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Report

Measures and scenario studies for emission reduction

CenSES Review

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ABSTRACT
To support the development and evaluation of a Norwegian sustainable energy strategy a scenario development process is conducted by the research center CenSES. This report provides background information for the work in two dimensions in particular. Firstly, a summary of possible emission reducing measures for Norway is presented with an emphasis on measures affecting the energy system. Secondly, scenario studies as a method is described and a collection of relevant scenario studies are presented.

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Contents

1 Introduction

The objective of this report is to provide relevant background information for the Scenario development activity in Research Area 5 in the research center CenSES, and discusses the development of *the Norwegian energy system in a long-term perspective*.

The content is twofold, it describes possible changes to the energy system that can contribute to fulfill Norway's climate targets and it collects scenario studies relevant for the assessment of long-term development of the Norwegian energy system.

While the *Norwegian* energy system is our main interest, there are several sources for international interaction, such as physical connections in the power system, joint energy and emission markets regionally as well as globally and common climate targets and policies. Due to this we include some background information and studies that we find relevant to put the Norwegian system in a relevant context.

The focus of this report is the *energy system*, and not climate studies and effects in general, but the necessary changes due to GHG emission reduction targets is the main motivation for changes we discuss in the energy system. As frequently pointed out, climate influence, value creation and security of supply are tightly connected in the energy system, hence also these subjects will be touched upon through the discussions.

The report will focus on a long-term perspective, meaning development towards 2030-2050. More detail is given for the 2030 horizon, reflecting the difference in amount and detail of conducted studies on the two horizons.

First some background information is given, with the underlying motivation in terms of the climate challenge and the a description of characteristics for the current Norwegian energy system. In Section 2 the decided targets and current policies for Norway, and relevant international context are presented, before Section 3 present possible measures for the fulfillment of Norway's targets. Next follows the overview of scenario studies, before some concluding remarks.

1.1 Energy and climate status

There is a broad and increasing acknowledgment of man-made climate change and a need for reduced greenhouse gas (GHG) emissions globally. The goal agreed upon by 195 countries during the 2015 Paris Climate Conference (COP21) was to keep the global temperature rise in this century well below 2°C and to strive to even keep it below 1.5°C. Prior to COP21 participating countries stated their national targets in terms of intended nationally determined contributions (INDCs) for 2030. Updated projections resulting from the implementation of the INDCs indicate emission levels well above the least-cost scenarios for 2°C presented by IPCC AR5[1] (United Nations Framework Convention on Climate Change 2015), illustrating the high ambition of the COP21 agreement and the need for perserving GHG emission reduction efforts.

Norwegian emissions were 53.2 Mt CO_2-eq. in 2014, accounting for approximately 0.1% of global emissions that year. This is 2.4% above 1990 level, but below 2010 when Norwegian emissions peaked. The largest emissions originated from the transportation sector, accounting for 31%, while the petroleum sector accounted for 28% and industry 22%. While the two first sectors have had increasing emissions since 1990, industry has reduced its emissions measured in absolute terms since 1990. Energy supply accounted for 3% of Norwegian emissions in 2014. The sector has had a substantial increase in emissions, particularly since 2007, due to increased emissions from gas power plants and combustion of waste. (Statistics Norway 2015)

The Norwegian energy system is characterized with a very high share of regulated renewable power production in terms of hydropower. This gives not only access to large amounts of climate friendly energy, but also a strong capability for balancing unregulated power sources and variable demand, both valuable for domestic use and as a possible exporter of balancing services. The large hydropower sources have been and still are the main motivation for a relatively large energy-intensive land-based industry with low carbon footprint relative to most international competitors. Also the energy supply in the residential and service sectors have been shaped by the availability of cheap hydropower, with electric power accounting for 80% of the supply in 2014 (Statistics

[1] IPCC - Fifth Assessment Report, 2013-2014

Norway 2015). The offshore oil and gas industry is a corner stone in Norwegian economy, accounting for 45% of Norwegian exports in 2014 (Statistics Norway 2015). While oil and gas export are still expected to have a central position the coming decades, with gas often referred to as a substitute for coal and oil in a transition period internationally, the long-term future is uncertain and dependent on amongst other the development of CCS technology. Building on the established competence on offshore installations from the petroleum industry, and due to the long cost line, Norway is assumed to have a comparative advantage on the development of offshore wind technology. The transportation sector has some particular challenges due to its distributedness and non-stationarity, which is emphasized through a sparsely distributed population. Amongst multiple technologies being developed for the decarbonization of the transportation sector internationally, Norway has been a forerunner on providing incentives for battery electric vehicles and in the development and implementation of low-carbon technologies, in particular LNG propulsion, in the maritime sector.

The Norwegian energy system has tight Nordic and European couplings both physically and marketwise. The power transmission grid is tightly coupled to the Nordic countries[2], with Sweden in particular, and the number of cables to continental Europe and UK is increasing. Similarly, a large network of pipelines for gas export from the Norwegian Continental Shelf to continental Europe and UK is established, with the addition of an liquefaction terminal facilitating global LNG sales. Norway is part of a integrated Nordic power market on day-ahead, intraday and tertiary reserve trade, and efforts are being taken to improve the integration both in terms of other products, in particular reserves, and towards an internal European power market. To increase the renewable power production with 28.4TWh, Sweden and Norway have formed a common market on green certificates that further links to power systems. EU Emissions Trading System (EU ETS), where also Norway participates, integrates the trade of GHG emission quotas in power production, a range of energy-intensive industries and airlines.

2 Targets and policies

The national Norwegian climate policy centers around 'The agreement on climate policy'[3] that was first approved by the Norwegian parliament in 2008 (Det kongelige miljøverndepartement 2007) and followed-up in 2012 (Det kongelige klima- og miljødepartement 2012) where the same targets were accompanied with more concrete instruments and measures. The primary targets are

- to cut the global GHG emissions with 30% by 2020 relative to Norwegian emissions in 1990
- to become carbon neutral by 2030 on the condition that an ambitious global agreement among developed countries are established
- to unconditionally become carbon neutral by 2050.

The carbon neutrality entails that national emissions should be compensated with achieving corresponding emission reductions abroad. Norway's intended nationally determined contributions (INDC) submitted to UN Framework on Climate Change (UNFCCC) prior to COP21[4] in 2015 comply with The agreement on climate policy and additionally states that Norway intends to

- reduce GHG emissions with at least 40% by 2030 relative to 1990 levels
- become a low emission society by 2050

The 2030 target is intended to be fulfilled collectively together with EU who has stated the same 40% emission reduction ambition.

EU's ambition in the Renewables Directive that 20% of the consumed energy should come from renewable energy sources (RES) in 2020 is well known, and through the EEA-agreement Norway is also committed by this

[2]except Iceland
[3]Klimaforliket
[4]Conference of Parties in Paris 2015

Table 1: Norwegian GHG emissions, historical and projected (Det konglige finansdepartement 2014), and emission targets.

