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Future energy demand - a Norwegian overview

Institute for Energy Technology

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Report title

Future energy demand - a Norwegian overview

Summary

The development of energy demand is a key driver of the future energy system. Energy demand forecasts are important input in many analysis carried out by both research partners and user partners in Centre for Sustainable Energy Studies (CenSES). This report gives an overview of different existing forecasts of energy demand and the need for and use of forecasts within CenSES. Future energy demand are vital when analysing policies to promote energy efficiency, technology implementation and renewable energy production and these are all important tasks of the research in CenSES.

An overview of some national forecasts is presented with their different scopes data. They have different time horizons, geographical areas, energy carriers, end-use demand sectors etc. The electricity consumption in 2050 of two official forecasts has been reduced from 197 TWh in the NOU 2006:18 to 153 TWh in the National Budget 2011, a decrease of 44 TWh in five years.

In addition, an overview of the scope, time horizon and areas of some international forecasts is also presented in this report. The annual global growth in electricity use varies from 2.4% in WEO 2011 to 3.1% in ETP 2012, compared to the European growth of 1.3% in EU Energy Roadmap and 0.8% in IEO 2011 (with different scenarios and time horizons). The growth in electricity, final energy demand and primary energy supply is highest on a global level, less on a European level and smallest for the Nordic countries.

Of the CenSES partners it is mainly IFE, Statnett, Hydro, NVE and Enova who work with forecasts or finance this work. The other CenSES partners use existing forecasts and sometimes have to adapt the data to fit their models. The geographic regions of interest varies from Norwegian regions, Norway as a country, the Nordic countries, Europe to global level. Some partners have a need of forecasts of certain energy carriers, such as electricity and gas, while other partners have a need of forecasts of useful energy for different end-uses, such as energy needed for space heating etc. The time horizon varies from 2020 to 2050, typically.

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Contents

1 Introduction

The development of energy demand is a key driver of the future energy system. Energy demand forecasts are important input in many analysis carried out by both research partners and user partners in Centre for Sustainable Energy Studies (CenSES). Some partners make their own forecasts, other partners use existing forecasts.

Analysing policies to promote energy efficiency, technology implementation and renewable energy production are all important tasks of the research in CenSES. A vital background to this work is the status of existing forecasts of energy demand and the need for and use of energy demand forecasts within CenSES, and this is summarized in this report. The focus is on long-term forecasts and thus, models and work with market models and short-term forecasts are out of the scope of this report.

Increased knowledge on how different partners develop their forecasts is important to be able to have a common understanding and a possibility to use common forecasts in analysis. We aim at using this work as a basis for the development of a projection of future demand which is available for all CenSES partners.

The work is carried out under the CenSES research area “Energy Systems and Markets”, but will also be used as input to the research area “Scenario analysis”. The authors of the report are responsible for the content, but important contributions come from many CenSES partners, and including Bjørn Bakken (SINTEF Energy Research), Kjetil Midthun (SINTEF TS), Ruud Egging (NTNU Indøk), Carlo Aall (WNRI) and Audun Fidje (NVE).

The identified need for energy demand forecasts within CenSES is described in chapter 2. This is followed by some information of energy use in Norway in chapter 3, as basis for the existing Norwegian forecasts that are included in chapter 4. In chapter 5 the view is enlarged to include international forecasts of major interest in CenSES. Finally, conclusions and ideas for further work are presented in chapter 6.

2 The need for energy demand forecasts within CenSES

A description of the different partners need for energy demand forecasts is presented in this chapter. In addition to a general description, the descriptions have the intention to include the following aspects of the need of forecasts as input to the models:

- Geographic regions
- Energy carriers (total, electricity/natural gas/…,) or energy service demand (space heating/electrical appliances, lighting….)
- Time horizon
- Time level (yearly, seasonal, daily, hourly….)
- Demand sections (by country, industry/residential/transport….)
- Sources of commonly used forecasts

2.1 Institute for Energy Technology (IFE)

IFE has a two-way approach to energy demand forecasts. First, the development in *useful* energy demand is calculated based on the assumption of no market based changes in energy efficiency, alternative fuels and no alternative use of technology. These forecasts are based on assumptions of economic growth, business development, demographics etc. It also includes normative measures such as building regulations. The energy demand is divided in four main sectors; industry, households, service & other and transport. These are further divided in sub-groups and the forecast is calculated for each of these sub-groups. Secondly, the forecast is input to analyses with the energy system model TIMES-Norway, with a modelling horizon of 2050, at present [1]. TIMES is a linear least cost optimization model that represents the entire energy system and can include extraction, transformation, distribution, end-uses and energy trade for different energy carriers. TIMES is developed in the frame of the implementing agreement IEA – ETSAP. The model is demand driven and investments are made to meet the future energy demand. Analyses with TIMES-Norway results in market adjustments due to alternatives of fuels, technologies, energy efficiency measures with different assumptions of oil prices etc. The time resolution of TIMES-Norway covers all weeks during each year with five time slices per week, giving 260 time slices annually. The TIMES-Norway model covers seven regions in Norway:

- Region 1: South
- Region 2: Central
- Region 3: West
- Region 4: East
- Region 5: Middle
- Region 6: North
- Region 7: Finnmark

Load profiles for thermal and electricity demand for the demand sectors are important input to the TIMES-Norway model. The load profiles have been developed based on measurements and modelling of sector specific load profiles and measured electricity data. The end use demands by sub sector and demand type are listed in Table 22 in Appendix A1. Each demand sector is divided into sub-sectors and demand types; electrical (non-substitutable), heating, cooling and raw material.

The demand sectors of each of the regions of TIMES-Norway are (see details in Table 23 in Appendix A1):

- Residential (10) – old and new single and multifamily houses + cottages, all with two end-uses (space heating &hot water + electric appliances incl. lighting)
- Commercial (21) – 8 subsectors with space heating, cooling & electricity
- Industry (33-36) – 11 subsectors – electricity, heat & raw material
- Transport (8) – short & long distance personal cars, freight transport, buses, train, sea, air, other

Summarized, the needs for energy demand forecasts of the TIMES-Norway model are:

- Useful demand of energy services (non-substitutable electricity, heating, cooling, raw material, vehicle-km)
- 7 Norwegian regions
- 260 time slices per year
- 33-36 sub-sectors per region
- Modelling horizon: 2006-2050

A new North-European TIMES-model is in progress, and this model will need forecasts of useful energy for Norway, Sweden, Finland, Denmark, Germany, the Netherlands and UK.

