD scheme constitutes a state aid according to Article 107 (I) TFEU. When assessing the compatibility of the CfD scheme with the common market, it is first analysed that the mechanism does not fall under the scope of the General Block Exemption Regulation or the Community Guidelines on state aid for environmental protection. For this reason, the CfD scheme has to be evaluated on the general provisions in Article 107 (III) TFEU. A compatibility of the CfD scheme with the internal market would have to consider all the compatibility principles, assessed in the balancing test by the Commission to be exempted from the general prohibition of state aid. As it is shown, the CfD scheme fails to be in line with the set out compatibility principles, so an exemption cannot be made. Especially, no common interest is given, there is no need for state aid and the appropriateness of the aid cannot be proven.

After the notification of the CfD scheme for nuclear energy by the UK Government in autumn 2013, the European Commission opened an in-depth investigation on 18th of December 2013 to examine whether the UK plans are in line with EU state aid rules. As it was announced by the Commission, there are in particular doubts that the project suffers from a genuine market failure.

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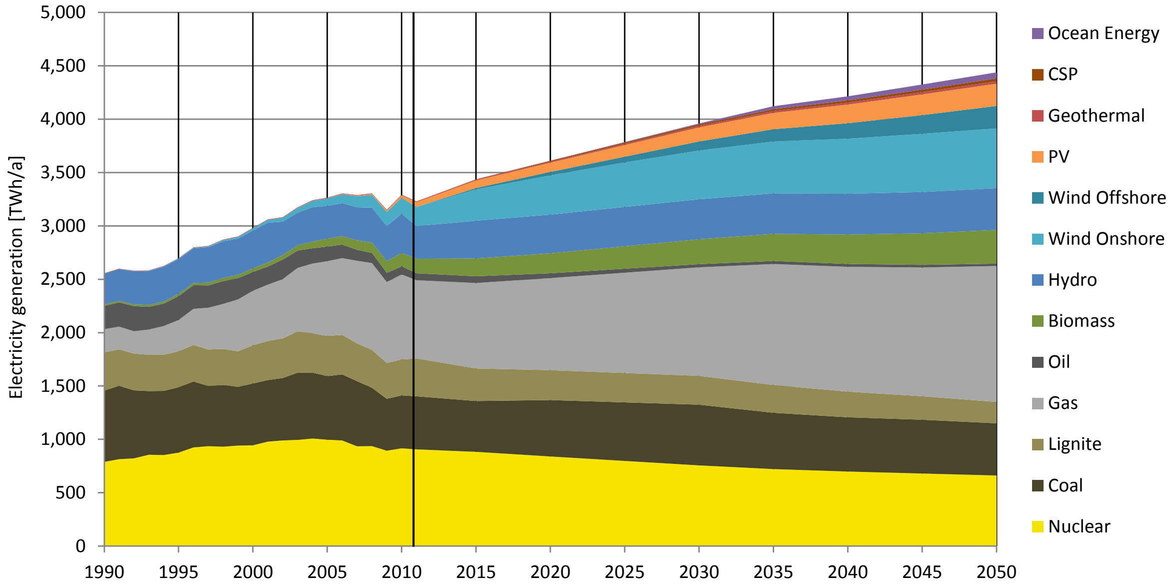
A Annex – Scenario details

