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Analysis of selected climate protection scenarios for European countries

Substudy Report – 2. Revised Edition

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Analysis of selected climate protection scenarios for European countries

Substudy Report – 2. Revised Edition

by

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Summary

Developing long-term visions of future economies is crucial for starting a transformation into a decarbonised future. More recently several European countries have started this process by developing ambitious decarbonisation scenarios. This paper presents a detailed analysis of six country studies, namely France, Italy, Poland, Sweden, United Kingdom, and Germany. It also provides the methodology chosen to analyse the six studies as well as a first comparison. Based on national circumstances, political orientation and differences in national starting points the scenarios differ from each other in the targeted ambition, the methodological approach and the (sectoral) coverage of the studies.

1 Introduction

Developing long-term visions of future economies is crucial for starting a transformation into a decarbonised future. In recent years, several European countries have started this process by developing ambitious decarbonisation scenarios. Based on national circumstances, political orientation and differences in national starting points, the scenarios differ from each other in the targeted ambition, the methodological approach and the coverage of the studies. In this paper, we present a detailed analysis of six country studies (see Table 1).

The six studies were identified from a longer list of low decarbonisation studies for European countries. The choice of studies was based on a stepwise process:

- Step 0: The studies have to fulfil the following conditions:
  - Provide enough detail
  - Cover at least electricity, heat and transport
  - No older than five years
- Step 1: The scenarios in the study should meet the following targets:
  - Annual per-capita emissions of 2t CO2e by 2050
  - Reduction of annual greenhouse gas (GHG) emissions by at least 90% below 1990 levels by 2050
  - Reduction of annual energy-related CO2 emissions by at least 90% below 2010 levels by 2050
  - Reduction of final energy consumption by at least 40% below 2010 by 2050
  - 100% electricity from renewable energies by 2050

The fit of the studies with the criteria introduced above was determined using a scoring system, with a higher scoring indicating a better fit.

- Step 2: The countries should show that a political process is in place for a 2050 climate strategy
- Step 3: The chosen set of studies should cover the span of sub-regions within Europe
- Step 4: If possible, the chosen set of studies should cover a study from the Deep Decarbonisation Project and a study from the Greenpeace energy [r]evolution.

An overview of the assessment of the different studies and countries is provided in the Appendix. This paper presents the methodology chosen to analyse the six studies. Moreover, it presents the findings of the respective study analyses of each country as well as offering a first comparison.[1]

1 In this study, we use the following definitions/assumptions: per-capita emissions: total GHG emissions per capita if available, otherwise the total energy-related CO2 emissions per capita; total GHG emissions: total emissions of all GHGs including emissions from international transport and land use whenever included in the study; energy-related CO2 emissions: total CO2 emissions of the sectors residential, tertiary, industry, transport and energy supply excluding process-related industrial emissions; final energy consumption: the final energy use in the sectors residential, tertiary, industry and transport including ambient heat and international aviation but excluding international shipping;share of renewable electricity: The share is calculated with regard to the electricity generation (not electricity consumption). The reader should be aware that the use of this common definitions and assumptions can lead to certain deviations between the figures shown in the evaluated studies and those shown here.

Table 1: Overview of country studies analysed

Country	Study	Sectors / Gases	Annual per capita emissions in 2050	GHG emissions 1990 - 2050	Energy-related CO_2 emissions 2010 -2050	Final energy consumption 2010 - 2050	Share of RES in electricity mix in 2050
France	Association/Institut négaWatt, „Scenario négaWatt 2011 – 2050“, 2013	All sectors except LULUCF / CO_2, partly CH_4, N_2O	1.2	- 84%	- 93%	- 57%	99%
Germany	Oeko Institute/Fraunhofer ISI, „Climate Protection Scenario 2050 – second round“, 2015	All sectors/ all gases	0.8	- 95%	- 96%	- 51%	96%
Italy	SDSN/IDDRI "Pathways to deep decarbonisation in Italy. IT 2015 Report", 2015	Energy / CO_2	1.1	n/a	- 83%	- 43%	93%
Poland	WISE/Institute for Sustainable Development, "2050.pl - the journey to the low-emission future", 2013	All sectors except LULUCF / all gases	4.9	- 63%[2]	- 53%.	- 3%	41%
Sweden	IVL Swedish Environmental Research Institute, "Energy Scenario for Sweden 2050", 2011	Energy / CO_2	0.7	n/a	- 85%	- 33%	99%
UK	Centre for Alternative Technology, "Zero Carbon Britain - Rethinking the Future", 2014	All sectors / all gases	0.0	- 100% (already by 2030)	- 99% (already by 2030)	- 57% (already by 2030)	100% (already by 2030)

[2] The study contains statements on how to achieve a reduction of 80%, but no scenario with sufficient details.

2 Methodology for study analysis and comparison of studies

To analyse the national studies, different aspects of the studies were looked at in detail. They include design aspects of the scenarios, levels of ambition, main outcomes, framework parameters, but also models applied, data used and objectives of the studies. The aspects covered were grouped into the following blocks:

- General information on the study itself: includes the name and link to download the study as well as the author and the sponsor of the study
- Coverage of the study: contains information on focus country/ countries, sector coverage as well as gases coverage
- Objectives and main results: covers the type of study, the main objectives, robust as well as less certain outcomes, lessons learned and main challenges
- Modelling information and input parameters: contains information on technology options, structural changes, multilateral dimension/ EU integration and whether long-term challenges are taken into account in the study; it further covers data sources for the main input parameters and information on the modelling timeframe and the models applied
- Framework parameters & key outcomes: provides information on main assumptions (population, GDP, oil price, CO_2 price) and key outcomes in total as well as by sectors (energy, buildings, transport, industry, LULUCF, agriculture and waste)[3]

The main source of information was the studies published. In addition, where available, background information was collected from the authors of the studies via telephone or email. Moreover, some information could be retrieved from the authors at a workshop organized in the context of this project that took place in Berlin in May 2016.

3 In the following, all parameters are evaluated for the period 2010 – 2050 to increase the comparability of the scenario studies. The base year 2010, however, may lead to deviations from the statements in the evaluated studies themselves.

3 Analysis of the country studies

France – Scenario négaWatt 2011-2050 (2013)

Table 2: Overview of the setup and outcomes of the négaWatt 2050 scenario

Country	Greenhouse gases covered	Sources covered	GHG emissions without LULUCF 2010 – 2050	Energy-related CO_2 emissions 2010 - 2050	Final energy consumption 2010 - 2050	Share of RES in electricity generation in 2050
France excl. DOM-COM	CO_2, partly CH_4 & N_2O	Energy, Processes, Agriculture	- 83%	- 93%	- 55%	99%
CCS & CO_2 removal	**Technology characteristics**	**Behavioural / structural changes**	**Multilateral considerations**	**Sector coupling**	**Economic effects**	**2°C compatibility**
not included	Nuclear phase-out; extensive biomass; no new technology	included for all sectors	Electricity im-/exports	E-mobility & power-to-gas (methane)	impacts on jobs but not on welfare	yes
Year	**Population (in millions)**	**GDP (in bn EUR of 2010)**	**Crude oil price (in USD / bbl of 2010)**	**CO_2 price (in EUR / tCO_2 of 2010)**	**Annual p.c. emissions (in t CO_2e)**	**GHG emissions (in Mt CO_2e)**
2010	62,9	n/a	n/a	n/a	8.2	514.2
2030	+ 9%	n/a	n/a	n/a	n/a	n/a
2050	+ 15%	n/a	n/a	n/a	1.2	87.4
Level of ambition	**Energy conversion**	**Buildings**	**Transport excl. international bunkers**	**Industry**	**Agriculture + Waste**	**LULUCF**
GHG emissions 2010 - 2050	- 83%	- 96%	- 91%	n/a (CO_2 -92%	- 50%	n/a
Share in 2050 GHG emissions without LULUCF	n/a (CO_2 3%)	n/a (CO_2 21%)	n/a (CO_2 54%)	n/a (CO_2 19%)	n/a (CO_2 2%)	n/a

The négaWatt 2050 scenario is a normative feasibility study, the main objectives of which are 1) to provide a sustainable pathway towards a low-carbon France with 100% renewable energies and 2) to show the possibility of a step-by-step implementation of an energy transition. The study was funded and authored by the NGO négaWatt, a France-based association that provides studies and policy recommendations on energy efficiency and renewable energy. The scenario focuses on the decarbonisation of the energy system, but also provides information on the reduction of all kinds of GHG emissions in the agricultural sector by adapting results from the "Afterres2050" scenario - a scenario for agriculture and sustainable land-use - developed by the NGO Solagro. The setup and outcomes of the négaWatt 2050 scenario are assessed below. An overview is provided in Table 2.

Setup

The négaWatt 2050 scenario assumes a mainly self-sufficient French energy sector with limited imports and exports. Imports and exports of goods are assumed to continue, but neither the role of neighbouring countries nor an effort-sharing within the EU is addressed. The study assumes no major technological breakthroughs, focussing instead on mature and close-to-mature mitigation options with the aim to provide a robust transition pathway that is open to positive surprises. Furthermore, no direct link between energy and economy is assumed to avoid a lock-in in today's economics. Most importantly, the study assumes that lifestyles change significantly based on health and sustainability considerations. In particular, the development of the energy system is modelled by initially looking at sufficiency of demand in every sector, then at energy efficiency and only in the last step at an energy supply based on renewable energies. The study excludes the use of nuclear, carbon sequestration and storage (CCS) and shale gas to reflect environmental and safety concerns.