The time resolution of this model will be 12 time slices per day (2 h *12) and 12 annual periods (1 - 9 weeks per period), that is 144 time slices per year. The time horizon is 2010 – 2050. The demand sectors will probably be:

- Residential (6) – old and new – space heating, hot water & electricity specific
- Commercial (3) – space heating, cooling & electricity
- Industry (8) – power intensive, other, agriculture, offshore sector –heat & electricity
- Transport (6) – long distance personal cars, short distance personal cars, freight transport, buses, train, other

IFE can also do analysis with the global energy system model ETSAP-TIAM, developed within the IEA-ETSAP Implementing Agreement. The demand of ETSAP-TIAM is calculated with input of growth in population, GDP and households, and with the use of elasticities. The model is described in Appendix A1.

2.2 SINTEF Energy Research

SINTEF Energy Research (SINTEF ER) uses many different energy system models such as:

- EMPS (EFI's Multi-Area Power Market Simulator)/Samkjøringsmodellen
- eTransport
- GCAM
- USELOAD
- SHOP (Short-term Hydro Operation Planning)
- PSST (Power System Simulation Tool)

All but eTransport are "single state" calculating at a certain stage (year or week). EMPS, eTransport and GCAM are briefly described below and for further information of all the models, see Appendix A1.

EMPS (EFI's Multi-Area Power Market Simulator)/Samkjøringsmodellen

The tool is widely used in the Nordic electricity market (e.g. producers, system operators, authorities) to calculate generation scheduling and expansion planning. It is specialized to simulate system and market analysis in hydrothermal electrical systems because of its detailed modelled water courses. Within the model different areas are defined which contains consumption, production from hydro power and conventional power plants as well renewables sources and includes uncertainty in inflow and temperature. These areas are connected based on the existing transmission system including transmission constraints. An overview of the model concept is given in Figure 32 in Appendix A1. The inputs to the model include costs and capacities for generation, transmission and consumption of electricity, information about climatic variables in the past, among other things.

- Geographic regions:
    - Nordic: Norway (12 areas), Sweden (6 areas), Denmark (2 areas) and Finland (1 area)
    - Northern Europe: Nordic countries + UK/DE/NL/BE
    - Europe: 55 nodes for 37 countries and offshore nodes
- Up to 2050 (runs one single year with various data sets)
- Multiple load levels per week down to hourly resolution
- Electricity use divided into price-dependent and inflexible load

eTransport

The tool is used for planning of local sustainable energy systems. The main task of the model is to optimize investments in infrastructure over a planning horizon of several decades. As part of the investment analysis, the model also optimizes hourly operation for different periods of the year. This operational module can be run independently from the investment module. Different energy carriers (electricity, heat, cooling, gas, biomass) and technologies are considered simultaneously to help companies planning with their multi-energy portfolio. The graphical interface shows the given energy system including the costs, energy sources and environmental consequences (compare Figure 31 in AnnexA1)

eTransport needs hourly load profiles for a flexible number of periods per year for all energy carriers.

GCAM

In the LinkS project SINTEF Energy Research uses the Global Change Assessment Model (GCAM) that calculates long-term projections of global energy demand up to 2100 (see Appendix A1) as function of labour force, labour productivity and GDP in 5 year time steps. This is too aggregated to be used directly in the electricity grid and market models and has to be broken down to national level for further analysis. With electricity demand projections on national level, the profitable expansion of the European electricity transmission grid up to 2050 is calculated with EMPS.

2.3 Industrial Economics and Technology Management, NTNU / SINTEF TS

SINTEF Technology and Society (SINTEF TS) participate in the Energy Modelling Forum (EMF) 28 and as a part of this they are looking at the European Gas Market and infrastructure until 2050. SINTEF TS participates in the EMF28 with two models, a stochastic infrastructure model (Ramona) and The Global Gas Model (GGM) [2].

The Ramona model is a multi-stage stochastic optimization model for natural gas infrastructure analysis. The model was originally developed for detailed infrastructure analysis on the Norwegian Continental Shelf. The objective of the model for the Norwegian continental shelf is maximization of net present value of investments. In general, the model handles infrastructure decisions such as development of new fields, construction of new infrastructure (pipelines, compressors, processing plants) as well as redesign of existing infrastructure. On the operational level, the model handles the relationship between pressure and flow, gas quality, processing and security-of-supply restrictions. For the EMF28 study, a national aggregation level is used for Europe, while the rest of the world is represented by aggregated regions. The focus is on optimal infrastructure development given the natural gas demand scenarios provided by PRIMES (based on a set of policy and technology assumptions). PRIMES provide data for most of the European countries. For the remaining European countries, as well as for the rest of the world, the data is supplemented with forecasts from other sources (such as IEA and EIA) to improve the data input. The model distinguishes between three demand sectors; industry, power generation and residential / commercial. For all these sectors inverse demand functions are estimated based on the demand level and price from PRIMES (or alternative sources) as well as assumed price elasticity. In the EMF28 study, the objective function is maximization of discounted social surplus in the time horizon from 2010 to 2050 with a 5 year resolution.

The GGM is an equilibrium model that represents all European countries, some surrounding countries, and the rest of the World by continent or aggregate region. The model has seasonal demand and distinguishes three demand sectors, and needs reference wholesale prices for all sectors and seasons. The model needs forecasts for production levels and consumption levels in all countries/regions in five year steps. Since GGM is an equilibrium model wherein demand responds to the price levels, the model must be calibrated. This is mostly done by adjusting reference market prices and production cost and capacities. In the model calibration, it is assumed that neither seasonality nor sector shares change over time, and prices are chosen to reflect average prices over large regions (so not by separate country). Demand forecasts are mostly from IEA World Energy Outlook, annual, (such as [3] and US Energy Information Administration (EIA) - International Energy Outlook, annual (such as [4]).