A.1 The European energy [r]evolution electricity scenarios



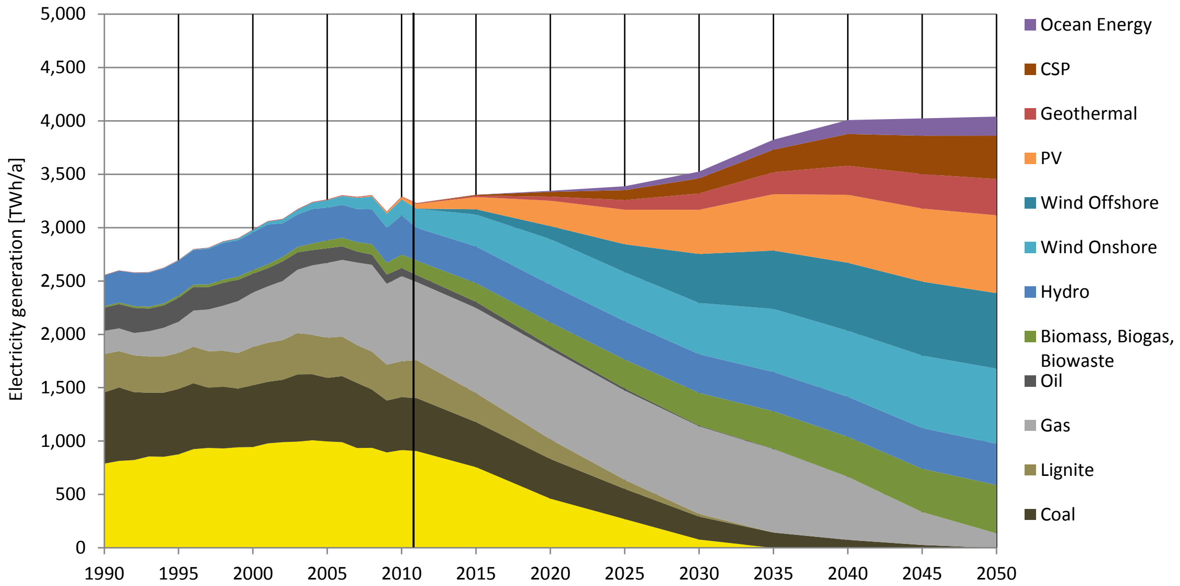
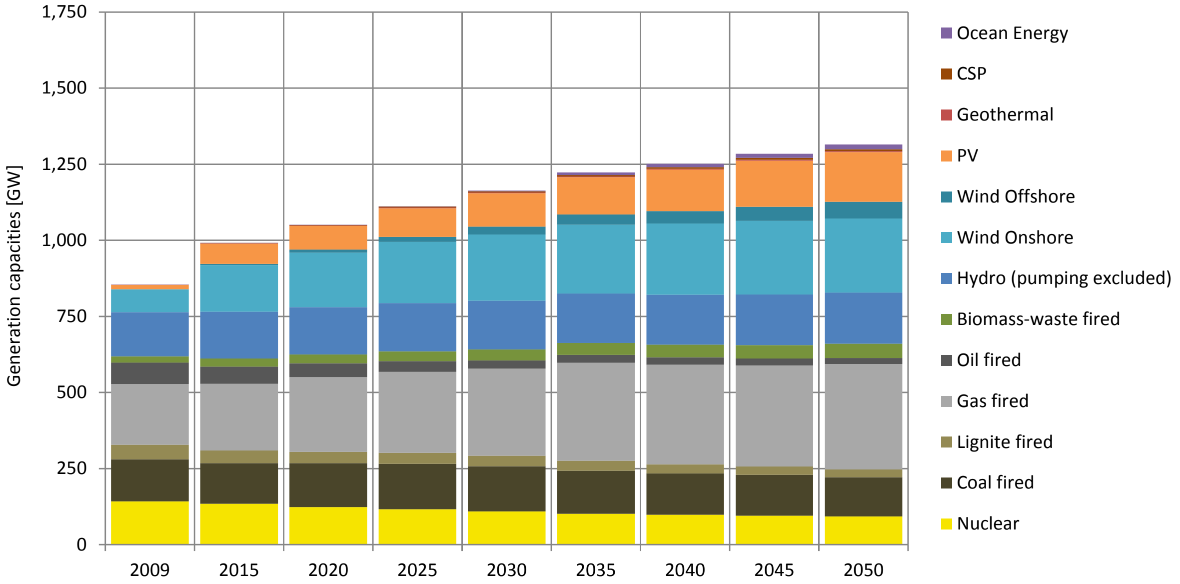


Figure 7-1. The historical (until 2011) and projected electricity generation in the energy [r]evolution Reference (above) and Advanced scenario (bottom). (Eurostat, 2013e; Greenpeace and EREC, 2012)