The modelling timeframe of the scenario is 2010 to 2050. Technology-specific bottom-up models are applied to explore the development of energy demand in the buildings, industry and transport sector. In order to balance electricity generation with demand, an hourly simulation model without cost optimization is run. For agriculture, waste and LULUCF, existing model results have been used. Economic impacts of the transition pathway developed are analysed based on the application of two different macroeconomic models. The underlying demographic and economic data is based on national statistics.

Main results

The négaWatt 2050 scenario addresses compliance with the 2°C target. The overall emission reduction of 83% between 2010 and 2050 and the resulting per capita emissions of 1.2 tons of CO2 equivalents per annum are in line with the contribution required from France, if the remaining emission budget is split proportional to population. Neither a possibly higher level of ambition nor further reductions of emissions after 2050 are discussed.

The study provides robust evidence that it is technically feasible to implement an energy transition of a country like France to almost 100% renewables by 2050 based on existing and emerging solutions. The study finds that the substitution of fossils and nuclear by renewables requires a more than 50% reduction in final energy consumption by 2050 and that such a level of reduction in energy consumption needs to mobilize both sufficiency and efficiency solutions. In a socio-economic impact study coupled to the scenario, there is some evidence that the négaWatt scenario leads to social and economic benefits by creating a net surplus of jobs. However, the costs and other welfare impacts of the scenario are not addressed quantitatively, but are only discussed vaguely. With regard to agriculture and land use, the study suggests that a reduction by a factor 2.5 seems to be the maximum reachable for GHG emissions.

Lessons learned from the modelling exercise concern the phase-out of nuclear energy and the use of biomass. The study indicates that the shutdown of the last nuclear power plants should take place between 2030 and 2035 in order to have sufficient renewable capacity in place while avoiding over-ageing of nuclear plants. Moreover, the study suggests that a successful energy transition foremost requires a modern biomass exploitation system due to the importance of heating buildings. As a main challenge, the study identifies the need to permanently ensure an instantaneous balance of the electricity grid, as a significant share of renewable sources cannot be directly controlled. Thus, the scenario makes use of a coupling of sectors via power-to-gas technologies. The sector results are presented in more detail in the following.

Energy conversion: Today, French power generation is dominated by the use of nuclear power (74% of electricity generation). A large share of heating of buildings is based on electricity. Electricity generation from fossil fuels plays only a minor role (coal share 4%). Accordingly, the use of coal is already phased out by 2020 in the négaWatt 2050 scenario, while the use of nuclear power continues until 2033. Gas plants remain part of the system to back-up volatile renewable, but natural gas is successively replaced by bio- and syngas. The share of renewable energies increases from 15% in 2010 to 99% in 2050. The expansion focuses on PV and wind power (both onshore and offshore), which have the largest potentials, but also includes relevant shares of biogas, hydro and marine power. With regard to structural changes, coupling of the different energy grids is assumed. In particular, the generation of methane via power-to-gas technologies rises to 47 TWh from 2020 to 2050. The importance of the roll-out of smart grids is also emphasized. Compared to 2010, the use of primary energy decreases by 66% and the emissions from the energy sector are reduced by 83% by 2050. However, the remaining share in total CO2 emissions in 2050 is only 3% because emissions already start out at a low level.

Buildings: Both for households and the tertiary sector, the major contributions stem from thermal insulation of new and existing buildings, efficiency of appliances and the use of biomass for heating purposes, while the use of solar-thermal and geo-thermal energy is also found to be important. Structurally, stabilization of household sizes and less urban sprawl is assumed. The rate of renovations of both households and tertiary area increases to 2.4% and 2.5% respectively until 2030 and only reduces to 0.8% for households between 2040 and 2050. Compared to 2010, the use of heating energy in buildings decreases by 49% and the share of renewables is maximized by the use of biomass. In total, the emissions from the buildings sector are reduced by 96% by 2050. The resulting share in total CO_2 emissions in 2050 is 21%.

Transport: Structural changes are considered the key to emission reductions in the transport sector. Both a modal shift and the reduction of transport distances based on improved urban planning and the relocalisation of industries is assumed. The mean travel distance decreases from 19 to 15 thousand kilometers per capita between 2010 and 2050. The share of public transport and rail increases from 12% to 33% in individual mobility and from 11% to 40% in transport of goods respectively. In addition, increased energy efficiency of, in particular, freight traffic and the expansion of e-mobility are found to be important. Biofuels are also included, though a preference with regard to the use of biomass is given to heating purposes. Compared to 2010, the final energy use of transport decreases by 64% and the share of electricity increases to 14%. In total, the emissions from the transport sector are reduced by 91% by 2050. However, the remaining share in total CO2 emissions in 2050 is still 54%.

Industry: The structure of industry is assumed to change based on sufficiency consideration with large reductions of material consumption (e.g. up to 40% of cement). Furthermore, the expansion of recycling is found to provide a significant contribution to the reduction of emissions. The recycling quotas for steel and aluminium are assumed to increase to 90% and 86% respectively. Fuel substitution in cogeneration plants, in particular the use of biomass and waste heat, also plays an important role. Compared to 2010, the final energy use of industry decreases by 52%. CO2 emissions are reduced by 92%. The resulting share in total CO2 emissions in 2050 is 19%. Process-related emissions are not covered in detail. Hence, the total reduction of emissions from the industry sector cannot be assessed.

Agriculture and waste: An important prerequisite for the development of the agricultural sector is that food consumption changes based on health considerations. In particular, meat consumption is reduced by almost 60% from 2010 to 2050. The share of biological farming increases to 50% in 2050, while the other 50% also becomes better integrated by a reduction of overconsumption, optimization of uses and the reuse of waste. Furthermore, animal feedstocks rapidly decrease, in particular because of a reduction of meat consumption by 56%. Compared to 2010, the emissions from the agriculture and waste are reduced by 50% by 2050. The resulting share in total CO2 emissions in 2050 is only 2%, but the other remaining GHG emissions are more than twice as large as the total CO2 emissions.

LULUCF: Emissions from land use and forestry area not covered in négaWatt 2050 scenario.

Germany – Climate Protection Scenario 2050 – second round, (2015)

Table 3: Overview of the setup & outcomes of the climate protection scenario 2050 – second round, 95% reduction

Country	GHGs covered	Sources covered	GHG emissions without LULUCF 2010 - 2050	Energy-related CO_2 emissions 2010 - 2050	Final energy consumption 2010 - 2050	Share of RES in electricity generation in 2050
Germany	All Kyoto GHGs	All sectors including LULUCF & intern. bunkers	- 93%	- 96%	- 51%	96%
CCS & CO2 removal	**Technological characteristics**	**Behavioural / structural changes**	**Multilateral considerations**	**Sector coupling**	**Economic effects**	**2°C compatibility**
BECCS included	Nuclear phaseout; biomass limits; new industrial processes	change in nutrition and mobility patterns; no change in industry structure	Electricity im-/exports	E-mobility & power-to-gas/ liquids	Exogenous analysis of effects	yes
Year	**Population (in millions)**	**GDP (in bn EUR of 2010)**	**Crude oil price (in USD / bbl of 2010)**	**CO2 price (in EUR / tCO2 of 2010)**	**Annual p.c. emissions* (in t CO2e)**	**GHG emissions* (in Mt CO2e)**
2010	80.6	2’496	n/a	15	12.2	986
2030	- 5%	+ 21%	128	87	5.4	408
2050	- 8%	+ 36%	195	200	0.8	59
Level of ambition	**Energy conversion**	**Buildings**	**Transport excl. international bunkers**	**Industry**	**Agriculture + Waste**	**LULUCF**
Reduction in GHG emissions 2010 - 2050	95%	96%	98%	98%	53%	n/a (364%)
Share in 2050 GHG emissions without LULUCF	27%	8%	4%	4%	56%	- 39%

* Including emission sources and sinks from LULUCF

The Climate Protection Scenario 2050 develops ambitious climate protection scenarios for Germany and analyses measures and strategies to reach those targets. The study is target-oriented, i.e. it starts off with the target values and develops the measures necessary to reach those targets. The study includes information on all GHG-relevant sectors including process emissions from industry, fugitive emissions from the energy sector, agriculture, waste and LULUCF as well as emissions from international shipping and aviation. By covering all sectors reported under the UNFCCC, the scenario provides a complete picture of all GHG sources relevant under international reporting. Three scenarios with different levels of ambition (current measures, 80% reduction and 90/95% reduction) are being analysed over a timeframe of 6 years and results are being compared between different ambition levels as well as between different modelling rounds. The study was funded by the German Ministry for the Environment and authored by Oeko-Institut and Fraunhofer ISI, two independent research organizations. The setup and outcomes of the Climate Protection Scenario 2050 – second round, 95% reduction scenario are assessed below. An overview is provided in Table 2.

Setup

The starting point for the Climate Protection Scenario 2050 – second round, 95% reduction was a target of 95% GHG reduction by 2050. Starting from there, energy and emission reductions in all sectors are determined and measures identified to reach that goal. The scenario allows the development of new major technologies such as CCS in industry or innovative alternative production processes. Furthermore, it takes into account rates of reinvestments in industry and buildings to determine the transition of the different sectors.

While a significant change in consumption patterns is assumed for mobility and nutrition, sufficiency measures are not directly discussed for other sectors, in particular private consumption other than nutrition. As a result, production patterns in industry follow current trends and assumptions on resource efficiency and recycling rates rather than assumptions on consumption patterns.

The modelling timeframe of the scenario is 2010 to 2050. Technology-specific bottom-up models are applied to explore the development of emissions and energy demand in all major sectors. Underlying data are taken from national statistics and UNFCCC inventories.