2.4 Department of Interdisciplinary Studies of Culture at NTNU

The focus at the Department of Interdisciplinary Studies of Culture at NTNU is on energy use and not primarily on forecasts of energy demand. The main interest at the department on energy forecasts is as input to evaluations of the volume of supply and the impact on new renewable energy sources, particularly electricity. Through the work possible development based on the implementation of different policies will be substantiated.

2.5 Western Norway Research Institute (WNRI)

WNRI has worked with combining two models or approaches in analysing past and future end-use energy use, namely that of drivers- and barriers approach (or pressure-state-response) and that of system dynamic modelling for creating a scenario model. In analysing household energy-use, the following direct drivers have been applied: Living area; the distribution of dwellings and living area according to types of building; the condition of the building envelope; indoor temperature; water heating; specific energy consumption; energy consumption relating to lighting and electrical equipment; choice of heating system; and the share of buildings with heat pumps. The following indirect drivers have been applied: Changes in environmental conditions (mainly outdoor temperature); demographic changes; economic considerations; technological development; and changes in terms of knowledge, attitude and preference. The following response drivers have been applied and the mechanisms in which they could influence the direct and indirect drivers were discussed and assessed: Information; taxation; regulations and economic support.

The scenario model incorporates a range of requirements enabling the user to select development rate (per cent change) and development type (linear, exponential or stepwise change) for a number of factors. The factors apply to area (total area, area by residence type or distribution of area among different residence types) and energy use (kWh/m^2). The user can modify requirements for future development relative to the following factors: Housing (area, residents, and numbers – overall, and distributed among types of residence); specific energy use, waste heat and technological development of major appliances, lighting, technical operations, electronic devices and water heating; ambient heat (distribution between type of residence and technological development); choice of energy carrier for heating; and gross heat demand (distribution between type of residence and technological development).

2.6 Statnett

The objective of working with foresights and forecasts is to identify the feasibility space for future challenges as transmission system operator. The thematic areas covered are electricity production and use. Statnett have the responsibility to write a power system review for the central grid and a plan for development of the central grid.

The foresights are updated every second year in relation to writing the Plan for Development of the Central Grid and if necessary they perform revisions of the foresight in between. The foresights have normally a 15-20 years perspective. The last Plan for Development of the Central Grid was released in 2011 with a time frame of 2010-2030.

The geographical scope is mainly national and Nordic since the electricity market is common in the Nordic countries. Connections to the Netherlands and thereby the rest of the European market, makes it interesting to also evaluate the rest of Europe. The implementation of new technologies are not included in detail, but energy efficiency, the development in wind power costs and plug-in hybrids are examples of technologies studied.

Statnett uses scenarios to handle the uncertainties in the driving forces which influence the future energy demand and future need for transmission capacity in the central grid. The analyses give the need for grid reinforcement due to change in energy demand and transmission capacity in the different scenarios. Statnett addresses the following subjects in this work:

- Security of supply
- Development of global and national economy
- Energy prices
- The European Renewable Energy Directive (EU20/20/20)
- Renewable policy in Norway (renewable directive, green certificates)
- Electricity demand in petroleum sector (onshore processes and offshore mining)
- Development in electricity intensive industry
- Energy efficiency
- Technology development

2.7 Hydro

Hydro makes medium-long forecasts of all energy carriers (up to 2035) by use of bottom-up methods. The end-use demand is very important and price elasticities are calculated based on statistical data on value added elasticities and electricity consumption. The main interest is the development of electricity price and the power market in Norway and Europe. Hydro studies the development in electricity price and its impact on industry production, but in order to study this, it is important to understand energy substitution possibilities and energy efficiency potentials. Hydro analyses future energy demand by use of their own models, as well as studying others forecasts. The main interest is Norway, but since the electricity price is dependent on the price in neighbour countries, Hydro also studies these forecasts. The global level is also important to Hydro, as they have facilities world-wide.

2.8 The Norwegian Water Resources and Energy Directorate (NVE)

The goals of The Norwegian Water Resources and Energy Directorate (NVE) are to ensure consistent and environmentally sound management of water resources, promote an efficient energy market and cost-effective energy systems, and contribute to the economic utilization of energy.

The short-term energy demand forecasts of NVE are focused on electricity, but the possibilities for substitutions with other energy carriers are of interest as well. The long-term forecasts include all energy carriers. NVE has different sector models for residential, service and industry. The forecasts of buildings (residential and service) are based on a calculation of activities and intensities, while the industry forecast is based on a study of individual plants, particularly of energy intensive industries. The forecast of energy demand services are input to TIMES-Norway, analysing the mix of energy carriers and end-use technologies. Other important input-data used by NVE when analysing with TIMES-Norway are results of the power market models BID and TheMa and the electricity market power model EMPS (Samkjøringsmodellen).

The studies are national, but in some cases regional studies are done with special focus on security of supply. The common electricity market in the Nordic countries makes it interesting to analyse the development in the neighbouring countries as well. A special interest is the common green certificate market between Norway and Sweden.

Forecasts of future energy demand is an important input to studies such as the national report on renewable energy policies published by the Ministry of Petroleum and Energy [5]. In such studies, NVE has a need for forecasts of future energy demand, mainly on a national level and on a medium long term.

2.9 Enova

Enova SF's main mission is to contribute to environmentally sound and rational use and production of energy, relying on financial instruments and incentives to stimulate market actors and mechanisms to achieve national energy policy goals.

The objective for Enova to support foresight studies is to understand the future energy demand, the drivers and the possibilities for Enova to influence the development. Another objective is to be able to measure the effects of supported measures that are difficult to measure directly. It is important for Enova to understand the premises and assumptions of the forecasts. Studying the difference between profitable, rational energy efficiency measures and the actual implemented energy efficiency measures is of major interest and it is more important to understand why not all profitable measures are implemented than to know the exact value of the energy efficiency potential.

The geographical scope is national and the time horizon is both medium (approx. 15 years) and long (until 2050).