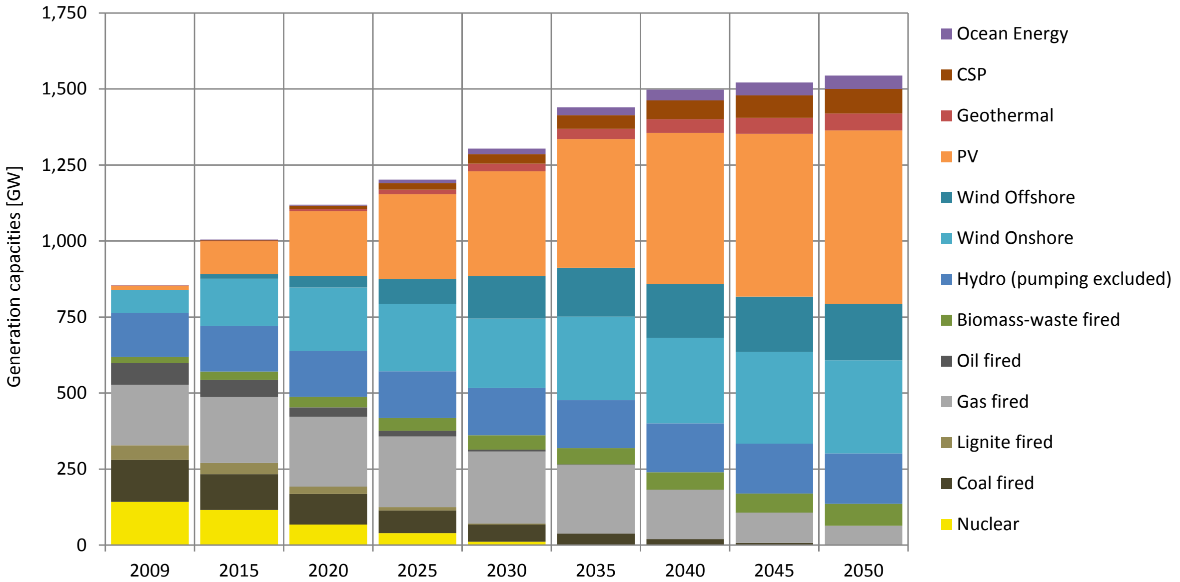


Figure 7-2. The gerneration capacities in the energy [r]evolution Reference (above) and energy [r]evolution Advanced scenario (bottom). (Eurostat, 2013c; Greenpeace and EREC, 2012)

A.2 The European nuclear power phase-out scenario in numbers

Table 7-1. The European gross electricity consumption in TWh per year by generation technologies and net electricity imports in 2010 and projections for 2020 and 2030. The projections for fossil fuel based generation technologies were assessed by the energy [r]evolution Advanced scenario. The projections for renewable based generation technologies were assessed by the application of the Green-X model. (Eurostat, 2013e; Greenpeace and EREC, 2012, Own calculations)

Gross electricity generation [TWh/a]	2010	2020	2030
Coal	495	372	215
Lignite	337	184	25
Gas	796	840	821
Oil	76	31	7
Nuclear	917	690	0
Biogas	31	65	123
Solid biomass	79	148	244
Biowaste	17	35	40
Hydro	367	372	382
Wind onshore	149	411	729
Wind offshore	0	75	399
Photovoltaics	22	142	281
Geothermal	6	13	30
Concentrated solar power	1	18	93
Ocean energy	1	2	38
Net electricity imports	3	2	102
Gross electricity demand	3292	3396	3429
Additionally utilized efficiency potential compared to the gross electricity demand assessed by the energy [r]evolution study	0	0	124

B Annex – Literature review

B.1 Ecofys, 2010 - How to triple the impact of energy saving policies in Europe

Full title: How to triple the impact of energy saving policies in Europe

Authors: Ecofys and Fraunhofer ISI

Bart Wesselink, Robert Harmsen, Wolfgang Eichhammer

Client: European Climate Foundation (ECF) and Regulatory Assistance Project (RAP)

Publication date: September 2010

B.1.1 Object of study

“Energy Savings 2020” is the latest report in the “Roadmap 2050” series. The role of this report is to assess and make recommendations on the required energy saving policies to achieve the broader goal of the decarbonisation of the European economy. This broader goal sets out to achieve a minimum of 80% emissions reduction by 2050 and 20% energy savings by 2020, as compared to business as usual energy use.

B.1.2 Geographical and time scope

The geographical scope is on the EU and the considered time scope is up to 2020 (20% target) and 2050 (80% target).

B.1.3 Scenario

The study considers four energy savings scenarios:

- Baseline scenario (based on PRIMES-2007)
- Low policy intensity scenario (LPI)
- High policy intensity scenario (HPI)
- Technical scenario (TECH)

B.1.4 Assumptions and Input data

Discount Rates of the four fields and two scenarios, LPI and HPI and the energy prices are based on PRIMES-2007.The shares of energy and power demand and supply by region are also being taken from PRIMES. Assumptions on technological learning are based on the literature and expert opinions.

B.1.5 Methodology

The central objectives of the study are threefold:

- Restate the energy saving potentials in the EU27 and its member states by 2020 and 2030.
- Estimate the extent to which current saving policies capture this potential and the policy gap that remains against achieving the EU´s target of 20% energy savings by 2020
- Explore feasibility of different design options of binding energy saving targets with a focus on their impact on the functioning of existing EU policies

The first two objectives are dealt with in Chapters 2 to 5 of the report:

- Chapter 2 summarizes the multiple justifications for additional energy savings efforts.
- Chapter 3 describes current energy and climate policies and their impacts on energy use and greenhouse gases.
- Chapter 4 discusses the energy savings potential in the EU.
- Chapter 5 discusses the role of a binding energy savings target in the policy mix.
- Chapters 2-5 serve as a starting point for the exploration of design options for binding energy savings targets.
- Chapter 6 discusses how best to express a binding target and the interaction of such a new policy element with existing legal EU energy and climate policies.
- Finally, Chapter 7 explores four main design options for a binding target.