Main results

The Climate Protection Scenario 2050 – second round, 95% reduction run provides a highly ambitious decarbonisation scenario for Germany. It covers all sectors reported under the UNFCCC, including emissions from agriculture, waste and LULUCF and international bunkers. Of the remaining 59 Mt CO2e in 2050, around 40 MtCO2e are required by the agriculture and waste sectors, despite ambitious reductions in those sectors. Hence, an almost complete decarbonisation of all energy sectors is required. Further emission reductions after 2050 are not discussed.

The scenario shows that to reach those reductions significant interactions are required between sectors. In particular, the demand for electricity increases significantly after 2030 to decarbonize the transport sector. CCS is applied in industry only, allowing a significant reduction of process emissions, but also a compensation of remaining process emissions from industry. With 41 Mt CO2e stored in 2050, the availability of CCS is key to reaching the ambitious reduction levels. Use of biomass is limited to a sustainably available amount from within Germany.

The study further shows that targets for 2020 and 2040 from the German energy concept are not compatible with reaching 95% reduction by 2050. Significantly more ambitious emission reductions of 65 to 70% and 80 to 85% reductions by 2030 and 2040 respectively are necessary to reach those targets. The targets for renewable energies and energy efficiency are also significantly exceeded in the 95% reduction scenario.

Energy conversion: The energy sector faces an almost complete decarbonisation while at the same time demand for electricity from other sectors increases significantly from 2030 onwards despite highly ambitious energy efficiency assumptions. In 2050, gross electricity consumption increases by 27% compared to 2010 and reaches a level of 778 TWh. New consumers make up 44% of electricity consumption, of which 75% are going into the transport sector. The share of renewables in electricity generation increases from 16% in 2010 to 96% in 2050. Wind and photovoltaic are the dominating technologies. A small amount of natural gas and waste are the only remaining fossil fuels. CCS is not applied in the utility sector. Import of electricity only covers around 1% of electricity demand. Power-to-X technologies are particularly important for the transport sector providing methane (capacity of 50GW) and liquid fuels (30GW). Primary energy consumption decreases by 55% between 2010 und 2050. The share of renewables in gross final energy consumption increases to 97% in 2050. In total, GHG emissions in the energy sector are reduced by 96% by 2050 compared to 2010. Emissions from electricity generation are 0Mt CO_2e. Remaining emissions stem from heat generation, refineries and fugitive emissions from the energy sector.

Buildings: Both for households and the tertiary sector, the major contributions stem from thermal insulation of new and existing buildings, efficiency of appliances and the use of renewable energies for heating purposes. The rate of renovations of households increases from 1.6% p.a. in 2010 to 4,8% p.a. in 2050, with an average rate 3.1%. Compared to 2010, the use of final energy in buildings decreases by 57%. The share of renewables used for district heating purposes increases from 8% in 2010 to 62% in 2050. In total, the emissions from the buildings sector are reduced by 96% between 2010 and 2050.

Transport: Structural changes - not a reduction of mobility and transport - are considered the key to emission reductions in the transport sector. Public transport, walking and cycling are major modes of transport in cities. Public and rail have a share of 23% in individual transport. The share of rail transport in freight transport increases to 38% in 2050. Electric vehicles are used for both individual mobility and freight transport. In addition, from 2030 onwards electricity-based fuels are also used to reduce the need for biomass. In total, final energy use in the transport sector decreases by 73% between 2010 and 2050. In this case, direct use of electricity makes up for 60%. Together with the electricity demand for power-to-liquid, 350 TWh electricity are needed for the transport sector in 2050. GHG emissions are reduced by 98% between 2010 and 2050.

Industry: Gross value added, which is the basis for the development of production in the industry sector, is assumed to increase by 0.7% p.a. on average between 2010 and 2050. Production in industry changes due to two reasons: on the one hand, recycling and secondary production routes become more important (e.g. steel, non-iron metals, paper). On the other hand, total production decreases in the iron and steel sector and in the cement sector in particular (which is compensated by a decrease of the clinker factor for cement), while production of chemicals and plastics increases between 2010 and 2050. Several new production technologies such as CCS in industry but also innovative production technologies e.g. in the cement sector are assumed to be ready for the market by 2030. Final energy demand in industry decreases by 40% between 2010 and 2050. Energy demand is covered by electricity, biomass and low amounts of district heating and coal. To reduce process emissions, CCS is applied in industry. It allows storage of 41Mt CO2 in 2050. The application of biomass CCS reduces energy-related emissions in industry to - 8.3 Mt CO2e in 2050 (without district heating emissions), which further compensates for the remaining process emissions in industry (5.3 Mt CO2e). In total, the emissions from the industry sector (including emissions from product use) are reduced by 98% compared to 2010.

Agriculture and waste: An important prerequisite for the development of the agricultural sector is that food consumption changes based on health considerations. In particular, meat consumption is reduced by 60% from 40 to 16kg per person and per year between 2010 to 2050. Also, the share of cattle in livestock decreases significantly while the livestock of poultry increases slightly. Dairy cows can be significantly reduced due to an increase in milk yield. The share of biological farming increases to 25% in 2050. Compared to 2010, the emissions from agriculture are reduced by 48% to 35,5 Mt CO_2e in 2050. Agriculture is the main emitter in 2050 with a share of 51% of total GHG emissions in 2050. Emissions from waste are reduced by 75% by 2050.

LULUCF: The sector land use and forestry is assumed to present a carbon sink in 2050. In 2050, 23Mt CO2e are assumed to be stored. In contrast, LULUCF represented a net-GHG source emitting around 9Mt CO2e in 2010. To reach the level of carbon storage, ambitious reductions of sources in the LULUCF sector are assumed. Increases of sinks (i.e. forests) are not yet included.

Italy – Pathways to deep decarbonization in Italy, (2015)

Table 4: Overview of the setup and outcomes of the pathways to deep decarbonization – Italy, demand reduction scenario

Country	GHGs covered	Sources covered	GHG emissions without LULUCF 2010 – 2050	Energy-related CO_2 emissions 2010 - 2050	Final energy consumption 2010 - 2050	Share of RES in electricity generation in 2050
Italy	CO_2	Energy, processes	n/a	- 83%	- 43%	93%
CCS & CO2 removal	**Technology characteristics**	**Behavioural / structural changes**	**Multilateral considerations**	**Sector coupling**	**Economic effects**	**2°C compatibility**
Limited use of CCS, no removal	No nuclear, extensive biomass, no new technology	Contraction of energy-intensive industries + lifestyle changes	Electricity im-/exports	E-mobility	yes	yes
Year	**Population (in millions)**	**GDP (in bn EUR of 2010)**	**Crude oil price (in USD / bbl of 2010)**	**CO2 price (in EUR / tCO2 of 2010)**	**Annual p.c. emissions (in t CO2)**	**CO2 emissions (in Mt CO2)**
2010	60.3	1691	n/a	n/a	7.1	429
2030	+ 5%	+ 26.5%	n/a	n/a	4.0	253
2050	+ 5%	+ 64%	n/a	n/a	1.3	84
Level of ambition	**Energy conversion**	**Buildings**	**Transport excl. international bunkers**	**Industry**	**Agriculture + Waste**	**LULUCF**
Reduction in GHG emissions 2010 - 2050	98%	97%	73%	51%	n/a	n/a
Share in 2050 GHG emissions without LULUCF	4%	3%	41%	52%	n/a	n/a

The Pathways to Deep Decarbonization (DDP) – Italy scenario develops three different pathways for Italy to reduce its CO2 emissions by 80% by 2050 (compared to 1990 levels): the CCS+ Renewable scenario, the Energy Efficiency scenario, and the Demand Reduction scenario. The scenarios only cover CO2 emissions from energy and processes. The study is target-oriented, i.e. it starts off with the maximum level of CO2 emissions and develops different approaches for addressing key challenges in the necessary transformation of the energy system. In a second step, the study provides a macroeconomic assessment of the impacts of the transformative pathways on the economy and society, investment costs, income and employment. The study was commissioned by Sustainable Development Solutions Network (SDSN) and Institute for Sustainable Development and International Relations (IDDRI) as part of the Deep Decarbonization Pathways Project. The project develops pathways for how countries can change their energy system to become low-carbon economies. The Italian study was written by Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and the Fondazione Eni Enrico Mattei (FEEM). The following analysis focuses on the Demand Reduction scenario since it achieves the highest level of CO2 emission reductions by 2050. An overview is provided in Table 4.

Setup

The starting point for the DDP - Italy scenario is a target of minimum 80% CO2 reduction by 2050 (from 1990 levels). Starting from there, the main trends for energy supply and final demand and available technologies are assessed and quantified, using the energy-system model TIMES-Italy. Assumptions on public transport infrastructure, grid infrastructure and related investment costs are exogenous. The model is not limited to already commercially available technology but allows the development of new major technologies such as CCS (to a limited extent) or innovative alternative production processes. The Demand Reduction scenario envisages a scale-down of energy-intensive industries, and lifestyle changes.

The macroeconomic impact of the three different scenarios is evaluated with the top-down models GDyn-E and ICES CGE. Underlying data are taken from national statistics and the EU reference scenario from 2013. The modelling timeframe of the scenario is 2010 to 2050.

Main results

The DDP – Italy Demand Reduction scenario achieves a reduction in CO2 emissions from energy and processes of 83% between 2010 and 2050. The remaining CO2 emissions in 2050 correspond to 1.3 t per capita. Other sectors and further emission reductions after 2050 are not discussed. Final energy consumption is reduced by 43% between 2010 and 2050 due to efficiency improvements as well as changes in industrial production and lifestyle changes. The scenario shows that to reach those reductions significant interactions are required between sectors. In particular, the demand for electricity increases considerably to decarbonise the transport and building sector. Electricity generation is almost completely decarbonised in the scenario and renewables reach a share of 93% in electricity generation by 2050. CCS is applied only to a limited extent in industry, and at coal power plants.