2.10 The Research Council of Norway (NRC)

The Research Council (NRC) is Norway's official body for the development and implementation of national research strategy. The Council is responsible for enhancing Norway's knowledge base and for promoting basic and applied research and innovation in order to help meet research needs within society. NRC also works actively to encourage international research cooperation. The Research Council serves as an advisory body on research policy issues, identifies research needs and recommends national priorities.

In 2001 an evaluation of the NRC recommended the Council to initiate an open foresight process. The Research Council decided in 2002 to initiate pilot projects to gain experiences with foresight as a tool in program planning and strategy processes. From 2003 to 2005, the Research Council implemented and carried out five foresight projects, one of them was Foresight Energy 2020+ (the energy sector after 2020). Each project was run by a project group with representatives from business/industry, academe and the public sector. The scenario group consisted of about 70 persons representing different views of the society. The main milestones were four workshops that identified first 132 mini-scenarios which later were merged to 6 main scenarios with 8 dimensions. This scenario-process was in 2007 followed up by a new scenario-process with focus on a few high-priority tasks (bio fuel, bio energy, offshore wind power and solar electric power), that had a minor scope but still were demanding processes.

The Research Council was also secretariat for the Energi21, an initiative launched by the Ministry of Petroleum and Energy in 2007, with the aim of designing a broad-based collective R&D strategy for the energy sector. The strategic committee prioritised areas in which R&D investments are essential to achieving results. The strategic committee consisted of 16 members from industry, the research community and the authorities and received input from six targeted sub-committees, each of which dealt with specific topics and then presented a report containing its recommendations. A number of dialog meetings were held with industry and research groups during the process.

In 2008 NRC decided to establish Centres for Environment-friendly Energy Research (FME) and now 11 centres are operating within renewable energy, CCS and social sciences. The objective of the FME is to establish time-limited research centres which conduct concentrated, focused and long-term research of high international calibre in order to solve specific challenges in the field.

2.11 Summary

Of the CenSES partners it is mainly IFE, Statnett, Hydro, NVE and Enova who work with forecasts or finance this kind of work. This work with Norwegian forecasts is further described in chapter 4. The other CenSES partners use existing forecasts and sometimes have to adapt the data to fit their models. The geographic regions of interest vary from Norwegian regions, Norway as a country, the Nordic countries, Europe to global level. Some partners have a need of forecasts of certain energy carriers, such as electricity and gas, while other partners have a need of forecasts of useful energy for different end-uses, such as energy needed for space heating etc. The time horizon varies from 2020 to 2050, typically. To facilitate the comparison, a brief summary of the different use of energy forecasts within CenSES is presented in Table 1.

Table 1 Summary of different model input from energy forecasts within CenSES

Partner / Model	Demand forecast work	Geographic region	Energy carrier
IFE / TIMES	Yes	Norway (7 regions) / Northern Europe /Global	Energy service demand (input) *All energy carriers (output)*
SINTEF ER /EMPS	No	Norway (multiple regions) / Northern Europe / Europe	Electricity
SINTEF ER /eTransport	No	Municipality / Supply area	Electricity, Heat, Gas, Biomass, Cooling
NTNU Indøk & Sintef TS /Ramona	No	Europe/Global	Natural gas
NTNU Indøk & Sintef TS /GGM	No	Europe /Global	Natural gas
Statnett	Yes	Norway / Nordic countries	Electricity
Hydro	Yes	Norway / Global	Electricity / all carriers
NVE	Yes	Norway	Electricity / all carriers / energy service demand (see IFE/TIMES)
Enova	Yes	Norway	All energy carriers

3 Norwegian energy use

As a background for the presentation of energy demand forecasts, an overview of energy use in Norway the last decades is presented in chapter 3.1. The overview is based on the project “ODYSSEE-MURE” [6]. This is followed by studies of energy by end-use in households in chapter 3.2 and a study of energy in households in chapter 3.3.

3.1 Overview of energy use in all sectors 1990-2010 (ODYSSEE-MURE project)

The Norwegian economy was growing every year from 1990 to 2008, had a small recession in 2009 and continued to grow after that, measured as the overall gross domestic product (GDP). There has in average been no development of the GDP during the past five years, see Figure 1. In 2010 GDP increased by 0.3 % and in 2011 by 1.3 %. The growth in GDP was highest in the 1990s, due to high activity in oil and gas drilling. Private consumption at constant prices has in average increased by 5.8 % annually from 1990 to 2011 but in 2009 there was a small decrease of 0.2 %. In 2011 private consumption increased by 2.5 %.

Industry value added had a rapid growth from 1990 to 1997, then had a slower growth until around 2004 and finally followed by a decrease from 2005 to 2011. The offshore activities had a strong increase from 1990 to 1997, a smaller increase until 2004 and have since been declining. In 2009 the industry value added decreased by 4.0 %, 2010 it was 2.2 % and in 2011 it was 0.6%. In average, industry value added has increased annually by 2.1% from 1990 to 2011. Value added in manufacturing industry increased annually by 1.5 % from 1990 to 2011, with a growth in 1995-1997, 2003-2008 and a slow growth the last three years.