B.1.5.1 Key findings

- EU has sufficient cost-effective energy end-use savings potential to release its overall 20% target by 2020 in conjunction with meeting its binding target for renewable energy sources
- Assessing the cost-effective potential of energy savings investments from a life cycle perspective using discount rates in line with government bond rates.
- To achieve the 20% target in 2020 around 394 Mtoe of energy savings compared to "pre-recession" baseline expectations of the 2006 Energy Efficiency Action Plan.
- It is expected, that a gap of 208 Mtoe towards the EU target remains in 2020
- Closing this gap requires a threefold increase in policy impact compared to energy saving policies adopted since 2006
- The gap could be closed most cost-efficiently, by realising the end-use savings potential, which is identified in the study
- Closing the gap in this way would lower EU energy bills by €78 billion annually in 2020 and save 560 Mt CO_2

The key question for policy makers is how to provide policy incentives that achieve this threefold increase in savings impact. The report provides arguments for a binding energy savings target as part of the policy mix. Furthermore, the introduction of a binding energy savings target is supported by the EU current approach on climate, renewable energy and air pollution policies. In all cases, the binding targets serve as a benchmark for implementation of a suite of targeted policy instruments.

B.1.6 Recommendations

The study assesses four design features and four design options for a binding energy savings target, ranging from a single economy-wide EU target to Member State national targets for a subset of sectors. Though in theory all design options may be open, the analysis suggests that the most feasible design option is to introduce a binding energy savings target for ‘end-users’ at the Member State level. Key findings on this and related design issues are summarized below:

- *Binding targets at Member State level are the most feasible*
  A binding target at Member State level would ensure political accountability and commitment to deliver results while providing flexibility to choose and apply the most suitable tools to achieve the target. It could provide a framework to guide ambitious and coherent implementation of the existing EU energy efficiency policies, while also strengthening national policies. Furthermore, binding targets at Member State level will incentivize Member States to take a progressive position at the EU level when new standards are set.
- *A Member State binding target for ‘end-users’ is a design option that covers the vast majority of energy savings potential*
  An economy-wide binding target clearly provides Member States with the most flexibility and highest captured savings potential. However, it should also form the most effective and coherent interaction with EU-ETS and RES policies:
  → EU-ETS participants may argue that a binding energy savings target that includes their facilities would reduce their EU-wide trade flexibility. The studies’ calculations suggest that the additional fuel savings, compared to the baseline assumptions, expected from EU-ETS covered facilities are comparatively small.
  → Applying the target to ‘end-users’ would work most effectively in combination with RES policies. This is because end-use energy savings are the most cost-effective way of increasing the percentage share of renewables in final energy consumption.
  Overall, a target focusing on energy use outside the scope of EU-ETS would still capture 94% of the savings potential required to reach the 20% energy savings target by 2020, when implemented in conjunction with the EU’s binding RES target. It is estimated, that the RES target will achieve 15% of that potential by increasing the efficiency of energy supply through an increased share of renewables in the generation mix. A binding energy savings target that focuses on electricity and fuel end-use in the built environment, the transport sector, small and medium size enterprises and the industrial energy use not covered by EU-ETS will achieve another 79% of energy savings potential in the EU economy by 2020.
- *A savings target is best expressed in absolute energy use terms*
  A savings target should be transparent and easy to monitor and measure. By far the most straightforward way to comply with these criteria is to define the target as an absolute energy use in a target year and monitor the absolute development of energy use over time. This means that the energy use which remains is measured, rather than estimating the savings. Under this approach, the volume of energy savings, as compared to a baseline, is only estimated once and upfront when setting the target. Subsequently, existing energy statistics, already implemented in all EU Member States through statistical offices, provide a straightforward way to monitor progress towards the target. Such an approach would also best safeguard the significant energy savings that are required to achieve the EU’s ambition of deep GHG reductions towards 2050.