Energy conversion: The energy sector faces an almost complete decarbonisation by 2050. In total, GHG emissions in the energy sector are reduced by 98% by 2050 compared to 2010. Remaining emissions from electricity generation are 2.7 Mt CO2. In 2050, final electricity consumption increases by 23% compared to 2010 and reaches a level of 368 TWh. This is mainly driven by increasing demand in the building and transport sectors from 2030 onwards. At the same time, the share of renewables in electricity consumption increases from 26% in 2010 to 93% in 2050. Solar PV, biomass and offshore wind are the dominating technologies. The remaining fossil fuel used is a small amount of coal (most of it combined with CCS technology in 2050) and natural gas. As a result, the emission intensity of electricity generation drops by 99% between 2010 and 2050. Import of electricity covers around 6.5% of electricity demand.

Buildings: CO2 emissions from buildings decrease by 97% between 2010 and 2050. Both for households and the tertiary sector, the major contributions stem from thermal insulation of new and existing buildings, efficiency of appliances and the switch to electricity and renewable energy for thermal purposes. The scenario envisages that by 2050 around 9 million buildings have been retrofitted. Compared to 2010, the use of final energy in buildings decreases by 49%. In the same period, electricity demand in this sector will increase by 29%, especially due to increased use of heat pumps and electric cookers. The increasing demand is only partly compensated by efficiency improvements in electric appliances. The scenario also assumes that energy demand is price elastic and that lifestyle changes will occur as a response to increasing energy prices.

Transport: The scenario assumes both a reduction of person travel kilometres (by around 9%) as a response to increased energy prices and structural changes in both passenger and freight transport. In total, final energy use in the transport sector decreases by 47% between 2010 and 2050. Use of electricity makes up for 17% of the energy demand in 2050. In total, 253 TWh electricity are needed for the transport sector in 2050, which is almost four times the current electricity demand in the sector. This is the result of a shift to electric vehicles and plug-in hybrids (accounting for 90% of road passenger transportation in 2050) as well as a shift from road to rail transport in passenger transport. Public and rail have a share of 21% in individual transport by 2050. For freight transport, there is also a major shift towards rail (17% of Gtonkm in 2050), as well as biofuels and LNG. In total, CO_2 emissions are reduced by 73% between 2010 and 2050.

Industry: Gross value added, which is the basis for the development of production in the industry sector, is assumed to increase by 37% between 2010 and 2050. At the same time, the scenario envisages that energy-intensive industries are down-scaled as a response to high energy prices. Fossil fuels are increasingly replaced by electricity and renewable sources. As a result, final energy demand in industry decreases by 31% between 2010 and 2050. Electricity covers almost half of the energy demand in 2050, together with district heating, biomass, gas and small amounts of solid fuels. CCS in industry is applied to a limited extent from 2040 onwards to store process emissions from the production of non-metallic minerals of around 3.2 Mt CO_2e in 2050. In total, the emissions from the industry sector are reduced to a level of 40 Mt CO_2 , a reduction of 51% compared to 2010. Part of that reduction is also achieved by applying CCS to industry installations.

Poland – 2050.pl - the journey to the low-emission future, (2013)

Table 5: Overview of the setup and outcomes of the 2050.pl - the journey to the low-emission future scenario

Country	GHGs covered	Sources covered	GHG emissions without LULUCF 2010 – 2050	Energy-related CO_2 emissions 2010 - 2050	Final energy consumption 2010 - 2050	Share of RES in electricity generation in 2050
Poland	All Kyoto GHGs	All, except for LULUCF	- 57%	- 53%	- 3%	41%
CCS & CO2 removal	**Technological characteristics**	**Behavioural / structural changes**	**Multi lateral ism**	**Sector coupling**	**Economic effects**	**2°C compatibility**
BECCS in industry & energy sector	Substantial use of biomass & nuclear; no new technology	not included	Electricity imports	limited	yes	no
Year	**Population (in millions)**	**GDP (in bn EUR of 2010)**	**Crude oil price (in USD / bbl of 2010)**	**CO2 price (in EUR / t CO2 of 2010)**	**Annual p.c. emissions (in t CO2e)**	**GHG emissions (in Mt CO2e)**
2010	38.3	586	n/a	15	10.5	402
2030	- 1.3%	+ 83%	n/a	25	9.3	351
2050	- 8.9%	+ 160.9%	n/a	45	4.9	171
Level of ambition	**Energy conversion**	**Buildings**	**Transport excl. international bunkers**	**Industry**	**Agriculture + Waste**	**LULUCF**
Reduction in GHG emissions 2010 - 2050	55%	34%	53%	2%	85%	n/a
Share in 2050 GHG emissions without LULUCF	15%	23%	13%	44%	4%	n/a

The 2050.pl scenario shows different pathways towards a low-emission future for Poland and provides economic and social arguments for modernising the energy demand sectors and diversifying Poland's energy supply. The pl.2050 scenario starts off from possible policy measures and then calculates their effect on energy demand, GHG emissions, GDP and health costs. The study was funded by the European Climate Foundation and authored by the Warsaw Institute for Economic Studies. The setup and outcomes of the pl.2050 scenario are assessed below. An overview is provided in Table 2.

Setup

The starting point for the pl.2050 scenario is the assumption that a low-emission transformation and the necessary modernisation of the economy are closely connected, and that improving efficiency and diversifying the energy mix will secure high levels of economic growth for Poland. The scenario thus does not focus on a GHG emission reduction target, but starts off from potential measures and economic arguments to justify such measures.

The study covers most GHG-relevant sectors, but does not include information on LULUCF or emissions from international shipping and aviation. For the covered sectors (energy, industry, transport, services, households, agriculture and waste), the study develops a reference scenario. A modernisation scenario shows how energy demand could be reduced in the demand sectors, with a focus on specific subsectors (e.g. heavy industry, motorised vehicles). For energy supply, the study provides five alternative scenarios, in addition to the reference scenario: European Coal, French Model, Distributed Integration, Distributed Autarky, and Full Diversification. The most far-reaching scenario in terms of emission reductions, the Full Diversification scenario, will be assessed here. It provides for a combination of all energy sources. The scenario allows the development of new major technologies such as CCS, and nuclear energy, which so far is not in use in Poland.

The modelling timeframe of the scenario is 2010 to 2050. No significant changes in consumption patterns are assumed for mobility and nutrition; production patterns in industry follow current trends. Instead, the scenario envisages improvements in resource efficiency and recycling rates.

Main results

The pl.2050 scenario achieves a reduction of GHG emissions of 63% between 2010 and 2050, and shows that such a pathway is not only economically feasible, but would bring about significant economic and health benefits. The implementation of the proposed scenario is expected to result in an increase in GDP of between 1 and 3.5% in 2050. Final energy demand remains almost stable in the same period, increasing slightly until 2030 before dropping to 97% of 2010 levels in 2050. To reach this level of emission reductions, considerable efficiency improvements in the buildings, transport, agriculture and waste sector are required, and minor reductions in energy demand in heavy industry. Emission reductions in the energy sector are the result of a mix of renewable sources, nuclear energy, and coal, gas and biomass installations combined with CCS. Further emission reductions after 2050 are not discussed, but the scenario suggests additional policy measures to achieve an 80% reduction against 1990 levels by 2050.

Energy conversion: Emissions in the energy sector will decrease by 85% by 2050 to 24 Mt CO2e. This can mainly be ascribed to the decline in emission intensity, which decreases by 91%. The Full Diversification scenario envisages a balanced mix of all available technologies. Large-scale renewable energy sources will account for 41% of the electricity mix. Additionally, 25% will stem from "distributed sources", i.e. small installations run by renewable sources but also waste, oil and gas. Coal power plants would still contribute 17% of electricity - CCS technology at these plants would start in 2030 and reduce emissions from coal-fired power plants. The first nuclear power station would start operating in 2035. Around 15% of electricity would be imported in order to support peak and reserve capacity, a significant increase in comparison to today where around 6% of electricity is imported.

Buildings: Emissions from the building sector will decrease by 34% between 2010 and 2050. The renovation rate for households drops from around 1.5% to 0.68% in 2050 (for non-residential buildings from 0.93% to 0.42%). Higher standards for thermal efficiency improvements and promotion of low-energy and passive buildings are expected to lead to a drop in heat demand in buildings per m^2 by 62%. However, this is partly levelled out by the increase in electricity demand, which almost doubles, despite efficiency improvements in white goods and consumer electronics. This is partly due to an increasing number of households and appliances, but mostly attributable to the installation of electric heating and air-conditioning.

Transport: The scenario only looks at road transport, which is identified as the main challenge in the transport sector – the total mileage per year is expected to almost triple between 2010 and 2050. The scenario envisages only technological changes and changes in the fuel mix, not a reduction of transport km. Developing attractive alternatives to private vehicle transport is also considered an important way to reduce emissions, but is not considered in the scenario due to the difficulty of quantifying behavioural changes. The scenario envisages technological improvements such as more efficient combustion engines and reduced weight. Furthermore, by 2050 40% of the passenger vehicle fleet will run on hybrid or plug-in hybrid engines. The remaining passenger cars and other vehicles will use gas or petrol, though using more efficient combustion engines, and with an increased share of biofuels in the fuel mix (around 24% in 2050). Electricity used in electric makes up a share of 3% in 2050.