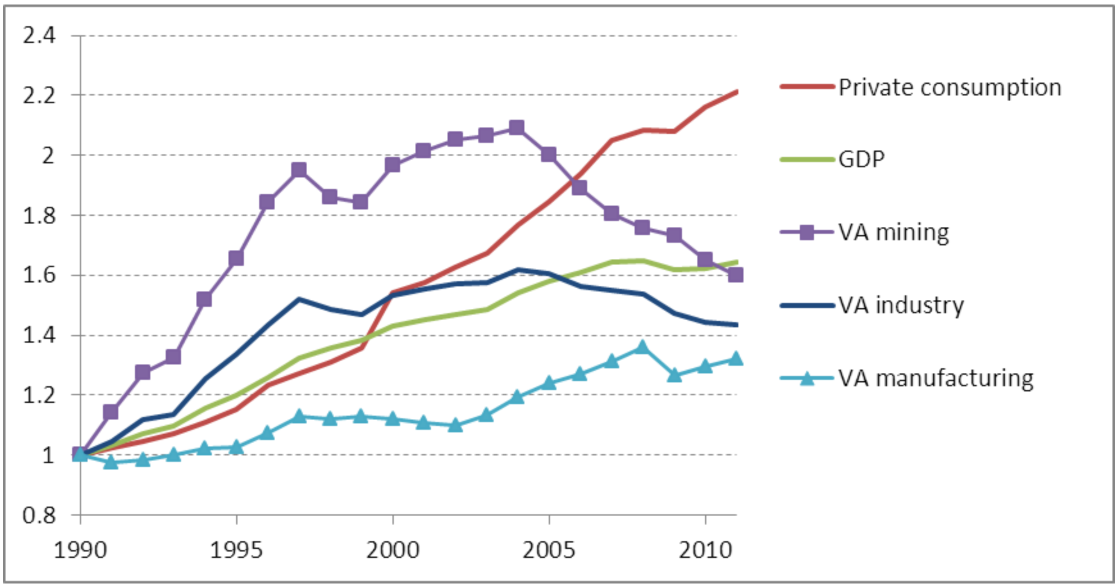

Figure 1 Macro-economic development in Norway 1990-2011 at constant prices; VA = Value Added (1990=1)

Half of all energy end use in Norway is electricity, see Figure 2. The electricity use has an annual increase of 0.8 % since 1990, but the last decade the annual increase is reduced to 0.14 %, down from an annual increase of 1.4 % in the period 1990-2000. Use of oil products increased until 1999 and has after that been rather constant, due to a reduced use of oil for heating and an increased demand of transportation. The share of gas is rather small, but shows an annual increase of 4.3 % from 1990 to 2010. District heating has increased by 21

% annually and was in 2010 4.5 TWh. The use of wood products shows an annual increase of 2.3 % and was 14.5 TWh in 2010.

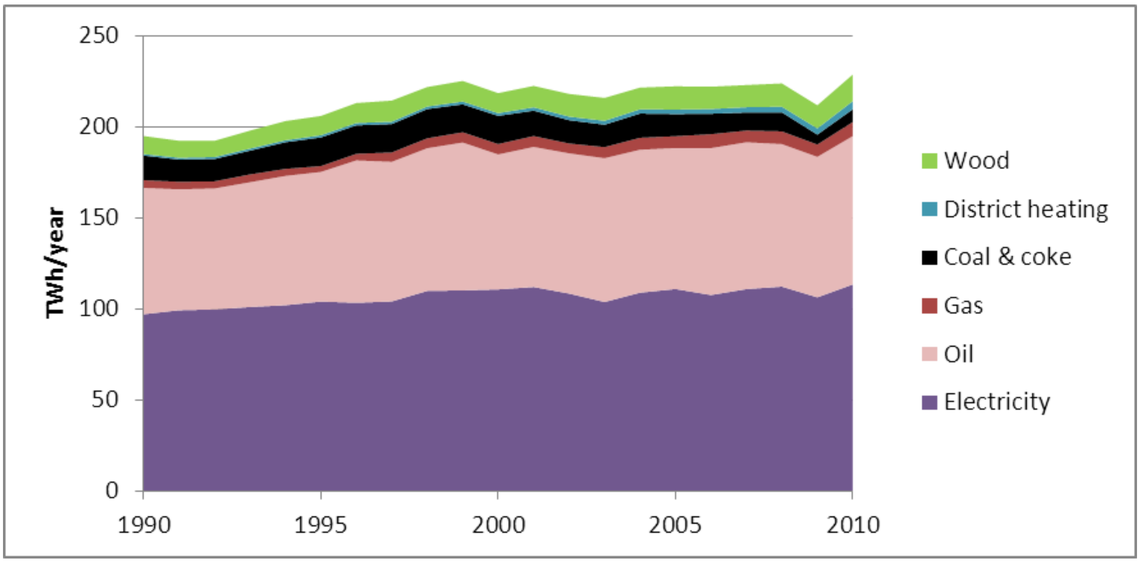

Figure 2 Final energy consumption in Norway 1990-2010

The sector using most energy both in 1990 and in 2010 was industry, but the share has decreased from 40 % in 1990 to 31 % in 2010, see Figure 3. All the other sectors have a higher share in 2010 and the transport sector has increased its share the most.