	1990	2013	2020	2030	2050
Emissions [mill. tonne CO_2-eq.]	50.4	52.8	53.7	51.5	NA
Change from 1990		4.8%	6.5%	2.2%	NA
Target			-30%	-40%	-100%

directive with a national target at 67.5%. Additionally the directive states a target of 10% RES in transportation by 2020 for all countries, including Norway. In 2013 the Norwegian RES share was 66.8%[5] which is 7 percentage points up from the 2005 level (Statistics Norway 2015)[6]. Within the transportation sector the RES share was 4.5%[5] in 2013, and increase of 3.3 percentage points since 2005. It could be noted that the energy consumption in the Norwegian petroleum industry is not included in the reported RES shares, which contributes to a significant higher overall RES share than would otherwise been observed.

3 Options

In the national budget for 2015 Norwegian GHG emissions are projected, taking approved policies into account.[7] (Det konglige finansdepartement 2014) In Table 1 the projections are quoted together with the stated targets. The substantial gap between projections and targets should be covered through domestic emission reductions or flexible mechanisms for emission trading or financing of emission reductions internationally.

A broad range of instruments and measures to achieve reduced CO_2-emissions are used and discussed. We use the term measure to denote technologies, processes or practices that reduce emissions or impacts, while instruments are non-technical approaches (informative, regulative, economic) that aim to promote the realization of one or more measures. Our main focus will be on measures for domestic CO_2-emission reductions, while we will first give a brief overview of currently implemented instruments in Norway.

Current instruments The main GHG emission reduction instruments in Norway are taxes, in particular the CO_2-tax imposed on petroleum products, and the participation in EU-ETS, the European emission trading system. (Det kongelige klima- og miljødepartement 2015) EU-ETS covers CO_2-emitting power plants, a range of energy-intensive industries and airlines within the 28 EU states, Iceland, Liechtenstein and Norway. (European Comission 2013) Due to the regulation of how many quotas that are made available the amount of GHG emissions within the EU-ETS-sector is known, while the geographical distribution of emission reductions are given by the market. These are multi-sectoral instruments, while a range of sector specific instruments are also implemented. E.g. within transportation electric vehicles are given particularly favorable terms, taxes are reduced on bio fuel and there are minimum requirements on bio fuel share in the road transport fuel mix. The substitution of oil for heating has been a main focus in the building sector, together with subsidies for energy efficiency efforts in private households. (Det kongelige klima- og miljødepartement 2015)

3.1 Possible additional future measures

The following are defined as prioritized areas for emission reduction efforts by the government (Det kongelige klima- og miljødepartement 2015):

- Reduced emissions in the transport sector
- Low emissions technology in industry

[5] Includes bio fuels despite lack of RES documentation according to EU rules. Overall RES share is 66.2% without bio fuels and 1.6% within the transportation sector.

[6] 'Tabell: 10842: Andelen fornybar energi for Norge totalt og transportmålet', accessed December 2015

[7] The projection is calculated by Statistics Norway with the economic equilibrium model MSG.(Miljødirektoratet 2015)

Table 2: Principle rule for categorization of measures into packages in (Miljødirektoratet 2015)

	Cost NOK/tonne CO_2-eq.	Implementability
Package 1	< 500	Less demanding
Package 2	500-1500	Medium demanding
Package 3	> 1500	More demanding

- CO_2capture and storage
- Renewable energy sources
- Environmentally friendly shipping

The Norwegian Environment Agency has in three reports analyzed possible measures for emission reductions towards 2020, 2025 and 2030. (Miljødirektoratet 2014*a*,*b*, 2015) In (Miljødirektoratet 2015) each of the measures is described together with estimates for emission reduction potential, cost per million tonne CO_2-eq. reduction, effect on energy production/consumption and an assessment of how easily implementable the measure is. Emission reductions and energy production/consumption effects are given for 2030 relative to the paths described in the national budget for 2015 (Det konglige finansdepartement 2014). The measures are also aggregated into three packages based on cost and ease of implementation, with increasing cost and complexity in implementation as described in Table 3.1. The aggregated estimated emission reductions per package are reproduced in Figure 1, where overlap between different measures are taken into account. It should be noted that electrification of offshore installations in the petroleum sector is not included in the report. A summary of the main measures reported in (Miljødirektoratet 2015), seen from an energy system perspective, is given below. As in the source report, the energy effects are given for 2030 relative to the national budget for 2015.

Domestic transportation The transportation sector has the largest emissions, accounting for 17.1 million tonnes CO_2-eq. in 2013. This was distributed on the different modes as illustrated in Figure 2. Only aviation within the European Economic Area is covered by EU-ETS, and this accounted for approximately 1.1 million tonnes CO_2-eq. in 2013. It should be noted that only domestic transportation is included in these statistics.

Many measures for emission reductions within transportation are evaluated. Most of them can be categorized as either change in activity level, technology, fuel mix or mode, some of them with multiple alternatives varying implementation time and level.

- Zero growth or 10% reduction of passenger transportation need with car in urban areas or nationally relative to 2016 levels. Expected energy effects are reductions in gasoline and diesel consumption of 0.7-2.9 TWh and reductions in bio fuel consumption of 0.03-0.1TWh.
- Modal shift from road to sea and railway for 5-20% of domestic freight transport. Expected reductions in diesel and biodiesel consumptions are 0.5-2.0 TWh and 0.03-0.1TWh, respectively. Corresponding expected increase in electric power and marine oil consumptions are 0.004-0.1TWh and 0.1-0.5TWh.
- Increasing share of new vehicles being electric vehicles (EV) or hydrogen driven vehicles (HV), with varying shares for passenger cars (60-100%), delivery trucks (60-100%), city buses (100%), long distance buses (75%), and trucks (25-50%). Aggregated over all vehicle types the maximal energy effect are estimated to give a 13.2 TWh reduction of fossil gasoline/diesel consumption and 0.62 TWh reduction of bio fuel consumption, while the electric power consumptions increases with 4.3 TWh with equal shares of EVs and HVs and 7.2 TWh with EVs only.
- Increasing share of new passenger cars and trucks being hybrid-electric vehicles in 2030 to 100% and 50% respectively. Aggregated energy effect is estimated to give a 5.7 TWh reduction in fossil diesel/gasoline