Industry: The scenario focuses on emission reduction potential in the most energy-intensive sectors: iron and steel industry, cement industry and chemical industry. Electricity use in industry is expected to increase considerably, due to structural changes in approaching levels in Western Europe. This is partly outweighed by measures such as increased heat recovery in iron and steel, cement and chemical plants, and overall efficiency improvements in production processes. GHG emissions from industry are expected to remain almost stable between 2010 and 2050. CCS technology in industry is considered as too costly and environmentally controversial and thus not included – although it is recognised that this technology would surpass all the other measures envisaged in the scenario in terms of emission reductions.

Agriculture and waste[4]: Emissions from agriculture drop by 97% between 2010 and 2050. Reasons for this drastic decrease include more sustainable farming as well as using crop residues for fertilizing and biogas production, which would result in significant fuel savings. Additionally, crop rotation, no-tillage, and leaving residues on the ground would help to capture carbon. Reduction of animal bowel gases is not envisaged in the scenario. To reduce waste, the scenario proposes measures to incentives waste recovery and recycling, and combustion of landfill gases. These measures are expected to result in emission reduction of 22%.

[4] The emission reductions in these sectors represent those provided in the study. It is, however, not transparent how these very ambitious emission reductions are linked to the measures provided in the report.

Sweden – Energy Scenario for Sweden 2050, (2011)

Table 6: Overview of the setup and outcomes of the Energy Scenario for Sweden 2050

Country	GHGs covered	Sources covered	GHG emissions without LULUCF 2010 – 2050	Energy-related CO_2 emissions 2010 - 2050	Final energy consumption 2010 - 2050	Share of RES in electricity generation in 2050
Sweden	CO_2	Energy sector	n/a	- 85%	- 33%	99%
CCS & CO_2 removal	**Technological characteristics**	**Behavioural / structural changes**	**Multi lateral ism**	**Sector coupling**	**Economic effects**	**2°C compatibility**
Not included	nuclear phaseout, strict biomass criteria; no new technology	not included	Energy imports allowed as long as balance is kept	E-mobility	yes	n/a
Year	**Population (in millions)**	**GDP (in bn EUR of 2010)**	**Crude oil price (in USD / bbl of 2010)**	**CO_2 price (in EUR / t CO_2 of 2010)**	**Annual p.c. emissions (in t CO_2)**	**GHG emissions (in Mt CO_2)**
2010	9.4	n/a	n/a	n/a	5.4	51
2030	+ 12%	+ 44%	n/a	n/a	2.6	27
2050	+ 14%	+ 88%	n/a	n/a	0.7	8
Level of ambition	**Energy conversion**	**Buildings**	**Transport excl. international bunkers**	**Industry**	**Agriculture + Waste**	**LULUCF**
Reduction in GHG emissions 2010 - 2050	n/a	n/a	n/a	n/a	n/a	n/a
Share in 2050 GHG emissions without LULUCF	n/a	n/a	n/a	n/a	n/a	n/a

The Energy Scenario for Sweden 2050 is a backcasting study with the main objective of covering all energy demand from domestic renewable sources while keeping within the carrying capacity of the ecosystem. The study was authored by IVL Swedish Environmental Research Institute and funded by WWF Sweden. The scenario focuses on the decarbonization of the energy system. The setup and outcome of the Energy Scenario are assessed below. An overview is provided in Table 6.

Setup

The Energy Scenario for Sweden 2050 presents an energy sector that is almost completely based on domestic renewable sources. While the study recognizes that interlinkages with neighbouring countries, the EU and global energy system play an important role, the scenario is geographically limited to the energy system in Sweden. Imports and exports are not excluded but assumed to level out. The scenario covers energy supply and demand in transport, industry, household and service sectors, but excludes international aviation and shipping.

The study excludes the use of nuclear and carbon capture and storage (CCS) since they are not considered renewable sources. The use of biomass in the scenario is based on dialogue with WWF; the authors aim to adhere to high environmental standards, reaching beyond the RED standards. Fossil fuels are assumed to be phased out almost completely by 2050 with some remaining coal used in steel production. The study assumes no major technological breakthroughs but instead focuses on mature and close-to-mature mitigation options. It is also assumed that energy efficiency improvements will rapidly be implemented in all sectors.

The modelling timeframe of the scenario is 2010 to 2050, with three checkpoints (2020, 2030, 2040) in the interim. The costs for the main sectoral changes have been calculated based on the Ecofys Energy Scenario.

Main results

The Energy Scenario for Sweden 2050 achieves a switch to nearly 100% renewable energy in 2050. For this purpose, nuclear energy will need to be phased out and the production of energy from renewable sources needs to increase. A small percentage of coal remains in the 2050 mix as the scenario was not able to completely substitute the coal use for steel production. There is a significant electricity surplus in 2020 and 2030, which diminishes in 2040 due to the nuclear phase-out. Energy demand shall decrease in all sectors, which is especially challenging in the transport sector. Primary energy demand will decrease by 49% between 2010 and 2050.

Overall CO2 emission in the energy sector will decrease by 85% by 2050 (against 1990 levels). The report highlights that additional emission reductions could be achieved by stimulating changes in consumption and introducing new technologies. No further reductions of emissions after 2050 are discussed.

The study calculates the costs for the main changes assumed in the scenario and compares them to current costs in the different sectors. If the scenario was implemented, the calculations exhibit significant financial savings in industry, transport and buildings.

Energy conversion: In 2050 29% of electricity will stem from wind power and 21% from solar PV. A small share of other renewable technologies (e.g. wave, algae) is also included in the 2050 mix, as well as 1% from waste, 3% bioenergy and 1% remaining coal and coke used for steel production. The remaining electricity is produced from hydropower, the production levels of which are assumed to remain stable compared to today. Nuclear power, the other main source for electricity in the energy mix today, is assumed to be phased out by 2040.

For district heating, the scenario envisages a phase-out of non-renewable carriers and a slight increase in surplus heat from industry and biofuel production, solar heat and heat pumps. Overall, district heating production is expected to decrease by 28% between 2010 and 2050.

Buildings: Heated area will increase by 0.5% per year, at a quicker pace than population growth. The scenario assumes that all buildings will be renovated once between 2010 and 2050, resulting in a 50% reduction of energy demand. The scenario also expects that heating demand will decrease by around 11% due to climate change between 2005 and 2050. Energy for heating will be sourced exclusively from district heating, heat pumps, biofuels and solar heat in 2050. The need for cooling energy will increase considerably (from 1 to 13TWh between 2010 and 2050), for instance due to climate change and will be mainly covered by absorption cooling by district heating and free cooling. For electricity demand in buildings, the scenario assumes a reduction by 1% per year.

Transport: The main changes in the transport sector are increased railway transport, electric vehicles and the use of renewable fuels. The scenario assumes that the transport of goods will increase by 0.52% per year. Rail transport of goods will cover around 50% in 2050 and the share of road transport will decrease from 55% in 2010 to 40% in 2050. Energy efficiency is assumed to increase by 20-30% between 2010 and 2050, depending on the mode of transport. Use of fossil fuels in road transport of goods will be gradually phased out. In 2050 short distances will be covered mainly with electricity and long distances with biofuels. For passenger transport, the scenario assumes an annual increase of 0.48%. In 2050, 62% of person transport will still be in cars but their energy efficiency is assumed to increase by around 50% - mainly due to a switch to electricity. Overall, in the transport sector natural gas will increasingly be replaced with renewable gases. Biofuels will consist of dimethyl ether, which is partly produced by gasification of black liquor in the pulp and paper industry, biogas and renewable synthetic natural gas.

Industry: In Sweden, the pulp and paper industry -which is energy intensive - accounts for around half of the energy used in industry. The scenario assumes that energy efficiency in this sector will increase by 1% per year and by 1.7% for steam needed for chemical pulp production. Biorefineries for this industry will be introduced to produce electricity and heat. For the other industrial sectors, the study does not consider major changes in the production mix. The scenario envisages that solid and liquid biofuels (e.g. dimethyl ether) increasingly substitute diesel, oil, liquefied petroleum gas and solid fossil fuels. Synthetic natural gas will replace natural gas. In the steel production, 45% of coal is replaced with wood charcoal, but the other 55% of coal will remain in the energy mix.

Bioenergy: The scenario notes that bioenergy has been an important energy source in Sweden but has resulted in growing pressure on forest ecosystems. The scenario envisages an increase in protected forest area and introduction of continued cover forestry practice in order to reduce this pressure. Bioenergy in the scenario is mainly produced from residues and by-products of e.g. industry or agriculture.

UK – Zero Carbon Britain - Rethinking the Future, (2013)

Table 7: Overview of the setup and outcomes of the Zero Carbon Britain scenario

Country	GHGs covered	Sources covered	GHG emissions without LULUCF 2010 – 2030	Energy-related CO_2 emissions 2010 - 2030	Final energy consumption 2010 - 2030	Share of RES in electricity generation in 2030
United Kingdom	All Kyoto GHGs	All sectors	- 94%	- 99%	- 57%	100%
CCS & CO_2 removal	**Technological characteristics**	**Behavioural / structural changes**	**Multi lateralism**	**Sector coupling**	**Economic effects**	**2°C compatibility**
No	no nuclear, but substantial use of biomass	yes	Electricity exports possible	E-mobility & power-to gas	no	yes
Year	**Population (in millions)**	**GDP (in bn EUR of 2010)**	**Crude oil price (in USD / bbl of 2010)**	**CO_2 price (in EUR / tCO_2 of 2010)**	**Annual p.c. emissions*(in t CO_2e)**	**GHG emissions* (in Mt CO_2e)**
2010	62.2		n/a	n/a	10.1	628.5
2030	+ 13%	+ 0%	n/a	n/a	0	0
2050	n/a	n/a	n/a	n/a	n/a	n/a
Level of ambition	**Energy conversion**	**Buildings**	**Transport excl. international bunkers**	**Industry**	**Agriculture + Waste**	**LULUCF**
GHG emissions 2010 - 2030	99%	99%	100%	89%	67%	n/a (862%)
Share in 2030 GHG emissions without LULUCF	3%	2%	0%	32%	63%	-121%

* Including emission sources and sinks from LULUCF

The Zero Carbon Britain – Rethinking the Future (ZCB) report develops a highly ambitious climate protection scenario for the United Kingdom. The study is target-oriented: it starts off from the objective of keeping the UK's GHG emissions within its share of the global carbon budget (based on per capita emissions) that would give the world an 80% chance of staying below 2°C. This implies that emissions need to reach a level of net zero by 2030. The study covers all GHGs and all sectors, including process emissions from industry, fugitive emissions from the energy sector, agriculture, waste and LULUCF as well as emissions from international shipping and aviation. By covering all sectors reported under the UNFCCC, the scenario provides a complete picture of all GHG sources relevant under international reporting. The study was authored by the Centre for Alternative Technology. The setup and outcomes of the ZCB scenario are assessed below. An overview is provided in Table 2.