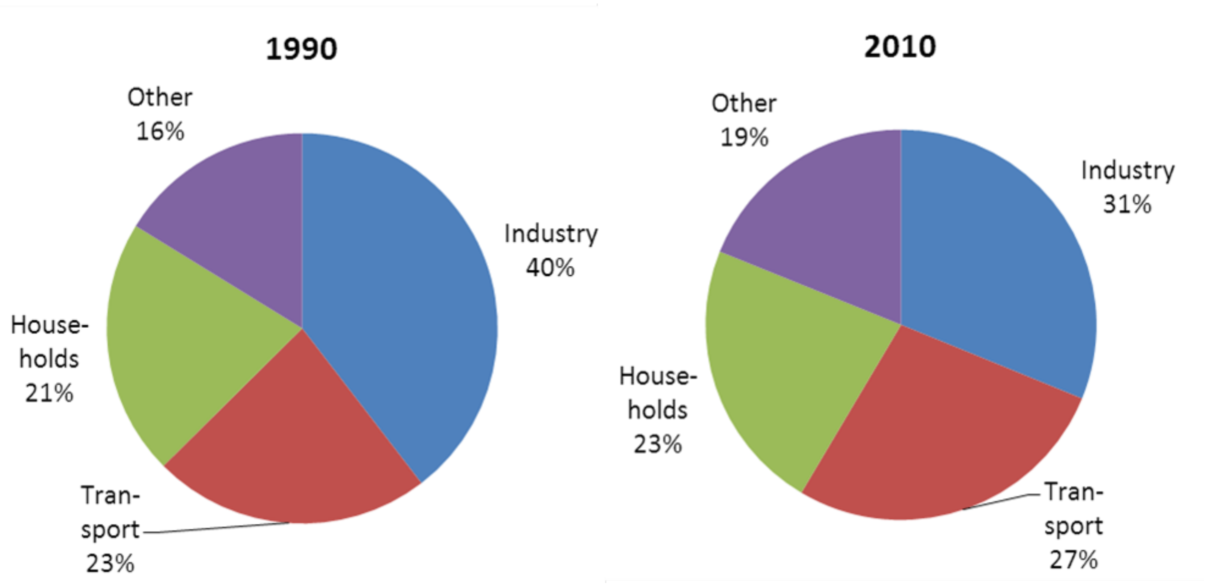

Figure 3 Final energy consumption by sector in Norway in 1990 and 2010

3.1.1 Industry

The industry sector uses about one third of the final energy in Norway and this share has decreased the last decades. In total, the energy use of industry was highest in the year 2000. Until 2008 the decrease was only 1 % per year, but in 2009 the energy use decreased by 21 % followed by an increase of 12 % in 2010. The energy consumption of industry (including mining and construction) was 88 TWh in 2000, 63 TWh in 2009 and 71 TWh in 2010. In 2010, 62 % of the energy use in industry was electricity, 31 % was fossil energy, 7 % was biomass and 1 % was district heat.

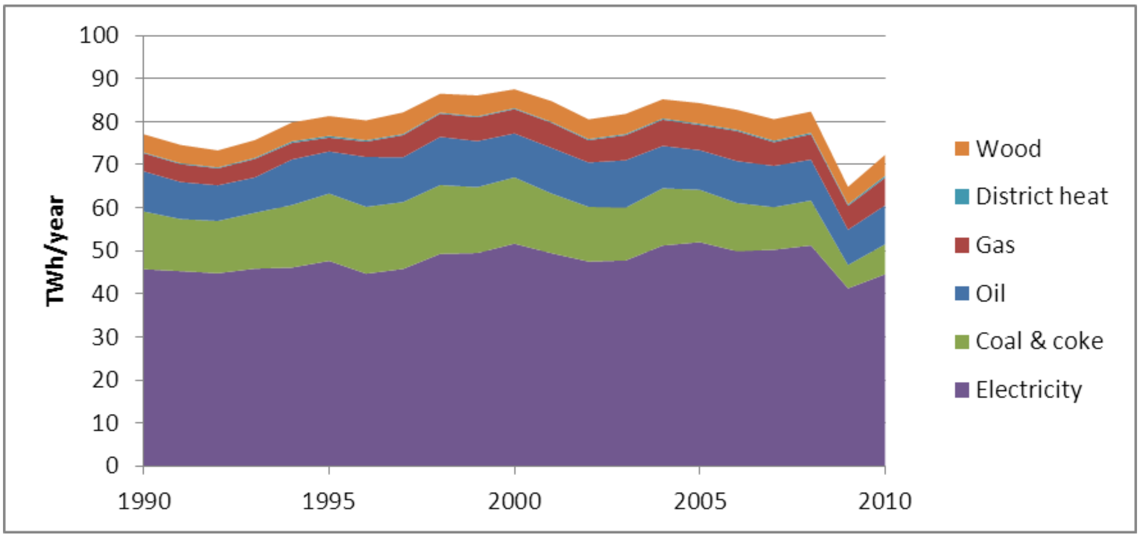

Figure 4 Final energy consumption by energy carrier in industry 1990-2010 (TWh/year)

Energy intensive branches such as metals manufacturing, basic chemicals and pulp & paper production dominates the sector's energy use, using 81 % of total energy use in industry in 2010. The sub-sector with the highest share is the production of non-ferrous metals (mainly aluminium) that used 30 % of total energy use in industry in 2010. The chemical industry had the second highest share (24 % in 2010) followed by the pulp & paper industry and the production of iron, steel and ferro-alloys with a share of respectively 14 % and 13 % in 2010.

Several energy intensive plants have been moved in the energy balance from one industrial sub-sector to another (especially from iron and ferrous to chemicals), making it difficult to analyse the development in these sub-sectors. The energy statistics was based on the old standard of classification until 2008 and the statistics of 2009 and 2010 follows the new standard of classification. The consequence of the change of classification is that graphic production, recycling and some industry service is moved from manufacturing industry to the service sector. In overall, the energy use of companies that have changed classification is less than 1 % of the energy used in the industry sector. The macro economic data are based on the new standard of classification back to 1990.

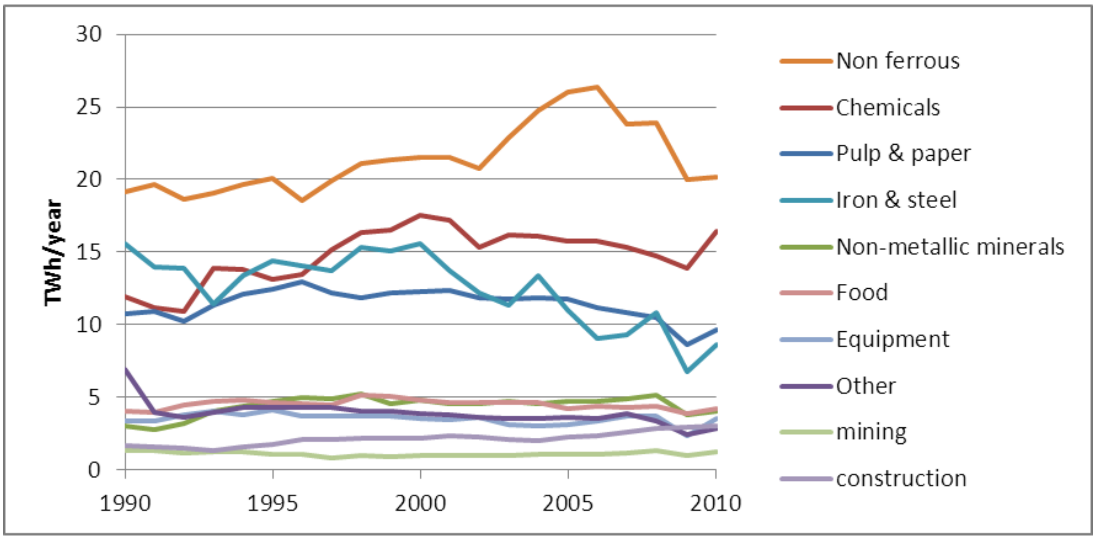

Figure 5 Trends in energy use per sector in industry 1990-2010 (TWh/year)