- *For targets applied to 'end-users', expressing the savings as 'adjusted final energy' will be the most transparent and measureable approach*
  The study suggests that a target for 'end-users' may preferably be expressed as 'adjusted final energy use'. Here, the electricity and district heat components of final energy use data, readily available from energy statistics, are weighted with a factor of 2.5 and 1.2 respectively. This is to ensure that electricity and district heat savings are weighted in a similar way as fuel savings. It is recommended to use weighting factors, which are constant over time and across Member States. This method resembles the primary energy use definition but will increase coherence across Members States. A constant factor over time would provide the most transparent view on end-use energy savings achieved.

B.1.7 Comments

The present study has three major directions of impact. First, it highlights the reason, why energy savings are essential for the decarbonisation of the European economy. At second, it shows which untapped potential exists and why a tripling of current policy impacts is necessary, to reach the 20% target up to 2020. Last, it discusses the role of a binding energy saving s target and the criteria and options of the design.

Based on the outcome of this study the reasonable conclusion can be drawn, that the expected gap towards the EU target in 2020 could be closed most cost-efficiently, by realising the end-use savings potential. Therefore a threefold increase in policy impact compared to energy saving policies adopted since 2006 is required.

B.2 Ecofys, 2012 - Economic benefits of the EU Ecodesign Directive - Improving European economies

Full title: Economic benefits of the EU Ecodesign Directive - Improving European economies

Authors: Edith Molenbroek, Maarten Cuijpers, Kornelis Blok

Client: Natuur en Milieu

Publication date: April 2012

B.2.1 Object of study

The Ecofys study aims to show the major benefits of a correct implementation of the Ecodesign Directive for Europe´s economy.

For that, Ecofys gives a general overview of the Ecodesign Directive and besides Ecofys´ economic impacts and the project´s status quo and issues.

B.2.2 Geographical- and time scope

Since the Ecodesign Directive is used in the EU, the geographical scope is on the EU.

The considered time scope is up to 2020.

B.2.3 Methodology

Ecofys split the study in the following parts:

- Description of Ecodesign Directive´s function
- Quantifying the potential benefits associated to the Directive
- Evaluation of the Directive´s implementation thus far
- Recommendations for improvement

B.2.4 Ecodesign Directive´s function

The Ecodesign Directive aims at reducing the environmental impact of a number of products sold in the EU, with emphasis on their energy consumption.

The Directive covers most energy-using products (domestic appliances but also commercial and industrial equipment), covering products responsible for as much as 80% and 60% of the EU's electricity and heat consumption, respectively.

Ecodesign regulations do not prescribe the method for achieving higher energy efficiency but only the required objective, thereby leaving the manufacturers free to determine their own technical solution.

According to the Directive, a product group can potentially be regulated under Ecodesign when it:

- Has more than 200.000 units sold annually in the EU
- Has a significant environmental effect, judging by the number of products in use
- Has significant improvement potential

Ecodesign implementing measures for specific product groups should:

- have no (significant) negative impact on (1) functionality, (2) health and safety, (3) affordability, (4) industry's competitiveness.
- not impose proprietary technology on manufacturers
- not be an excessive administrative burden for manufacturers

Furthermore, Ecodesign parameters:

- consider all phases of the life cycle (manufacturing, transport, use, disposal)
- consider the essential environmental aspects (consumption, material, emission, waste etc.) for each phase
- determine energy efficiency or energy consumption levels which allow minimum life cycle cost for end consumers

B.2.5 Conclusions

The cost-effective energy savings would lead to:

- reduce EU´s dependency on energy imports
- create jobs
- help EU to achieve its mid- and long-term climate and energy objectives
- Gross economic savings

The Ecodesign Directive can create huge benefits for the European economy:

- €90 billion net savings per year for business and consumers by 2020
- Investment of saved energy costs creates 1 million jobs by 2020
- The reduced need for heat and electricity can reduce gas imports by 23% in 2020 and coal imports by 37%. Import of gas from Russia could be reduced by 56% and import of coal from Russia could be stopped altogether.

Until 2011, 12 products have been regulated under Ecodesign.

However, it has been observed that there are problems with the implementation of Regulations for specific groups that put these economic benefits at risk.

First, there is a large lead time between the initiation of an appliance standard and a standard coming into effect. For the 12 measures in place the timeframe was reasonable and to be expected. However, 6 more appliance groups have failed to result in measures up until now, years after the preparatory study was finished. Product groups with huge saving potentials such as boilers and water heaters are among the delayed groups. The delays are due to the complexity of the products and the lack of sufficient manpower at the European Commission to handle this complexity. Second, for the product groups that did result in standards in a reasonable time frame there is a risk that standards do not go far beyond business as usual and do not reach the Ecodesign ambition of lowest life cycle costs. This is because standards are based on information on efficiency and cost that is outdated by the time the standard takes effect.