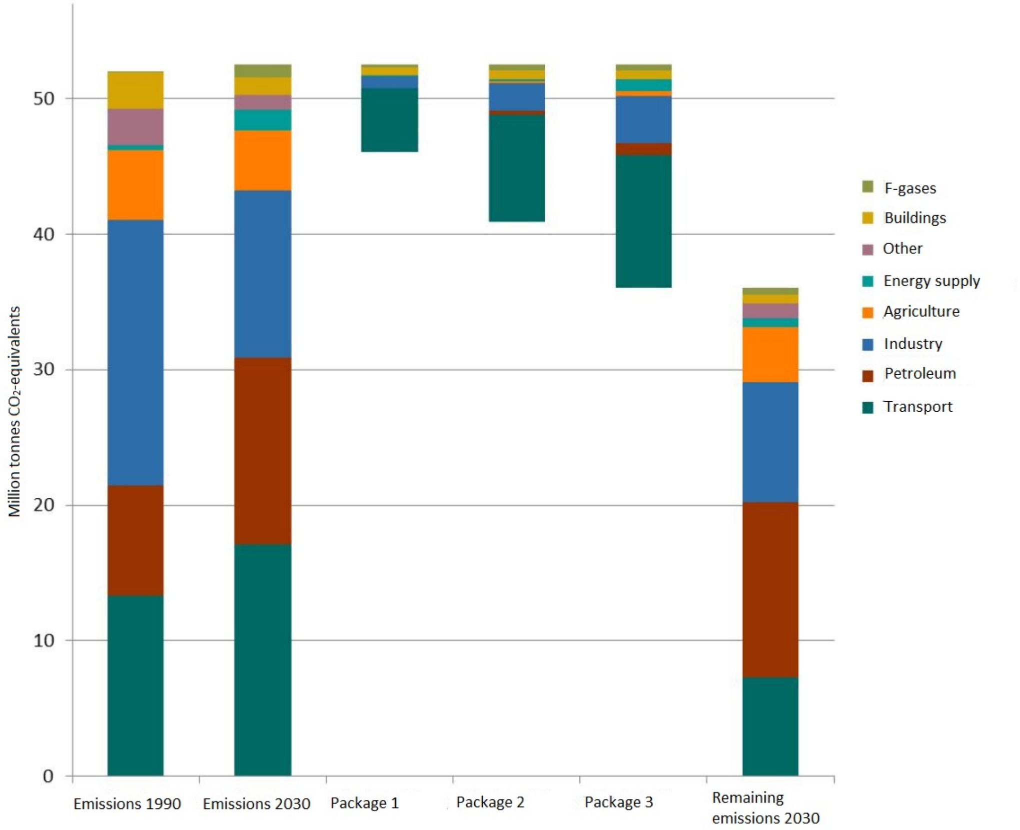

Figure 1: Norwegian GHG emissions per sector. Source: Miljødirektoratet (2015)

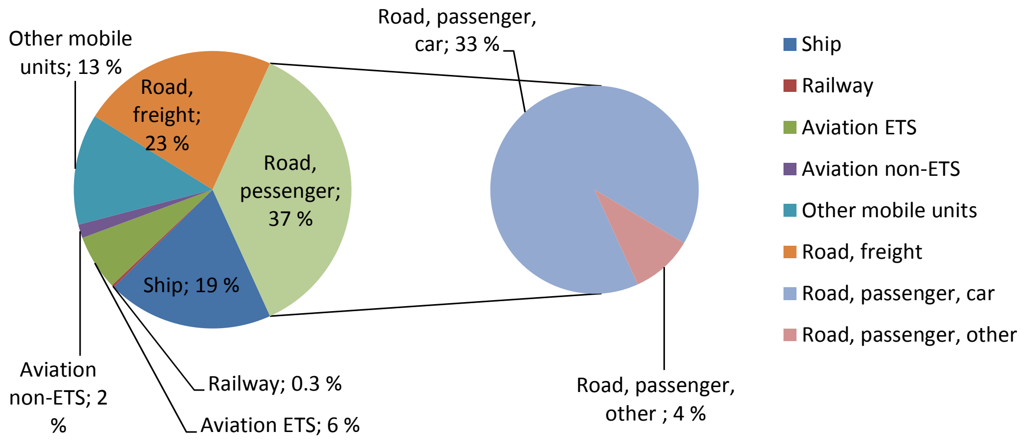

Figure 2: Specification of GHG emissions from domestic transportation in 2013. Right pie indicates how road transport of passengers are split between cars and other vehicle (bus, moped and motor cycle). 'Other mobile units' ranges from construction and agricultural machinery to leisure boat and chain saw, with the former contributing the most to emissions. Data source: Miljødirektoratet (2015)

consumption, 0.23 TWh reduction in bio fuels consumption, and less than 1.9 TWh increase in electric power consumption.

- Increased mix-in of bio fuels in road transport fuels, non-ETS aviation fuels, fuels for other mobile units and marine fuel, with varying mix-in levels for each of the modes. Maximum increased share of bio fuels are set to 40% for road transport and aviation, 20% for other mobile units and 100% for parts of the fleet of ships. This is estimated to give substitution from fossil to bio gasoline, diesel, aviation gasoline and marine fuel of 2.85, 15.2, 0.4 and 3.27 TWh, respectively.
- Electrification of all non-electric railway, with estimated reduction of diesel consumption of 0.1 TWh and increased electric power consumption of 0.06 TWh.
- Liquefied natural gas (LNG) as fuel in all new and some existing supply ships is expected to give a substitution of 0.87 TWh marine oil with LNG.
- All new passenger ships and ferries being electric, which means approximately half the fleet begin electric in 2030. This is expected to reduce marine oil consumption with 1.96 TWh and increase electric power consumption with 0.78 TWh.
- Increased supply of electric power from the onshore grid to vessels in port can reduce the marine oil consumption with approximately 0.72 TWh and increase power consumption with approximately 0.29 TWh.
- Multiple energy efficiency efforts within sea transportation are possible, both in terms of technical improvements, ship operation and fleet operation.
- 20-40% mix-in of bio fuels in aviation will contribute with a substitution of 0.7-1.5 TWh from fossil to bio fuel consumption.

The last measure is the only one affecting emissions within EU-ETS.

Petroleum The petroleum sector covers both offshore facilities and onshore terminals and processing facilities. Total emissions from the sector was 13.9 million CO_2-eq. in 2013, of which 92% was covered by EU-ETS. The largest source for emissions is combustion of gas for energy production, representing 78% of the 2013-emissions, while flaring represented 11%. Suggested measures for the petroleum sector are directed towards these two sources:

- Reduce need for flaring through avoiding unplanned events and disturbances.
- Reinject gas for flaring into the production system rather than flaring it.
- Multiple energy efficiency improvements, ranging from relatively small operational improvements to building cable connections between offshore installations.
- Electrification of Hammerfest LNG by replacing existing local heat and power supply with power from the grid and new gas boilers. This will require approximately 1.9 TWh power from the grid.
- Replace gas turbines on multiple installations offshore with combined heat and power (CHP), which will improve the energy efficiency.
- Electrification of new and existing offshore topside installations with power supply from shore. Due to high uncertainty on measurement cost and timing for different fields this measure is not included in the aggregated packages presenting emission reductions in 2030.

All these measures will reduce the gas consumption and thereby increase the potential for gas exports. The measures are covered by the EU-ETS. All but the last measure are already partly included in the projections from the Norwegian Petroleum Directorate, and therefor expected emission reductions are not specified in (Miljødirektoratet 2015).