3.1.2 Households

Final energy use in households has increased from 41 TWh in 1990 to 51 TWh in 2010, see Figure 6. The energy use has been on the same level from about 1994 with minor variations partly because of different outdoor temperatures. The electricity share has been between 75% and 79% in the period 1991-2010, with an exception in 2003 when the share was only 72% due to high electricity prices. The use of oil has decreased from 5.0 TWh in 1990 to 2.1 TWh in 2010. The use of fire wood increased from 5.7 TWh in 1990 to 8.3 TWh in 2010. The use of district heat was 1.1 TWh in 2010 and the gas consumption was 0.05 TWh in 2010. Climate variations explain to a large extent short-term variation in energy use. The climate corrected final energy use[1] has been rather constant since about 1995 at approximate 45 TWh, but the last three years there is an increasing trend in residential energy use. The climate corrected energy use increased from 44.5 TWh in 2007 to 48.5 TWh in 2009 and 2010.

[1] In ODYSSEE, climate corrections are carried out for all countries using the same methodology, even if climate-corrected national data exist. They are only applied to a certain proportion of the space heating consumption (90%) to account for the fact that some losses are not dependent on the number of degree-days. The correction is done for each country in a linear way on the basis of the ratio between the normal degree-days and the real degree-days.

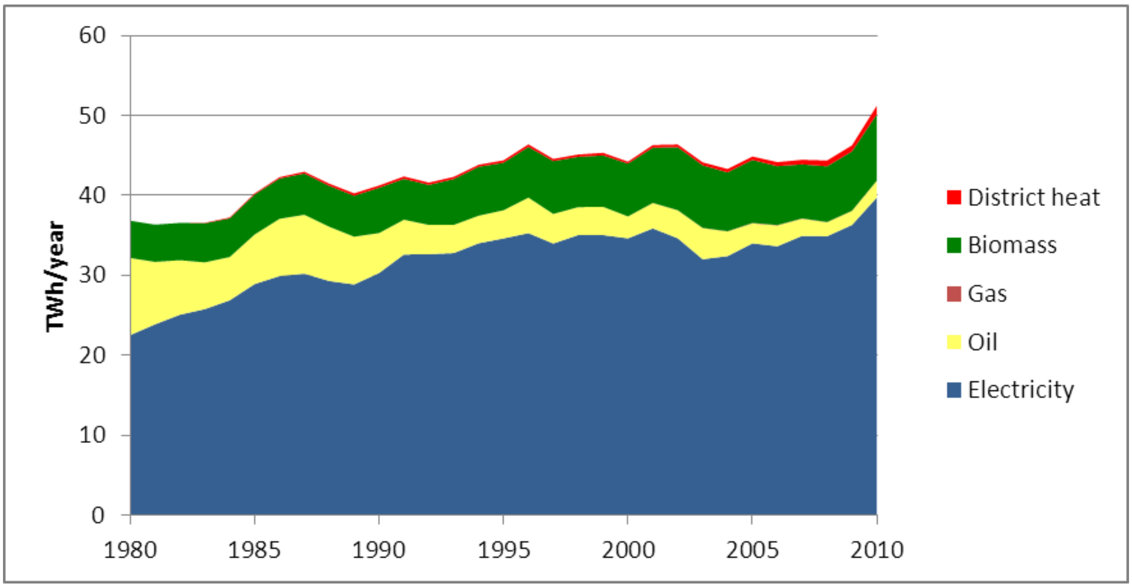

Figure 6 Final residential energy use by fuel (not climate corrected); 1980-2010 (TWh)

Driving forces such as private consumption, number of households and population have increased more than the residential energy use, see Figure 7. Around 1990 there seems to be a decoupling of the energy use from private consumption. Until about 2002 the number of households and the energy use have the same trend, but despite the increased number of households from 2002 to 2010 the energy use did not increase.

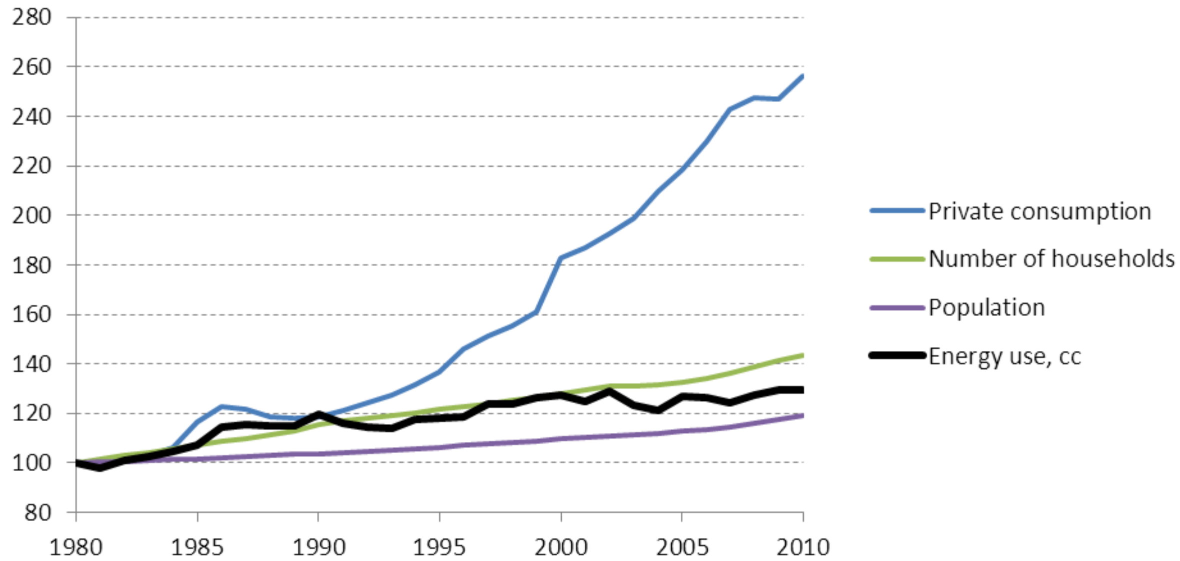

Figure 7 Trends in useful, climate corrected energy, private consumption, area, number of households and resident population 1980-2010

In the first part of the 1990s an increasing residential area can explain the growth in energy use in the residential sector. But since mid-1990's the energy use has stopped growing despite a continued growing area, see Figure 8. A higher share of electricity with higher energy efficiency gives a lower growth in final energy than in useful energy. In 2010 the final energy would have been 1.5 % higher if the share of fuels was as in 1990.