Setup

The scenario provides a vision of how the UK society and economy could become carbon-neutral by 2030. The scenario does not model the pathway towards this vision but offers possible policy measures. The scenario covers all UNFCCC GHGs and all emissions within the UK borders, as well as emissions from international shipping and aviation.

The study assumes a zero growth economy. Per capita output of industrial production is the same as in 2007. The scenario builds on already existing technology only and solutions that could be implemented immediately. It aims to avoid unnecessary expensive or risky solutions and thus rules out nuclear energy and CCS and instead opts for 100% renewable energy. To avoid impacts abroad, the study also excludes the use of international carbon credits, energy imports and livestock imports. At the same time, the study rules out an increase of managed land area in the UK – the necessary land use changes for carbon sequestration, food production and biomass production are based on a redistribution of currently managed area.

The modelling timeframe is 2010 to 2030. Underlying data are taken mostly from national statistics. Economic costs of the scenario are not modelled

Main results

The scenario achieves a reduction of GHG emissions to net-zero by 2030. Energy demand is heavily reduced, especially in the buildings and transport sector. The sectors also experience an increased electrification. Energy supply relies on 100% renewable energy (mostly wind, wave/tidal and biomass). Non-energy emissions are reduced by 61%, and emissions from land use by 74% (including dietary changes, waste reduction, better land management). Remaining emissions (around 45 MtCO2e) are balanced with forests, biochar and silo storage. To achieve this level of emission reductions, major structural changes and behavioural changes are envisaged.

Energy conversion: Electricity is produced 100% from renewable sources, heavily relying on offshore wind energy. Onshore wind, wave, tidal, solar PV, geothermal and hydropower only account for small shares of the electricity mix. To balance supply and demand, the scenario includes short-term storage mechanisms (pumped electricity storage, smart appliances, electric car charging, heat storage), electrolysis units, renewable gas power stations and 60,000 GWh of methane gas storage. In total, emissions from the energy sector are reduced to nearly zero. Remaining emissions of 1.1 MtCO2e stem from methane leakages and management of disused coal mines.

Buildings: Energy demand in buildings is reduced by 34%. Demand for heating energy can be significantly reduced because all new buildings adhere to Passivhaus standards, a mass retrofit of existing buildings is rolled-out, better heating controls are introduced and behavioural changes are induced (reduce average room temperature to 16°C). This reduction is only partly balanced out by the increased population. The remaining demand is mostly met by heat pumps and electricity. Efficiency improvements reduce energy demand for electric appliances by more than 40% and smart appliances and heat stores in buildings make energy demand more flexible. In total, emissions from buildings are reduced by 99%.

Transport: Energy demand from transport decreases by 78% to 155 TWh by 2030 due to structural changes, behavioural changes and reduced mobility. People travel 15% less due to better communication tools and because they live closer to work. They increasingly use of public transport, cycling and walking (33% of passenger transport in 2030) while the occupancy of cars increases to an average of 2 persons per vehicle. 90% of passenger transport on roads and 95% of the rail network is based on electricity – the remaining cars (for longer distances of heavy commercial vehicles) drive on hydrogen or carbon neutral synthetic liquid fuels. Domestic aviation is not envisaged. For international aviation, aircrafts become more efficient, are better managed and switch to biofuel and synthetic liquid fuel made from biomass. But since these improvements have only limited effects and land becomes a constraining factor for biomass production, the scenario envisages that international aviation is reduced by 30%. Freight transport is reduced because energy and more food stems from the UK itself, but only by 5%. Around 20% of this transport is by rail. Heavy goods vehicles are powered with synthetic liquid fuels or hydrogen.

Industry: The scenario assumes that industrial output per capita once again rises to 2007 levels (pre-recession levels) but that efficiency improvements will reduce industry energy intensity by 25%. Final energy demand thus decreases slightly by 6% between 2010 and 2030. However, energy demand is almost completely met by electricity and synthetic/biogas. Industrial process emissions are reduced by around 48% (from 2010 levels). The study suggests using more plant-based building material to decrease demand for steel and cement. However, this is counterbalanced by increasing iron, steel and cement demand for wind farms and other infrastructure. Nevertheless, emissions from iron and steel production will be reduced by around 58% through reuse, recycling, electric arc furnaces, biomass and biogas for heat and top gas recycling. Clinker in cement production is to be replaced with cleaner alternatives. In total, emissions from industry are expected to decrease by 89%.

Agriculture and waste: Agricultural GHG emissions are reduced by 66% (from 2010 levels) to 17 MtCO2e as a result of dietary changes, improved land management and waste reduction. The study envisages that import of food is reduced to 17% of the products (42% in 2010) so as to limit emissions from transport and agriculture abroad. The diet is envisaged to change to more fruits, vegetables, pulses and starchy food, reducing the consumption of meat and dairy products by 59-92%. As a result, 75% of land area can be converted from grazing land to land for other purposes (e.g. biomass, carbon capture, conserved areas). Despite an increasing population, the total food production can be reduced because food waste is halved. Furthermore, nitrogen inhibitors are applied to the soil, which reduce N2O emissions by 38%.

GHG emissions from waste are reduced by 69% (from 2010 levels) to 5.1MtCO2e. Food waste is halved and the rest used for livestock or composted. Methane emissions from wastewater processing and agricultural waste are used to produce energy, using anaerobic digestion. Landfill emissions are expected to reduce by 75%, while emissions from burning waste are expected to remain the same.

LULUCF: The land use and forestry sector is assumed to present a carbon sink in 2030. In 2030, 45 Mt CO2e are assumed to be absorbed – equivalent to the remaining GHG emissions in the scenario including 3 Mt CO2e from land use itself (in 2010, the LULUCF sector only captured 3.9 Mt CO2e). This is mainly achieved by doubling the forest area and capturing emissions in plant-based products used for buildings and infrastructure. Additionally, 50% of peatlands is restored, some wood is turned into biochar and some construction and demolition waste is captured in silo storages.

4 Conclusions

The provided analysis of the six individual country studies allows for a first comparison and assessment.

- Coverage of the studies: While all studies provide ambitious decarbonisation scenarios our analysis shows that there are significant differences in the coverage of the studies. Four of the six studies cover nearly all GHG emissions reported under the UNFCCC (Germany, France, Poland and UK). Here the French study integrates the results of another study for emissions from agriculture and waste. For Italy and Sweden, the study covers exclusively CO_2 and energy-related emissions.
- Modeling approach and transparency: All the studies are partly based on bottom-up or energy system models. However, the information on the models applied is not provided within the study itself in all cases. Moreover, the studies differ in the amount of information they provide. All modeling institutions have been very helpful in providing further underlying data to allow a deeper analysis of the studies.
- Technological characteristics: All but one study rule out the use of nuclear or phase it out before 2050. The Polish study is the only one that opts for nuclear as a mitigation technology. With regard to renewable energies, technology choices differ depending on regional resources and potentials as well as the role of biomass. While the German and Swedish study limit the use of biomass based on sustainability criteria, all other studies make substantial use of biomass. Largely comparable are the levels of reduction of final energy demand (33 – 57%) in all the normative studies. Only the explorative study for Poland shows a reduction of final energy demand by only 3%.
- CCS and CO_2 removal: None of the studies takes into account carbon dioxide removal technologies to a large extent. While the French, Swedish and UK studies have fully excluded CCS, CCS in coal-fired power plants is applied to reduce emissions in the Polish and Italian study. The German study allows CCS in industry to achieve reductions in process emissions necessary to meet the ambitious reduction target of 95%. At the same time, the scenario also includes CCS with biomass (BECCS) as does the Polish study. No CCS is applied in the electricity sector in the German scenario.
- Structural change/ behavioural change: With regards to structural changes, most studies assume that the future industry structure does not change significantly compared to today. The French study takes a closer look at how industry structures could change while taking into account differences in consumption patterns in the future. The French study is also special in that it specifically looks at sufficiency options first before applying efficiency and mitigation measures. Of the other studies, only Germany and UK require behavioural changes, in particular in nutrition to reach the (almost) complete decarbonisation of the economy.
- Time horizon: Except for the UK study, all studies focus on the target year 2050. All studies with the exception of the UK and Poland do not take into account any further emission reductions afterwards. For Poland, additional measures are provided in the report for reductions of 80%. The UK study focuses on 2030 and not 2050, thus reaching decarbonisation a lot earlier than the other studies. Moreover, the UK study is the only study that achieves net-zero emissions in 2030 when including sinks from LULUCF. Hence, no further emission reductions are required after 2030.
- Multilateral considerations: All countries focus on GHG emissions within their borders. Except for the study from Poland, which assumes a significant share of electricity to be imported in 2050, none of the studies uses an intensification of imports to reach the reduction targets. Instead, all studies focus on reaching the reductions domestically and under circumstances comparable to those of today. Also, no synergies from cross-border activities are taken into account in the studies.
- Pathways and policy instruments: Most of the studies focus on designing the decarbonization scenario, but do not yet look at the pathways and policies necessary to reach that scenario. This is different for the German study, where a specific modeling of policies is included as well as for Poland, which focuses on exploring the consequences of certain mitigation policies