Industry Total emissions from the industry was 12.1 million tonnes CO_2-eq. in 2013, 90% of these emissions are covered by EU-ETS. 66% of the emissions comes from industrial processes while 34% comes from energy consumption through combustion of fossil fuels. Most suggested measures seeks to reduce emissions from the industrial processes. Energy consumption related measures are:

- Substitution of coal with biomass as fuel in the cement production, with an estimated reduction of coal consumption of 0.4 TWh.
- Multiple energy efficiency improvements in the two Norwegian oil refineries, with an estimated aggregated energy consumption reduction of 0.45 GWh assuming the gas coming from the refining process and currently used for heating can be used for other purposes.
- Multiple energy efficiency improvements in wood processing, chemical industries and aluminum production at varying costs per CO_2-eq., with an estimated aggregated energy consumption reduction of 2.0 GWh through reduced consumption of fossil oil and gas and electric power.
- Carbon capture and storage (CCS) at Norcem Brevik, Yara Porsgrunn and Mongstad Cracker will give a substantial emission reduction. Energy consumption effects are not quantified and depends on technology choice and share of CO_2captured.
- Energy efficiency improvements in the food industry, with an estimated aggregated energy consumption reduction of 1.0 GWh, mainly due to reduced combustion of fossil gas.

All these measures except the last affects emissions that are covered by EU-ETS.

Energy supply The GHG emissions from energy supply is relatively small in Norway due to the large share of hydropower. Total emissions from energy supply was 1.8 million tonne CO_2-eq. in 2013, of which 67% was covered by EU-ETS. The emissions are mainly induced by gas power plants, combustion of waste and other fossil carriers for district heating and coal based power and heat production at Svalbard. Suggested emission reduction measures for the energy supply are:

- Substitute fossil oil with biodiesel/biooil for peak load district heating, with estimates of 134 GWh reduced fossil and increased bio fuel consumption.
- Substitute fossil gas with electricity or bio gas for peak load district heating, with estimates of 413 GWh reduced fossil gas consumption and a similar increase in electric power consumption assuming equal efficiency.
- Realizing CCS at Mongstad combined head and power plant by using excess steam and natural gas to drive the capture process.
- CCS at Klemetsrud waste energy recovery facility which will give a carbon negative contribution to the CO_2balance.

All measures except the last are covered by EU-ETS.

Agriculture Agriculture is fully outside EU-ETS and accounted for 4.7 million tonne CO_2-eq. in 2013, with more than 70% coming from farm animals and manure. Potentials for emission reductions in agriculture are limited, even in a 2050 low emission society, but still some measures are possible. From a energy perspective the most relevant is production of bio gas from manure and excess crops with an estimated potential for 0.7 TWh bio gas.

Buildings The building sector is fully outside EU-ETS. It accounted for 1.5 million tonne CO_2-eq. in 2013, mainly caused by combustion of oil, paraffin, LPG and firewood. The emissions have been substantially reduced from the emission level of 2.7 million tonne CO_2-eq. in 1990. The most relevant measure in this sector is substitution of fossil oil for heating, both base load and peak load. There are a range of alternatives to fossil oil, such as bio energy (bio oil, pellets, etc), electricity for direct heating or heat pumps and reduced consumption through energy efficiency measures, and the mix of these will decide how the energy system is affected.

3.2 Norwegian opportunities

The agreement on climate policy states that the policy choices should seek cost efficient measures. (Det kongelige klima- og miljødepartement 2015) At the same time the importance of utilizing potentials for new green business developments is pointed out, and this more offensive mindset focusing on business opportunities arising as a consequence of the green shift is getting increasing attention. On the political side the Norwegian government did in 2015 appoint an expert commission to help develop a strategy for green competitiveness [8]. And the same year a coalition of ten major Norwegian businesses together with three NGOs published a report on business opportunities in meeting the climate targets (Xyntéo 2015). An pronounced and early voice in this direction of thinking has been The New Climate Economy reports (The Global Commission on the Economy and Climate 2014, 2015) pointing at the possibility to "build lasting economic growth and at the same time reduce the immense risk of climate change".

'Norway 203040' (Xyntéo 2015) points at three opportunity areas where they find Norway to be in a particularly good position for value creating in a low-carbon economy, all three with tight connections to the energy system:

High-tech industry - utilize access to clean hydropower, advanced technology and highly skilled workforce in for instance aluminum production with, offshore wind technology and data centers.

Electric mobility - utilize the frontrunner position in transition to electric vehicles with access to clean hydropower to take a leading position in development of applications and business models for electric transportation both on land and at sea.

Bio-economy - utilizing resources, competence and infrastructure within fisheries, forestry and agriculture to develop businesses with biofuels and bio-products (bio-chemicals and -plastics).

These areas are highly overlapping with areas The Norwegian Environmental Agency point to as particular relevant for Norwegian climate efforts in light of needs for both emission reductions and value creation. (Miljødirektoratet 2014*b*)[Section 7.2] Additionally they emphasize the need for production processes with less emissions in several industries, such as ferro-alloy, aluminum, cement and chemical fertilizer production, with CCS as a key technology within several industries. The utilization of resources in waste, through treatment of bio waste and focus on circular economy is highlighted as an area with potential. Generally, good planning and cooperation on all levels, both in public and private sector are needed to achieve efficient infrastructure and land use that facilitates a low-carbon society in particular in terms of low transportation needs.

The relation between emission reductions and value creation also touches upon the carbon leakage issue. This is the effect where reduced emissions due to climate policies in one country or region is partly offset by increased emissions in other regions due to changed competitive power in global energy markets or markets for energy intensive products (Rosendahl 2014). According to The Confederation of Norwegian Enterprise (NHO) the Norwegian petroleum industry and energy intensive process industry both have low emissions relatively to global competitors, and based on this and the carbon leakage issue they argue that Norwegian activity in these industries needs to be evaluated in a global context and not within the Norwegian climate targets only. (Næringslivets Hovedorganisasjon 2014) Also other measures and industries have international interactions that

[8] https://www.regjeringen.no/no/aktuelt/ekspertutvalg-om-gronn-konkurransekraft/id2422687/

can give different CO_2-emission effects depending on the geographical scope of measurement. For instance bio-for-fossile fuel substitution in Norway gives a close to 100% emission reduction within Norway and on average 40% reduction globally (Miljødirektoratet 2015)[p. 152].

4 Scenario studies

This section provides an overview of scenario studies for the energy system. Initially we describe how we see the term 'scenario study' and some words on how scenarios can be designed, followed by the scenario study overview.

4.1 What are scenario studies?

Despite its frequent use there are to our knowledge no widely accepted and exact definition of the term 'scenario study'. Therefore, we will here describe our interpretation of the term, which has also been the guidance for the following scenario study overview.

Scenario studies are typically used by decision makers, both making strategic decisions in the industry and policy decisions in the public sector. The underlying motivation for scenario studies are usually the need for a knowledge base for decisions that will take effect in the future, addressing issues such as uncertainty, discontinuity, path-dependency and system complexity. (European Environment Agency 2011)[Section 1]

Some characteristic features are listed below. In line with the somewhat vague framing of the term, not all studies in our overview necessarily comply with all features listed.