B.2.6 Recommendations

The correct implementation of the Ecodesign Directive would strengthen the competitive position of the European Union and would bring considerable environmental benefits. A lack of enough awareness of the full potential of the Ecodesign Directive and technical and organizational issues are standing in the way between these benefits and the European citizens and businesses that would benefit from them.

In order to reap the full fruit of this piece of legislation we recommend to boost efforts for effective and timely Regulations that sufficiently encompass market and technological evolution:

1. Raise awareness among decision makers on the full power of the Ecodesign Directive to reduce Energy dependency of member states and diminish energy bills of companies and citizens. In contrast to some other EU policies, strengthening the minimum energy requirements of appliances would not deteriorate the competitive position of European manufacturers. This is because non-EU manufacturers should also comply with these requirements when entering the EU-market.
2. Devoting more manpower within the European Commission (EC) and/or Member States to ensure that Ecodesign Implementing Measures are adopted timely and with sufficient ambition.
3. Taking into account market dynamic and expected cost reductions of energy efficient technologies when setting minimum energy performance standards under individual Implementing Measures. Only then will Ecodesign measures be at the lowest life-cycle cost to consumers by the time they enter into force.

4. Improve market monitoring, with particular attention to energy efficiency and cost data. This would facilitate the job of setting minimum energy performance standards and will help evaluate their effectiveness once they enter into force.

B.2.7 Comments

The present study has two main parts. First, it gives a general overview of the Ecodesign Directive and the economic impacts and second it discusses the projects advantages, status quo and issues. Overall it discusses the correct implementation of the Ecodesign Directive for Europe´s economy.

Based on the outcome of this study the reasonable conclusion can be drawn, that a correct implementation of the EU Directive would lead to many benefits like generating new jobs, reducing dependency on energy imports, net savings per year and achieving EUs mid- and long-term climate and energy objectives.

B.3 EU Roadmap 2050 - Impact assessment and scenario analysis

Authors: European Commission, Energy, unit A1 Energy policy and analysis

Manfred Decker, Livia Vasakova

Client: -

Publication date: July 2011

B.3.1 Object of study

In the 2nd Strategic Energy Review in November 2008 the Commission undertook to prepare an energy policy roadmap towards a low carbon energy system in 2050, where the targeted 80-95% GHG emissions reduction is in the focus.

This study aims to examine conceivable pathways to a low-carbon economy in Europe, while maintaining energy security and the environmental and economic goals of the European Union.

In fact, 7 different target scenarios have been analysed in terms of feasibility, costs and benefits. Beside a Reference- and a Current Policy Initiatives scenario, five further scenarios for a decarbonisation analysis of the energy system are getting used, which are different combinations of the four decarbonisation routes. All decarbonisation scenarios are built on Current Policy Initiatives and driven by carbon pricing to reach some 85% energy related CO_2 reductions by 2050 (40% by 2030) which is consistent with the 80% reduction of GHG emissions.

B.3.2 Geographical and time scope

The geographical scope is on the EU and their member states and the considered time scope is up to 2030 (40% target) and 2050 (80% target).

B.3.3 Scenarios

All decarbonisation scenarios build on Current Policy Initiatives and are driven by carbon pricing to reach some 85% energy related CO_2 reductions by 2050 which is consistent with the 80% reduction of GHG emissions. All scenarios will reflect significant development of electrical storage and interconnections (with the highest requirements in the High RES scenario).

B.3.4 Reference scenario – Business as usual

The European Commission has carried out an analysis of possible future developments in the so-called Reference scenario, which is a projection, not a forecast, of developments in the absence of new policies. The Reference scenario includes current trends and long-term projections on economic development (GDP growth). It takes into account rising fossil fuel prices and includes policies implemented by March 2010.

Sensitivities:

- a case with higher GDP growth rates,
- a case with lower GDP growth rates,
- a case with higher energy import prices,
- a case with lower energy import prices.

B.3.4.1 Current Policy Initiatives scenario (CPI)

In order to include the most recent developments and the latest policies on energy efficiency, energy taxation, internal markets, transports and infrastructure adopted or planned after March 2010, an additional scenario called Current Policy Initiatives scenario was modelled. Technology assumptions for nuclear were revised reflecting the impact of Fukushima and the latest information on the state of play of CCS projects and policies were included.

Both scenarios build on a modelling framework including PRIMES, PROMETHEUS, GAINS and GEM-E3 models.