- Emission reductions: The studies can be grouped into three groups with regard to overall emission reductions in the scenarios (with regard to the sectoral coverage and the gases covered within the studies). The UK and Germany achieve a reduction of total GHG emissions (excluding LULUCF) by 93 and 94% between 2010 and 2050 (UK: 2030). For the UK, including emissions from LULUCF even results in zero carbon emissions. Italy, France and Sweden focus on emission reductions of 80 to 85% compared to 2010 (energy-related CO_2 emissions for Italy and Sweden), i.e. significantly lower, but yet basically meeting the EU target range of 80 to 95% reduction by 2050. The study from Poland does not meet that target range, only achieving a reduction of total GHG emissions by 57% between 2010 and 2050.
- Sectoral emissions:
  - Energy conversion: In the energy sector, emissions are reduced significantly in all scenarios. Reductions are between 83% in France and 99% in the UK. Even in Poland, where the overall emission reductions are significantly lower than in the other scenarios, energy sector emissions are reduced by 85%. As a result, the energy sector's share in emissions in 2050 is low in most of the scenarios. An exception is the German scenario, where the energy sector makes up about 32% of remaining emissions due to the use of heating networks (which require centralized thermal power stations) and as no CCS is applied to biogas and bio-refineries.
  - Buildings: Even higher emission reductions can be achieved in the buildings sector in all scenarios. Where sector-specific data is available, reduction rates are between 96 and 99% (excepting Poland). In the Polish scenario, where the ambition of the overall scenario is significantly lower, only 34% reductions are achieved in 2050.
  - Transport: Emission reductions in the transport sector are more difficult to achieve from a technological perspective and uncertainties of the future availability of technologies are higher compared to electricity and heat generation. This is reflected in the scenarios by the fact that emission reductions in this sector differ significantly between scenarios. Some scenarios, such as those for Germany and the UK, achieve emission reductions of close to 100% by 2050. In other countries' studies, emission reductions are between 53, 73% and 91% (Poland, Italy, France respectively). As a result, the transport sector still has a significant share in emissions in 2050 in those scenarios (41% in Italy, 54% in France).
  - Industry: For industry, the overall emission reduction ambition of the scenario mainly defines the sectoral level of emissions reductions. The UK and Germany depict very ambitious overall reduction targets while in France emission reductions in the industry sector are also sizeable. CCS in industry allows significant emission reductions in the German example. For the UK and France, emission reductions are achieved by changes in the production structure, i.e. substitution of cement clinker by cleaner alternatives and recycling in iron and steel and aluminium industry. This allows for a reduction not only in energy-related, but also in process emissions. In the other countries, emission reductions in the industry sector are significantly lower and industry emissions hence make up a significant share of total emissions in 2050.
  - LULUCF: In the UK study, LULUCF is used to offset the remaining emissions and achieve a zero carbon scenario. In the German scenario, the LULUCF sector provides a carbon sink in 2050, although the study does not take into account all possible mitigation options in that sector yet. For the other studies, no information is provided for LULUCF.
  - Agriculture and Waste: In the German, French and UK study, agriculture and waste accounts for a significant share of remaining emissions in 2050. Even though both studies already assume significant changes in eating habits, the agricultural sector's emissions remain a particularly important emission source in 2050.

5 Publication bibliography

Allen, Paul; Blake, Laura; Harper, Peter; Hooker-Stroud, Alice; James, Philip; Kellner, Tobi (2013): Zero carbon Britain. Rethinking the future. Machynlleth Powys UK: CAT Publications CAT Charity Ltd. Available online at http://zerocarbonbritain.com/images/pdfs/ZCBrtflo-res.pdf, checked on 12/12/2016.

Gustavsson, Mathias; Särnholm, Erik; Stigson, Peter; Zetterberg, Lars (2011): Energy Scenario for Sweden 2050. Based on Renewable Energy Technologies and Sources. Available online at http://www.wwf.se/source.php/1409709/Energy%20Scenario%20for%20Sweden%202050_bakgrundsrapport%20IVL_sep%202011.pdf, checked on 12/12/2016.

Maciej Bukowski; Jan Gaska; Franciszek Jackl; Andrzej Kassenberg; Anna Pankowiec; Aleksander Sniegocki et al. (2013): 2050.pl the journey to the low-emission future. Available online at http://np2050.pl/files/pliki/raport_low-emission_poland_2050.pdf, checked on 12/12/2016.

Maria Rosa Virdis; Maria Gaeta; Enrica De Cian; Ramiro Parrado; Chiara Martini; Maria Cristina Tommasino et al. (2015): Pathways to deep decarbonization in Italy. Available online at http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_ITA.pdf, checked on 12/12/2016.

négaWatt, Association (2013): The négaWatt 2050 Scenario. Executive Summary. In *New Directions for Youth Development* 2013 (139), pp. 5–8. DOI: 10.1002/yd.20064.

Ökoinstitut; Fraunhofer ISI (2015): Klimaschutzszenario 2050 for projections of electricity demand from households in Germany up to 2050.

6 Appendix

Table 8: Overview of the assessment of available long-term decarbonisation scenarios for EU member states

Member State	Title (original)	Publish-ing Year	Authors (name of institution)	Sponsor (name of in-stitution)	Sectors covered	Annual pc emis-si-ons ~2t CO_2e by 2050	GHG emis-sion 90% by 2050 (1990 levels)	CO_2 reduc-tion en-ergy sector 90%	Final energy con-sump-tion 40% (2010 levels)	100% re-newa-ble elec-tricity in 2050	de-taile d stud y (yes/ no)	Crite-ria in-dex (15 to -5)
Germany	Treibhausgas-neutrales Deutschland im Jahr 2050	2014	Umweltbundes-amt	Umweltbun-desamt	All Sectors	yes	yes	yes	yes	yes	yes	15,0
France	Scenario Nega-Watt	2011	Negawatt	Negawatt	Energy (incl power, heat, transport)	n.a.	yes	yes	yes	yes	yes	12,5
United Kingdom	Zero Carbon Brit-ain - Rethinking the Future	2013	Centre for Alter-native Techno-logy	Centre for Al-ter-native Technology	All Sectors	n.a.	yes	yes	yes	yes	yes	12,5
Belgium	Scenarios for a Low Carbon Bel-gium by 2050	2013	CLIMACT, VITO	Federal Pub-lic Service Health, Food Chain Safety and Environ-ment	All Sectors	n.a.	yes	yes	almost	yes	yes	11,5

Member State	Title (original)	Publishing Year	Authors (name of institution)	Sponsor (name of institution)	Sectors covered	Annual pc emis-si-ons ~2t CO_2e by 2050	GHG emission 90% by 2050 (1990 levels)	CO_2 reduction energy sector 90%	Final energy consumption 40% (2010 levels)	100% renewable electricity in 2050	detailed study (yes/ no)	Criteria index (15 to -5)
Austria	Energiezukunft Österreich - Szenario für 2030 und 2050	2015	Global 200, Green-peace, WWF		Energy (incl power, heat, transport)	n.a.	almost	yes	yes	almost	(yes)	10,5
Austria	Energie [R]evolution Österreich 2050	2011	Institute for Advanced Studies, Vienna	Greenpeace Zentral- und Osteuropa	Energy (incl power, heat, transport)	n.a.	n.a.	yes	yes	almost	yes	9,0
France	Energy [r]evolution - A Sustainable France Energy Outlook	2012	DLR	Greenpeace Inter-national, EREC, GWEC	Energy (incl power, heat, transport)	n.a.	n.a.	yes	yes	almost	yes	9,0
Ireland	Ireland and the Climate Change Challenge: Connecting 'How Much' with 'How To' - A Vision for 2050: Evaluating the Options, Background Paper No. 7	2012	National Economic & Social Council, NESC Secretariat		All Sectors	almost	yes	yes	n.a.	n.a.	(yes)	9,0

Member State	Title (original)	Publishing Year	Authors (name of institution)	Sponsor (name of institution)	Sectors covered	Annual pc emis-sions ~2t CO_2e by 2050	GHG emission 90% by 2050 (1990 levels)	CO_2 reduction energy sector 90%	Final energy consumption 40% (2010 levels)	100% renewable electricity in 2050	detailed study (yes/no)	Criteria index (15 to -5)
Sweden	Energy Scenario für Sweden 2050	2011	Swedish Environmental Research Institut	WWF	Energy, Industrial Processes	n.a.	n.a.	yes	almost	yes	(yes)	9,0
Germany	Klimaschutzszenario 2050. 1. Modellierungsrunde	2014	Öko-Institut, Fraunhofer ISI	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit	All Sectors	yes	yes	n.a.	yes	no	yes	8,5
Poland	Energy [r]evolution - A Sustainable Poland Energy Outlook	2013	DLR; Institute for Renewable Energy	Greenpeace Inter-national, EREC, GWEC	Energy (incl power, heat, transport)	n.a.	n.a.	yes	almost	almost	yes	8,0
Austria	Energieautarkie für Österreich 2050	2010	Universität Innsbruck	Klima- und Energiefonds der Bundesregierung Österreich	Energy (incl power, heat, transport)	n.a.	n.a.	n.a.	yes	yes	yes	7,5