- Forward-looking - a consequence of the common motivation for conduction a study
- Combines controllable options and uncontrollable uncertainties
- Describes a possible future without probability-weight, not necessarily the expected future
- Uses quantitative methods, usually combination with qualitative methods
- Can be normative (backcasting, 'How to reach the X target?') or explorative ('What effect will this measure have?')
- Group of related scenarios in a study rather than a single scenario

A common challenge in the scenario studies is addressing the trade-off between system stability and change, the ability to describe revolution not just evolution, which have motivated critics to refer to a 'straight-line-syndrome' (Carbon Tracker 2015). There could be several reasons for such a 'syndrome' if present, amongst other embedded in the methodology. Quantitative models, frequently used in the scenario analysis, provide an ability to describe large systems with complex interactions in a well-defined and rational way. They are usually set up to describe a stepwise pathway from a current state into the future, which by design has a certain conserving property. Further, most models mainly build on linear modeling principles, which complicates a precise representation of non-linear phenomena like dramatic changes in policies, technologies and behavior (Carbon Tracker 2015) as well as learning effects and economy of scale that stimulates technology change (Bråten 2014). This challenge, amongst other, is a driver for continued development of scenario studies as method, both in terms of improved quantitative models and the overall work process.

Many scenario studies are comprehensive multi-disciplinary processes, with heavy and broad involvement of stakeholders both in the early phases establishing scenario outlines, through quantification of assumptions to evaluation and interpretation of model results, as for instance described by Entso-E (2014). In addition to contributing to counteract modeling weaknesses like the 'straight-line-syndrom' and addressing un-quantifiable phenomena, such processes seeks to improve the quality of assumptions and interpretations, strengthen the study's relevance for decision makers and increase its impact.

4.2 Scenario design

The design of the scenarios is naturally a key process in a scenario study, and different approaches are used for this purpose, from which some examples are shortly presented here. The level of detail in which the design approach in a scenario study is documented and published is largely varying, which is also reflected in this presentation.

An early specification of a research question, focus area or the like, describing the objective of the study is usually an important guidance for the scenario design process. A distinction between two main approaches can be drawn, top-down processes and bottom-up processes. In a top-down process some criteria on how the different scenarios should relate to each other are established, for instance the defining dimensions in a matrix of scenarios, and from this the scenarios are detailed. A bottom-up process typically starts with a wider brainstorming on factors influencing the focus area of the study, followed by a organizing, categorizing and prioritizing process that leads to a set of scenarios. The top-down approach has the advantage of giving a structured set of scenarios that supports comparative analysis and eases communication of the scenarios. On the other hand, bottom-up has a strength in a early creative phase that makes early and wide stakeholder involvement easy. Though, as will be seen in the following examples, the distinctions between the approaches are not absolute, and hybrid versions exists.

The EU Energy Roadmap 2050 (European Commission 2011*b*) uses a top-down approach. 'The general objective is to shape a vision and strategy of how the EU energy system can be decarbonised by 2050 while taking into account the security of supply and competitiveness objectives.' This is concretized in a 85% reduction of energy related CO_2emissions. From this four decarbonisation routes are identified (energy efficiency, RES, nuclear, and CCS) that are combined into five scenarios. Additionally, two reference scenarios are defined that represent projections of the current situation assuming no new policies.

A similar approach is used in ECF's Roadmap 2050 (European Climate Foundation 2010), with the objective of using backcasting to analyse how a 95% reduction of GHG emissions from the European power system can be achieved. They use a set of main assumptions listed below, and defines four scenarios (called pathways) by varying the share of RES between 40% and 100% while the remaining power demand is supplied by equal shares of nuclear generation and thermal generation from fossil sources with CCS.

- Use existing or close to deployment technologies only
- No single-technology solutions, require mix to achieve robustness in results
- No import from outside Europe (except in 100% RES scenarios)
- Solutions should have security-of-supply similar as today

In the development of the 2016-version of the ten year network development plan (TYNDP) for the European power grid Entso-E uses a top-down approach that is characterized by evolution (Bastiaensen 2014, Entso-E 2015). The scenario development builds on TYNDP 2014 and the two dimensions of a scenario matrix giving four scenarios (called visions) are taken from the previous version and seen as fixed. The dimensions are strong versus loose European framework and on-track versus delayed for the implementation of EU Energy roadmap 2050. The interpretation of a strong versus a loose European framework is not only reflected in the final scenarios, but also in the scenario development. For a loose European framework national decisions are assumed to stand strong, and the specification of these two scenarios are to a large extent left to the national TSOs. For the scenarios representing a strong European framework on the other hand, a more centralized process is used and larger parts of the generation mix in the scenarios is handled by pan-European optimization. It is a goal for the scenario design that the final scenarios are sufficiently extreme to span the space of possible developments for the power grid by 2030. On the contrary, for the years until 2020 a single expected progress development, used for all scenarios, is estimated.

e-Highway 2050 uses a bottom-up approach which is described in detail in Huertas-Hernando & Bakken (2013). Based on the research question a plethora of driving forces are identified, and these are categorized as either uncontrollable uncertainties or controllable options. This process requires a up-front definition on who's perspective the study should take, who is the decision maker. For each uncertainty and option the boundary conditions, that is the upper and lower limits, are defined. Individual uncertainties are further combined into five futures, and options are combined into six strategies, where the set of futures and strategies forms the rows and columns of a scenario matrix. As opposed to the typical two-by-two matrix of a top-down approach, the initial scenario matrix of e-Highway is five-by-six, and the rows and columns are not increasing/decreasing values over named dimensions. In the next step scenarios that have conflicting strategies and futures are eliminated, for example when the public perception of a technology given by the future contradicts the deployment of this technology in the strategy. This elimination reduce the number of scenarios from 30 to 15, which is still seen to be too many for detailed analysis. A criterion for the further selection of scenarios is similar to the one used by Entso-E, namely that the scenarios should be extreme scenarios spanning the solution space. Additionally two guiding assumptions are defined (quote):

1. The chosen grid architectures coping with the selected e-Highway2050 challenging scenarios should be able to launch any possible energy scenario by 2050
2. The independent parameters depicting the scenarios are linked to generation, demand and level of power exchange: all the other factors (such as socio-economic variables, policies, etc) are embedded in the above independent parameters (with various types of dependencies).

The second assumption is closely linked to the research question and is operationalized by grouping all uncertainties and options into 10 relevant parameters that either affect generation, demand or power exchange. Matrices defined the relevant parameters enabling quantification of the intensity of each parameter for each possible scenario. This is used to create radar plots spanning these 10 parameters, which gives an visual comparison of the possible scenarios to select among. Comparison with other scenario studies is also conducted in the selection process leading to five final scenarios.