B.3.4.2 High Energy Efficiency scenario (HighEE)

The High Energy Efficiency scenario is driven by a political commitment of very high primary energy savings by 2050 and includes a very stringent implementation of the Energy Efficiency plan. This includes minimum requirements for appliances and new buildings, energy generation, transmission and distribution, high renovation rates for existing buildings, the full roll-out of smart grids, smart metering and significant and highly decentralised RES generation to build on synergies with energy efficiency.

B.3.4.3 Diversified supply technologies scenario

The Diversified supply technologies scenario shows a decarbonisation pathway where all energy sources can compete on a market basis with no specific support measures for energy efficiency and renewables and assumes acceptance of nuclear and CCS as well as solution of the nuclear waste issue.

B.3.4.4 High Renewable Energy Sources (HighRES)

The High RES scenario aims at achieving a higher overall RES share and very high RES penetration in power generation.

B.3.4.5 Delayed Carbon Capture and Storage (Delayed CCS)

This scenario follows a similar approach to the Diversified supply technologies scenario but assumes difficulties for CCS regarding storage sites and transport while having the same conditions for nuclear.

B.3.4.6 Low nuclear (LowNuc)

The low nuclear scenario also follows a similar approach to the Diversified supply technologies scenario but assumes, that public perception of nuclear safety remains low and that implementation of technical solutions to waste management remains unsolved leading to a lack of public acceptance. In case of CCS same conditions as in Diversified supply technologies scenario are mentioned.

B.3.5 Assumptions and Input data

The GDP developments (GDP growth rate about 1,7% p.a. on average for 2010-2050) and most technology assumptions are nearly same in all scenarios as in the Reference scenario, although there are additional mechanisms to stimulate decarbonisation and technology penetration. As a result of lower global demand for fossil fuels reflecting worldwide carbon policies the scenarios achieving the European Council's GHG objective have lower fossil fuel prices (106$/barrel in 2030 and 127$/barrel in 2050).

The Reference scenario 2050 includes current trends and recent Eurostat and EPC/ECFIN long term projections on population and economic development. It takes into account the upward trend of import fuel prices in a highly volatile world energy price environment. Economic decisions are driven by market forces and technological progress in the framework of concrete national and EU policies and measures implemented by March 2010.

The CPI scenario builds on the same macroeconomic framework and includes policy initiatives adopted after March 2010 or policy initiatives currently being planned as well as updated technology assumptions for nuclear and electric vehicles.

In addition all scenarios were conducted under the hypothesis that the whole world is acting on climate change which leads to lower demand for fossil fuel prices and subsequently lower prices. Perfect foresight regarding policy thrust, energy prices and technology developments are assumed and lead to low uncertainty for investors. The model includes a regulatory framework, which allows for investments to be built and costs fully recovered and assumes an average household or consumer and continuous improvements of technologies.

B.3.6 Methodology

This study is mainly concerned with analysing possible energy related pathways to achieve the decarbonisation targets and focuses on energy consequences. It assumes the implementation of the European Council´s decarbonisation objective.

The central objectives of the study are threefold:

- Which assumptions have to be made?
- Who is affected and how?
- To what impacts would that lead?

Section 2 gives an overview about the problem itself and the underlying drivers of the problem where Section 3 and 4 are looking into the objectives ad policy options including the methodology.

In Section 5 an assessment of the environmental, economic and social impacts is proposed. The assessment is supported by modelling results and/or by academic research. A 40-year outlook is naturally steeped in uncertainty. Whereas some parameters such as population growth can be projected with a reasonable degree of confidence, the projection of other key factors such as economic growth, energy prices or technological developments over such a long time span incorporates a great deal of uncertainty.

B.3.7 Key findings

According to EC (2011b) Energy Roadmap following table shows the mayor impacts of the various scenarios.

Table 7-2. Roadmap 2050 Summary of impacts

	1 Reference scenario	1bis Current Policy Initiatives	2 High Energy Efficiency	3 Diversified supply technologies	4 High RES	5 Delayed CCS	6 Low nuclear
Environmental impacts							
Energy consumption/Energy intensity			+ + +	+	+ +	+	+ +
RES share		+	+ +	+ +	+ + +	+ +	+ +
Energy related CO2 emissions		=	+ + +	+ + +	+ + +	+ + +	+ + +
Economic impacts							
Economic growth		=	=	=	=	=	=
Competitiveness		=	+	+	+	+	+
Energy security (import dependency and imports from third countries)		=	+ +	+ +	+ + +	+ +	+
Social impacts							
Employment		=	+ +	+	+ +	+	+
Quality of jobs		=	+ +	+ +	+ +	+ +	+ +
Affordability		=	-	=	-	=	=

Legend:
= equivalent to Reference scenario
+ to +++ improvement compared to Reference scenario
- to - - - worsening compared to Reference scenario

- Successful decarbonisation while preserving competitiveness of the EU economy is possible.
- Predictability and stability of policy and regulatory framework creates a favourable environment for low carbon investments. Discussions about policies for 2020-2030 should start now leading to firm decisions that provide certainty for long-term low-carbon investments. Uncertainty can lead to a sub-optimal situation where only investment with low initial capital costs is realised.