Member State	Title (original)	Publishing Year	Authors (name of institution)	Sponsor (name of institution)	Sectors covered	Annual pc emis-sions ~2t CO_2e by 2050	GHG emission 90% by 2050 (1990 levels)	CO_2 reduction energy sector 90%	Final energy consumption 40% (2010 levels)	100% renewable electricity in 2050	detailed study (yes/ no)	Criteria index (15 to -5)
Ireland	A technical and eco-nomic analysis of one potential pathway to a 100% renewable energy system	2014	Aalborg University, Copenhagen		Energy (incl power, heat, transport)	n.a.	n.a.	yes	n.a.	yes	yes	7,5
Austria	Zukunftsfähige Energieversorgung für Österreich	2011	Umwelt Management Austria, Institut für Industrielle Ökologie, Forum Wissenschaft & Umwelt	Bundesministeriumg für Verkehr, Innovation und Technologie	Energy (incl power, heat, transport)	n.a.	n.a.	n.a.	yes	almost	yes	6,5
Spain	Cambio Global Espana 2020/2050 - Energía, Economía y Sociedad	2011	Fundacion CONAMA; CCEIM	Caja Madrid	Energy (incl power, heat, transport)	n.a.	n.a.	almost	n.a.	yes	yes	6,5
Denmark	Energiscenarier frem mod 2020, 2035 og 2050	2014	Danske Energistyrelsen	The Danish Gov-ernment	Energy (incl power, heat, transport)	n.a.	n.a.	n.a.	n.a.	yes	yes	5,0

Member State	Title (original)	Publishing Year	Authors (name of institution)	Sponsor (name of institution)	Sectors covered	Annual pc emis-sions ~2t CO_2e by 2050	GHG emission 90% by 2050 (1990 levels)	CO_2 reduction energy sector 90%	Final energy consumption 40% (2010 levels)	100% renewable electricity in 2050	detailed study (yes/ no)	Criteria index (15 to -5)
France	Pathways to Deep Decarbonisation - France Chapter	2014	Université Grenoble Alpes,CNRS, PACTE-EDDEN; Centre International de Recherche sur l'Environnement et le Développement (CIRED)	SDSN, IDDRI	Energy (incl power, heat, transport)	n.a.	n.a.	almost	yes	no	(yes)	5,0
Italy	Pathways to deep decarbonization in Italy. IT 2015 Report	2015	Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and the Fondazione Eni Enrico Mattei (FEEM).	SDSN, IDDRI	Energy (incl power, heat, transport)	yes	almost	n.a.	n.a.	no	yes	5,0
Sweden	Underlag till en färdplan för ett Sverige utan klimatutsläpp 2050	2012	NATURVÅRDS-VERKET		All Sectors	yes	almost	n.a.	no	n.a.	(yes)	5,0

Member State	Title (original)	Publish-ing Year	Authors (name of institution)	Sponsor (name of in-stitution)	Sectors covered	Annual pc emis-si-ons ~2t CO_2e by 2050	GHG emis-sion 90% by 2050 (1990 levels)	CO_2 reduc-tion en-ergy sector 90%	Final energy con-sump-tion 40% (2010 levels)	100% re-newa-ble elec-tricity in 2050	de-taile d stud y (yes/ no)	Crite-ria in-dex (15 to -5)
United Kingdom	Pathways to 2050 - Detailed Anal-yses. MARKAL model Review and Scenarios for DECC's 4t Carbon Budget Evidence Base	2011	AEA	Department of Energy and Cli-mate Change	Energy (incl power, heat, transport)	n.a.	n.a.	yes	n.a.	n.a.	yes	5,0
United Kingdom	The UK energy sys-tem in 2050: Com-paring Low-Carbon, Resilient Scenarios	2013	UCL	UKERC	Energy (incl power, heat, transport)	n.a.	n.a.	yes	n.a.	n.a.	yes	5,0
United Kingdom	Pathways to Deep Decarboni-sation - UK Chap-ter - Multivector scenario	2015	UCL Energy Insti-tute	SDSN, IDDRI	Energy (incl power, heat, transport)	almost	almost	yes	no	no	yes	5,0
Nether-lands	Energy [r]evolu-tion - A Sustaina-ble Nether-lands Energy Outlook	2013	DLR	Greenpeace Inter-na-tional, EREC, GWEC	Energy (incl power, heat, transport)	n.a.	n.a.	almost	almost	no	yes	4,0

Member State	Title (original)	Publishing Year	Authors (name of institution)	Sponsor (name of institution)	Sectors covered	Annual pc emis-si-ons ~2t CO_2e by 2050	GHG emission 90% by 2050 (1990 levels)	CO_2 reduction energy sector 90%	Final energy consumption 40% (2010 levels)	100% renewable electricity in 2050	detailed study (yes/no)	Criteria index (15 to -5)
Netherlands	Exploration of path-ways towards a clean economy by 2050	2011	Energy research Centre of the Netherlands	PBL Netherlands Environmental Assessment Agency	All Sectors	n.a.	almost	n.a.	n.a.	n.a.	yes	4,0
United Kingdom	Analysing Technical Constraints on Re-newable Generation to 2050	2011	Pöyry Management Consulting (UK) Ltd	Committee on Climate Change	Energy (incl power, heat, transport)	n.a.	n.a.	n.a.	n.a.	almost	yes	4,0
United Kingdom	Positive Energy: how renewable electricity can transform the UK by 2030	2011	GL Garrad Hassan	WWF	Energy (incl power, heat, transport)	n.a.	n.a.	n.a.	n.a.	almost	yes	4,0
Belgium	Towards 100% Re-newable energy in Belgium by 2050	2012	VITO, ICEDD	Federal Planning Bureau	Energy (incl power, heat, transport)	n.a.	n.a.	n.a.	no	yes	yes	3,5

Member State	Title (original)	Publishing Year	Authors (name of institution)	Sponsor (name of institution)	Sectors covered	Annual pc emis-si-ons ~2t CO_2e by 2050	GHG emission 90% by 2050 (1990 levels)	CO_2 reduction energy sector 90%	Final energy consumption 40% (2010 levels)	100% renewable electricity in 2050	detailed study (yes/ no)	Criteria index (15 to -5)
Finland	Energy and Climate Roadmap 2050. Re-port of the Parliamentary Committee on Energy and Climate Issues on 16 October 2014	2014	Ministry of Em-ploy-ment and the Economy, Energy and the climate		Energy (incl power, heat, transport)	n.a.	yes	no	n.a.	n.a.	yes	3,5
Germany	Langfristszenarien 2011	2012	DLR, Fraunhofer IWES, IFNE	BMU	Energy (incl power, heat, transport)	almost	no	n.a.	yes	no	yes	3,5
Hungary	Energy [R]evolution in Hungary - Green-peace study on re-new-able energy	2011	DLR	Greenpeace Inter-natio-nal, EREC	Energy (incl power, heat, transport)	yes	almost	n.a.	no	no	yes	3,5

Member State	Title (original)	Publish-ing Year	Authors (name of institution)	Sponsor (name of in-stitution)	Sectors covered	Annual pc emis-si-ons ~2t CO_2e by 2050	GHG emis-sion 90% by 2050 (1990 levels)	CO_2 reduc-tion en-ergy sector 90%	Final energy con-sump-tion 40% (2010 levels)	100% re-newa-ble elec-tricity in 2050	de-taile d stud y (yes/ no)	Crite-ria in-dex (15 to -5)
Portugal	Roteiro Nacional de Baixo Carbono 2050 - Opções de transição para uma Economia de Baixo Carbono Competitiva em 2050	2012	Agencia Portu-guesa do Ambi-ente		Energy (incl power, heat, transport)	almost	no	no	almost	no	yes	1,0
Sweden	Nordic Energy Tech-nology Per-spectives: Path-ways to a Carbon Neutral Energy Future	2013	International Energy Agency		Energy, In-dustrial Processes, Agri-cul-ture	n.a.	n.a.	almost	no	no	yes	1,0
United Kingdom	Pathways to Deep Decarboni-sation - UK Chap-ter	2014	UCL Energy Insti-tute	SDSN, IDDRI	Energy (incl power, heat, transport)	n.a.	n.a.	almost	no	no	yes	1,0
Germany	Entwicklung der Energiemärkte - Energiereferenz-prognose (Leit-studie)	2014	EWI, GWS, Prog-nos	BMWi	Energy (incl power, heat, transport)	no	no	n.a.	yes	no	yes	0,5

Member State	Title (original)	Publishing Year	Authors (name of institution)	Sponsor (name of institution)	Sectors covered	Annual pc emis-sions ~2t CO_2e by 2050	GHG emission 90% by 2050 (1990 levels)	CO_2 reduction energy sector 90%	Final energy consumption 40% (2010 levels)	100% renewable electricity in 2050	detailed study (yes/ no)	Criteria index (15 to -5)
Germany	GROKO II - Szenarien der deutschen Energieversorgung auf der Basis des EEG-Gesetzentwurfs - insbesondere Auswirkungen auf den Wärmesektor	2014	Bundesverband Eneuerbare Energien e.V.	Bundesverband Erneuerbare Energien e.V.	Energy (incl power, heat, transport)	no	no	n.a.	yes	no	(yes)	0,5
Germany	Energiesystem Deutschland 2050	2013	Fraunhofer ISE	BMWi	Energy (incl power, heat, transport)	n.a.	n.a.	n.a.	no	no	(yes)	- 0,5