HydroBalance (Sauterleute et al. 2015) uses a similar approach as e-Highway 2050, but defines only two criteria for the final selection of scenarios, which is possible due to a clear and relatively narrow research question. This gives a structured relation between the selected scenarios, enabling presentation of the selected scenarios in a 2D plot, similar to what is usually reached in a top-down approach.

Several studies seeks to design scenarios such that they 1) represent extreme situations spanning the multi-dimensional scenario space and 2) give robust energy systems that perform well in several different future situations. These criteria have the common property to depend on the observations of the analysis and computations of the scenario study, which make them demanding to operationalize. The most common approach to handle this seems to be the use of system insight to qualitatively assess how the different scenarios evaluates on the criteria. An alternative approach is given by scenario-based tradeoff analysis, a method developed at MIT to structure scenario planning with a multi-stakeholder audience. (Connors 2004, Bakken 2012) The approach in e-Highways is inspired by this method when structuring the scenario design through options, strategies, uncertainties and futures. Further, it defines a set of objective matrices, typically cost and emission. For scenario selection scenario-based tradeoff analysis takes a computational-intensive approach, performing computer simulations to evaluate the objective matrices for all scenarios. This gives amongst other insight in the efficient frontier for the strategies under different futures, and makes it possible to point out which strategies are superior (on the frontier) and inferior, and how robust a strategy is relative to the alternatives. To make this task more tractable options can be evaluated independently in a stage-wise process to exclude inferior options prior to the fully integrated analysis.

4.3 Studies overview

This overview of scenario studies are presented through two tables, Table 3-4, describing the overall study and each scenario, respectively. The table structures are slightly revised versions of the overview tables defined in Morch et al. (2013, Section 3). For the column Category the following alternatives are used, inspired by Morch et al. (2013):

Predictive The scenario tries to describe the most likely future.

Explorative The scenario explores a particular future with a certain characteristic typically based on a current trend

Normative The scenario describes a vision for the future and uses backcasting to describe a pathway to this future

Extrapolative The scenario seeks to project the current situation into the future. Typically a benchmark scenario.

These categories are not disjunctive, for instance a scenario can use backcasting to calculate the pathway towards a target that is most likely going to be reached, making it both normative and predictive. The most characteristic category is chosen in Table 4 in such situation.

There are a large amount of studies on global and European scale published, and this overview do not seek to be complete but rather to present selected studies that are particularly comprehensive, relatively new and/or particularly relevant in a Norwegian perspective.

5 Summary

This report provides background information relevant for the Reaserch Area 5 on Scenario development in the research center CenSES. The scope of the scenario development and the report is the Norwegian energy system in a long-term perspective. Initially, the status of Norwegian energy system, green-house-gas emissions and emission targets are presented. Next, possible national emission reduction measures are presented and options for achieving emission reductions while keeping or increasing the value creation is discussed. In the last section, scenario studies as a method is described and a collection of relevant scenario studies are presented with their main properties and references.

Table 3: Overview of scenario studies

Title of the study	Scope	Origin	Published	Time horizon	No. of scenarios	Main idea
Global						
World Energy Outlook 2015[a]	World	IEA	2015	2040	4	Comprehensive study with annual updates. Includes COP21 INDCs[b] as guidance for central scenario (=New Policies). The scenario shows one-third energy use growth to 2040 all driven by non-OECD, and a significant increased share of non-fossil fuels globally.
Energy Technology Perspectives 2015[c]	World	IEA	2015	2050**?**	3	Comprehensive study focusing on energy sector trends and technology development and deployment. Evaluates necessary paths to reach stated climate targets in terms of temperature increase.
BP Energy Outlook 2015[d]	World	BP	2015	2035	1	Yearly updated global energy outlook seeking a 'most likely' view.
Energy [r]evolution 2015[e]	World	Greenpeace, GWEC[f] and SPE[g]	2015	2050	3	Fundamental ambitious pathways towards global decarbonization of the energy system with a high focus on RES.

[a] International Energy Agency (2015*b*)
[b] COP21= 21st Conference of the Parties, UN climate summit in Paris. INDC=Intended Nationally Determined Contribution
[c] International Energy Agency (2015*a*)
[d] BP (2015)
[e] Greenpeace International et al. (2015)
[f] GWEC=Global Wind Energy Council
[g] SPE=Solar Power Europe

Title of the study	Scope	Origin	Published	Time horizon	No. of scenarios	Main idea
European (p1:2)						
EU Energy Roadmap 2050[a]	EU27[b]	EC	2011	2050	7	Explores pathways to reach the EU target of 80% reduction of GHG emissions by 2050.
EU Reference Scenario 2013[c]	EU28[d]	EC	2013	2050	1	Update of the reference scenario given in EU Energy Roadmap 2050. A 2015-update is under preparation.
TYNDP 2014[e]	Europe-BY-MD-RU-TR-UA	Entso-E	2014	2030	4	Power grid development plan developed with comprehensive stakeholder interaction. Builds on Regional Investment Plans. Scenarios (called visions), which are intended to span the extremes, vary in whether EU are on track on decarbonisation targets and in how strongly the EU policies coordinate the national climate policies and efforts.
TYNDP 2016[f]	Europe-BY-MD-RU-TR-UA	Entso-E	2016	2030	4	Power grid development plan developed with comprehensive stakeholder interaction. Scenarios are in broad the same as for TYNDP 2014. Scenarios definitions are available, and final report with analysis will be published in mid 2016.

[a] European Commission (2011*a*)
[b] All EU member states as of 2008
[c] European Commission (2013)
[d] All EU member states as of 2014
[e] Entso-E (2014)
[f] Entso-E (2015)

Title of the study	Scope	Origin	Published	Time horizon	No. of scenarios	Main idea
European (p2:2)						
e-Highway 2050[a]	Europe[b]	e-Highway consortium	2012	2050	5	Focus on transmission network planning for reliable delivery of renewable power and market integration. Project within EU 7th framwork with high TSO participation.
CCS for industry [c]	EU28+ CH+NO	ZEP[d]	2015	2050	6	Evaluates CCS' contribution and competitiveness to decarbonising the industry and power sector. Decarbonisation is driven by increasing CO_2-prices.
Phasing out nuclear power in Europe[e]	EU27+ CH+NO+IS	CREE[f]	2015	2030	12	Explores an EU-wide nuclear phase-out assuming EU 2030-policies with 40% GHG reduction relative to 1990 with separate targets for ETS and non-ETS. Observes a moderate impact on total power production. Supplementary analysis comparing methodologies in Aune, Golombek, Le Tissier, Jaehnert, Völler & Wolfgang (2015).