- A well-functioning internal market is necessary to encourage investment where it is most cost effective.
- Energy efficiency tends to show better results in a model than in reality.
- Due attention should be given to public acceptance of all low carbon technologies and infra-structure as well willingness of consumers to undertake implied changes and bear higher costs. This will require the engagement of both the public and private sectors early in the process.
- Transition to a decarbonised economy may involve shifts to more highly skilled jobs, with a possibly difficult adaptation period.
- Relations with energy suppliers should be dealt with pro-actively and at an early stage given the implications of global decarbonisation on fossil fuel export revenues and the necessary production and energy transport investments during the transition phase to decarbonisation.

Table 7-3. Roadmap 2050 Comparison of policy scenarios to rthe Reference scenario

	1bis. Current Policy Initiatives	2. High Energy Efficiency	3. Diversified supply technologies	4. High RES	5. Delayed CCS	6. Low nuclear
Effectiveness						
Sustainability	-	+++	+++	+++	+++	+++
Security of supply	-	++	++	+++	++	+
Competitiveness	-	+	+	+	+	+
Efficiency						
Additional annual average total costs relative to Reference scenario in bn EUR'08	37	33	-47	8	-57	-29
Additional annual average total costs as % of GDP	0.21%	0. 19%	-0.26%	0.05%	-0.31%	-0.16%
Coherence						
Trade-offs between economic, social and environmental impacts		Scenario reducing the most energy consumption and significantly improving import dependency but rather costly for households and difficult to implement when it comes to behavioural changes	Scenario with lowest cost from the economic actors' point of view, significant energy efficiency gains and renewables shares but depending on success (technological progress of CCS and some RES as well as public acceptance of nuclear and CCS)	Scenario showing the highest penetration of RES; highest decrease in import dependency and second strongest reduction of energy consumption pushing innovation in new technologies, but rather costly and leading to highest electricity prices	Scenario with lowest costs scoring well on security of supply, RES penetration and competitiveness but the least effective in terms of energy efficiency; rather strong reliance on nuclear being contingent on absence of further public acceptance problems	Scenario scoring well on costs, RES shares and energy efficiency but still with high consumption of fossil fuels and dependency on their imports. Heavily dependent on technological progress and acceptance of CCS

Legend:
= equivalent to Reference scenario
+ to +++ improvement compared to Reference scenario
- to - - - worsening compared to Reference scenario

B.3.8 Recommendations

According to the Energy Roadmap 2050 following recommendations can be drawn:

- The need for a decarbonisation of heating and transport relies heavily on the availability of decarbonised electricity supply, which itself depends on very low carbon investments in generation capacity as well as significant grid expansions and smartening.
- Electricity reaches a 36-39% share in 2050 in decarbonisation scenarios (almost doubling from the current level). Decarbonisation in 2050 requires an almost carbon free electricity sector in the EU and around 60% CO_2 reductions by 2030.
- Significant energy efficiency improvements happen in all decarbonisation scenarios. One unit of GDP in 2050 requires around 70% less energy input compared with 2005. The average annual improvement in energy intensity amounts to around 2.5% pa.
- The share of renewables rises substantially in all scenarios, achieving at least 55% in gross final energy consumption in 2050.
- The increased use of renewable energy as well as energy efficiency improvements require modern, reliable and smart infrastructure including electrical storage.
- Nuclear has a significant role in decarbonisation in Member States where it is accepted in all scenarios (besides Low nuclear and High RES), with the highest penetration in case of CCS delay.
- CCS contributes significantly towards decarbonisation in most scenarios, with the highest penetration in case of problems with nuclear investment and deployment. Developing CCS can be also seen as an insurance against energy efficiency, RES and nuclear (in some Member States) delivering less or not that quickly.
- All scenarios show a transition from high fuel/operational expenditures to high capital expenditure.
- The costs of such deep decarbonisation are low in all scenarios given lower fuel procurement costs with cost savings shown mainly in scenarios relying on all four main decarbonisation options.
- Costs are unequally distributed across sectors, with households shouldering the greatest cost increase due to higher costs of direct energy efficiency expenditures in appliances, vehicles and insulation.