[a] e-Highway 2050 (n.d.)
[b] EU28-CY-MT+RS+MD+CH+NO+MA+LY+DZ+TN+AL+MK+RU+Middle East
[c] Zero Emissions Platform (2015)
[d] ZEP=Zero Emissions Platform
[e] Aune, Golombek & Le Tissier (2015)
[f] Oslo Centre for Research on Environmentally friendly Energy

Title of the study	Scope	Origin	Published	Time horizon	No. of scenarios	Main idea
Nordic (p1:2)						
Nordic Energy Technology Perspectives 2013[a]	Nordic[b]	IEA and Nordic Energy Research	2013	2050	5	Evaluates different climate targets for the Nordic countries deploying proven technologies and current/planned policies.
Nordic Energy Technology Perspectives 2016	Nordic	IEA and Nordic Energy Research	2016			
Norstrat[c]	Nordic	SINTEF Energy Research	2014	2050	4	Analyzes how the Nordic power system can become carbon neutral, focusing on grid integration and increased RES capacity.
HydroBalance[d]	Norway(?)	SINTEF Energy Research	2015	2050	4	Focuses on the Norwegian hydropower's potential role as contributor of balancing flexibility to Europe. Scenarios defined, but analysis not completed yet.

[a]Nordic Energy Research & International Energy Agency (2013)
[b]Denmark, Finland, Iceland,Norway,Sweden
[c]Graabak & Warland (2014)
[d]Sauterleute et al. (2015)

Title of the study	Scope	Origin	Published	Time horizon	No. of scenarios	Main idea
Nordic (p2:2)						
Norway's national budget 2015[a]	Norway	The Ministry of Finance	2014	2030	1	Extrapolation of Norway's economy. Includes GHG emission trajectories.
CenSES Energy demand projections towards 2050[b]	Norway	CenSES[c]	2015	2050	5	Presents projections for the Norwegian energy consumption with 2010 as base year, varying the assumptions on energy efficiency and industry activity level.
Energy scenarios for 2020, 2035 and 2050[d]	Denmark	The Danish Energy Agency	2014	2050	5	Evaluates different paths towards the Danish vision of becoming fossil free together with one alternative path with fossil energy sources.
Basis for Swedish Roadmap 2050[e]	Sweden	Profu	2012	2050	4	Energy system analysis varying assumptions on energy demand, global fossil fuel and CO_2-prices. Conducts sensitivity analysis on new nuclear power production, cable integration with Nordic and Continental European countries, CCS and biomass prices. Constitute part of the basis for the development of a Swedish Climate Roadmap for 2050[f] ordered by the government.

[a] Det konglige finansdepartement (2014)
[b] Rosenberg et al. (2015)
[c] CenSES = Centre for Sustainable Energy Studies
[d] Energistyrelsen (2014), the original title in Danish is 'Energiscenarier frem mod 2020, 2035 og 2050'
[e] Profu (2012), Original title 'Beräkningar med MARKAL-NORDIC inför Färdplan 2050'
[f] 'Färdplan 2050'

Table 4: Overview of scenarios in studies

Title of the study	Scenario title	Category	Main ideas
Global			
World Energy Outlook 2015	New Policies	Predictive	The central scenario. Takes into account adopted policies by mid-2015 and declared policy intentions including INDCs.
World Energy Outlook 2015	Current Policies	Extrapolative	Enacted policies only.
World Energy Outlook 2015	450	Normative	A pathway to the 2°target using technologies close to being available commercially.
World Energy Outlook 2015	Low Oil Price	Explorative	Studies implications of sustained low oil prices.
Energy Technology Perspectives 2015	6°C (6DS)	Normative	Continues current trends. Broadly consistent with WEO[9] 2015 Current Policy Scenario.
Energy Technology Perspectives 2015	4°C (4DS)	Normative	Requires significant policy and technology change to achieve 4°target. Broadly consistent with WEO 2015 New Policy Scenario.
Energy Technology Perspectives 2015	2°C (2DS)	Normative	Is the main scenario in the study. 60% cut in energy- and process-related CO_2emissions by 2050 and substantial reductions in other sectors to meet 2°target. Broadly consistent with WEO 2015 450 Scenario.
BP Energy Outlook 2015	Outlook	Predictive	Seeks to describe the 'most likely' future for the global energy system.
Energy [r]evolution 2015	Reference	Extrapolative	Current trends and policies. Based on WEO 2014 Current Policies scenario.
Energy [r]evolution 2015	Energy [r]evolution	Normative	Pathway to achieve GHG emission reduction compatible with the 2°target giving a widely decarbonized energy system in 2050. Global phase-out of nuclear energy.
Energy [r]evolution 2015	Advanced energy [r]evolution	Normative	Ambitions pathway towards a fully decarbonized energy system in 2050.

Title of the study	Scenario title	Category	Main ideas
European			
EU Energy Roadmap 2050	Reference	Extrapolative	Current trends, 1.7% GDP growth and policies adopted by March 2010 including 2020 targets and ETS. Several sensitivities.
EU Energy Roadmap 2050	Current Policy Initiatives	Extrapolative	As reference scenario but includes policy initiatives on nuclear, energy efficiency and energy taxation.
EU Energy Roadmap 2050	Energy Efficiency	Explorative	Political commitment to very high energy savings leads to a decrease in energy demand of 41% in 2050 relative to 2005/2006.
EU Energy Roadmap 2050	Diversified Supply Technologies	Explorative	Technology neutral support measures and decarbonisation driven by carbon prices. Both nuclear and CCS accepted.
EU Energy Roadmap 2050	High RES	Explorative	Strong support measures for RES leading to a RES share of 75% in final energy consumption and 97% in power consumption by 2050.
EU Energy Roadmap 2050	Delayed CCS	Explorative	As diversified supply technologies, but with delayed CCS.
EU Energy Roadmap 2050	Low Nuclear	Explorative	As diversified supply technologies, but with no new nuclear investments.
EU Reference scenario 2013	Reference	Extrapolative	Current trends updated with statistics up to 2010. Includes policies adopted by spring 2012.
TYNDP 2014	Slow Progress	Explorative	Delay of Energy Roadmap 2050 and low integration on internal electricity market gives low electricity demand.
TYNDP 2014	Money Rules	Explorative	Delay of Energy Roadmap 2050 but high integration on internal electricity market gives medium electricity demand.
TYNDP 2014	Green Transition	Explorative	On track for Energy Roadmap 2050 but low integration on internal electricity market gives medium electricity demand.
TYNDP 2014	Green Revolution	Explorative	On track for Energy Roadmap 2050 and high integration on internal electricity market gives high electricity demand.
e-Highway 2050	Large scale RES	Explorative	Focus on development of large-scale RES accompanied with centralized storage solutions.
e-Highway 2050	100% RES el.	Explorative	100% renewable electricity, with both large-scale and small-scale links with North Africa and storage technologies.
e-Highway 2050	Big and market	Explorative	High GDP growth and highly integrated market-based energy system in EU. Mature CCS.
e-Highway 2050	Large fossil fuel	Explorative	Large fossil fuel with CCS and nuclear power, low RES generation. Mainly centralized electrification of transport, heating and industry.
e-Highway 2050	Small and local	Explorative	Focus on decentralized generation and storage and smart grid at distribution level.

Title of the study	Scenario title	Category	Main ideas
CCS for industry	Baseline	Explorative	CCS available when economical.
CCS for industry	CCS delay	Explorative	Delay in CCS deployment to 2035.
CCS for industry	CCS for power	Explorative	CCS deployment for power only.
CCS for industry	CCS for industry	Explorative	CCS deployment for industry only.
CCS for industry	No CCS	Explorative	CCS not available.
CCS for industry	No el. storage	Explorative	Large-scale electricity storage not available.
Phasing out nuclear power in Europe	Reference	Extrapolative	Nuclear capacity according to decisions up to 2014.
Phasing out nuclear power in Europe	50% nuclear phase-out	Explorative	50% reduction of nuclear capacity by 2030 relative to 2009.
Phasing out nuclear power in Europe	100% nuclear phase-out	Explorative	Complete phase-out of nuclear by 2030.
Phasing out nuclear power in Europe	No EU policy	Explorative	Complete phase-out of nuclear by 2030 and no climate target.
Phasing out nuclear power in Europe	Efficient	Explorative	Complete phase-out of nuclear by 2030 and common emission target for ETS and non-ETS.
Phasing out nuclear power in Europe	High emissions	Explorative	Complete phase-out of nuclear and 20% GHG reduction by 2030 relative to 1990.
Phasing out nuclear power in Europe	Low emissions	Explorative	Complete phase-out of nuclear and 50% GHG reduction by 2030 relative to 1990.
Phasing out nuclear power in Europe	Cheap CCS	Explorative	Complete phase-out of nuclear. EU covers 50% of CCS investment costs.
Phasing out nuclear power in Europe	EU renewable target	Explorative	Complete phase-out of nuclear. Common EU target for RES of 40%.
Phasing out nuclear power in Europe	National renewable policy	Explorative	Complete phase-out of nuclear. Subsidies to RES in selected countries.
Phasing out nuclear power in Europe	Balancing power	Explorative	Complete phase-out of nuclear. Increased requirement of balancing power.
Phasing out nuclear power in Europe	Energy efficiency	Explorative	Complete phase-out of nuclear. Energy efficiency rates neutralizes effect of economic growth on energy demand.

Title of the study	Scenario title	Category	Main ideas
Nordic			
Nordic Energy Technology Perspectives 2013	4DS	Normative	Targets corresponding to global 4°target. Nordic contribution to scenario with same name in ETP 2012 (International Energy Agency 2012).
Nordic Energy Technology Perspectives 2013	2DS	Normative	Targets corresponding to global 2°target. Nordic contribution to scenario with same name in ETP 2012 (International Energy Agency 2012).
Nordic Energy Technology Perspectives 2013	CNS	Normative	Carbon Neutral Scenario. CO_2 emissions fall by 85% and remaining 15% offset by global carbon credits.
Nordic Energy Technology Perspectives 2013	CNBS	Normative	Carbon Neutral high Bioenergy Scenario. As CNS, but pushes high use of bio energy both in transportation and buildings.
Nordic Energy Technology Perspectives 2013	CNES	Normative	Carbon Neutral high Electricity Scenario. As CNS, but with increased electrification and grid integration both internally and with neighboring countries.
Norstrat	Carbon Neutral	Explorative	Planned and existing grid connections to Europe. Fossile power production replaced by 100-150 TWh new RES.
Norstrat	Pure RES	Explorative	Planned and existing grid connections to Europe. Nuclear and fossile power production replaced by 200-250 TWh new RES.
Norstrat	European Hub	Explorative	Profitable grid integration extensions to Europe included. 200-250 TWh new RES and up to 20 GW new hydropower capacity.
Norstrat	European Battery	Explorative	Profitable grid integration extensions to Europe included. 100-150 TWh new RES and up to 20 GW new hydropower capacity.
HydroBalance	Small Storage	Explorative	Small amounts of Norwegian hydropower for balancing in Europe. Medium grid and market integration.
HydroBalance	Big Storage	Explorative	High amounts of Norwegian hydropower for balancing in Europe. Large grid and market integration.
HydroBalance	Niche Storage	Explorative	Medium amounts of Norwegian hydropower for balancing in Europe, though limited to balancing on long (daily) horizons. Low grid and market integration.
HydroBalance	Nordic Storage	Explorative	Small amounts of Norwegian hydropower for balancing in Europe. Low grid and market integration.
Norway's national budget 2015	Reference	Extrapolative	Extrapolates the economic development from 2013 including existing policies.

Title of the study	Scenario title	Category	Main ideas
CenSES Energy demand projections towards 2050	REF	Extrapolative	Extrapolation of current state and policies with current industry activity corrected for decided changes and minor energy efficiency improvements.
CenSES Energy demand projections towards 2050	REF-EE	Extrapolative	As REF, but all profitable energy efficiency measures implemented and increased efficiency in transportation.
CenSES Energy demand projections towards 2050	FROZEN	Extrapolative	Current state extrapolated with increasing population.
CenSES Energy demand projections towards 2050	HIGH	Extrapolative	Increased activity and energy demand in industry and unlimited availability of battery electric vehicles.
CenSES Energy demand projections towards 2050	LOW	Extrapolative	Decreased activity and energy demand in industry, decreased transport demand and increased global energy prices.
Energy scenarios for 2020, 2035 and 2050	Wind	Explorative	Biomass consumption limited by own supply (250PJ). Massive electrification of transport, industry and district heating and expansion of offshore wind.
Energy scenarios for 2020, 2035 and 2050	Biomass	Explorative	200 PJ biomass imported. No hydrogen.
Energy scenarios for 2020, 2035 and 2050	Bio+	Explorative	Fuel-based system with with consumption of 700PJ where fossil fuels are replaced with biofuel. No hydrogen.
Energy scenarios for 2020, 2035 and 2050	Hydrogen	Explorative	200 Considerable hydroben use and increased wind power. Bioenergy consumption < 200PJ.
Energy scenarios for 2020, 2035 and 2050	Fossil-fuel	Explorative	Low cost focus, allowing fossil fuel and disregarding all policies and targets.
Basis for Swedish Roadmap 2050	Outcome 1	Extrapolative?	Low power demand, mainly due to increased energy efficiency and supply conversions for residential and service heating. Increasing global fossil fuel prices due to fragmented climate policies internationally.
Basis for Swedish Roadmap 2050	Outcome 2	Extrapolative?	High power demand, mainly due to power substituting fossil fuels in industry and transportation. Increasing global fossil fuel prices due to fragmented climate policies internationally.
Basis for Swedish Roadmap 2050	Outcome 3	Extrapolative?	Low power demand, mainly due to increased energy efficiency and supply conversions for residential and service heating. Decreasing global fossil fuel prices, but increasing fossil fuel costs due to increasing CO_2-prices, motivated by strong global climate policies.
Basis for Swedish Roadmap 2050	Outcome 4	Extrapolative?	High power demand, mainly due to power substituting fossil fuels in industry and transportation. Decreasing global fossil fuel prices, but increasing fossil fuel costs due to increasing CO_2-prices, motivated by strong global climate policies.

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