The climate explains a major part of the increased energy use in 2010, but final climate corrected energy use seems to have increased slightly the last years. In order to calculate the influence of temperature on the energy use, it is important to know how much of the total energy that is used for heating. No Norwegian data for each year is available and therefore the calculation is based on estimates. The heating share was recently calculated to be 66 % [7] and in the beginning of 1990's it was calculated to be approximately 55 %. Based on these two studies, an estimate of climate corrected final energy use is calculated, as shown in Figure 8. In average the households used 22 325 kWh/dwelling and 172 kWh/m² in 2010 of final energy (not climate corrected).

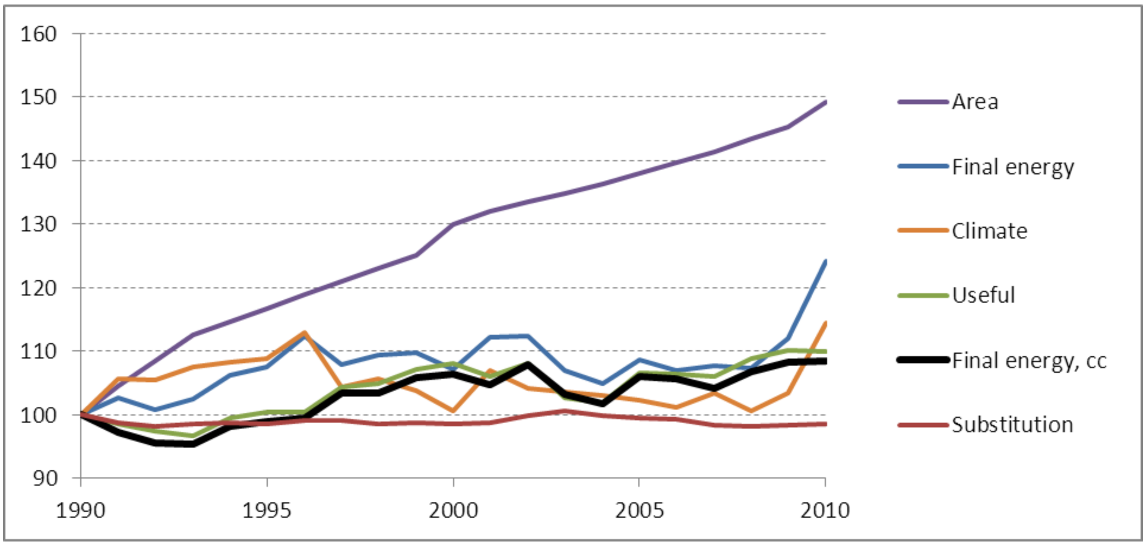

Figure 8 Effect of fuel substitution, climate and heated area on final energy use, 1990-2010

Climate corrected energy use per capita has decreased annually by 0.27 % from 1990 to 2010, see Figure 9. Climate corrected energy use per household has decreased annually by 0.6 % and per private consumption by 2.5 %. Climate corrected energy per heated area is used as energy intensity indicator in the residential sector in ODYSSEE, and a decrease of 26 % indicates an annual saving of 11 TWh.

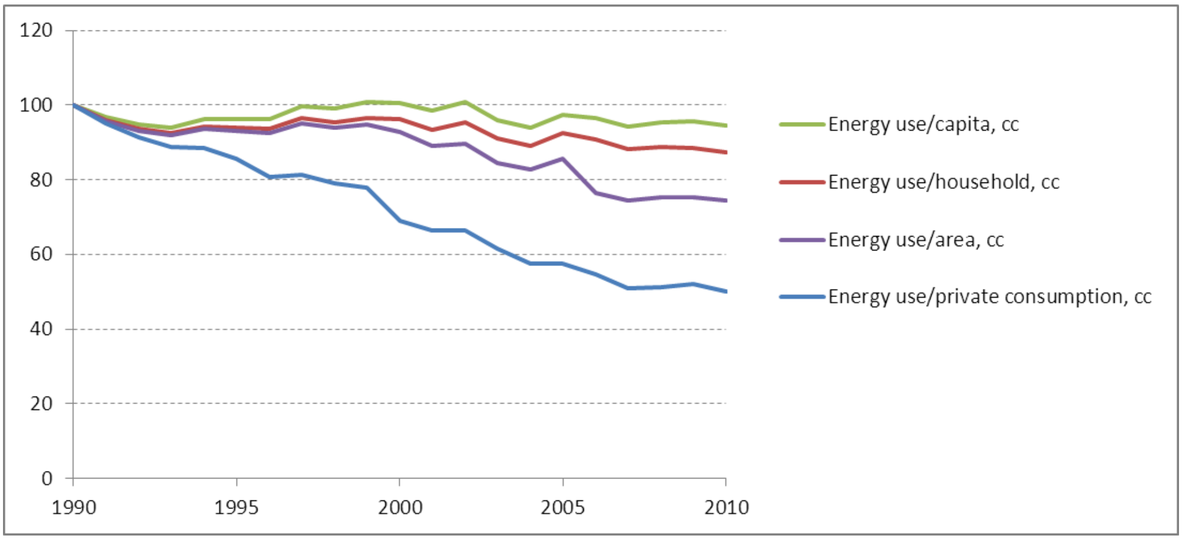

Figure 9 Trends in energy use per capita, household and private consumption, climate corrected; 1990-2010 (1990=100)

The area per capita has increased by 0.9 % annually from 1990 to 2010. At the same time the number of persons per household has decreased by 0.4 % annually, see Figure 10. Both these factors have an increasing impact on the energy consumption.

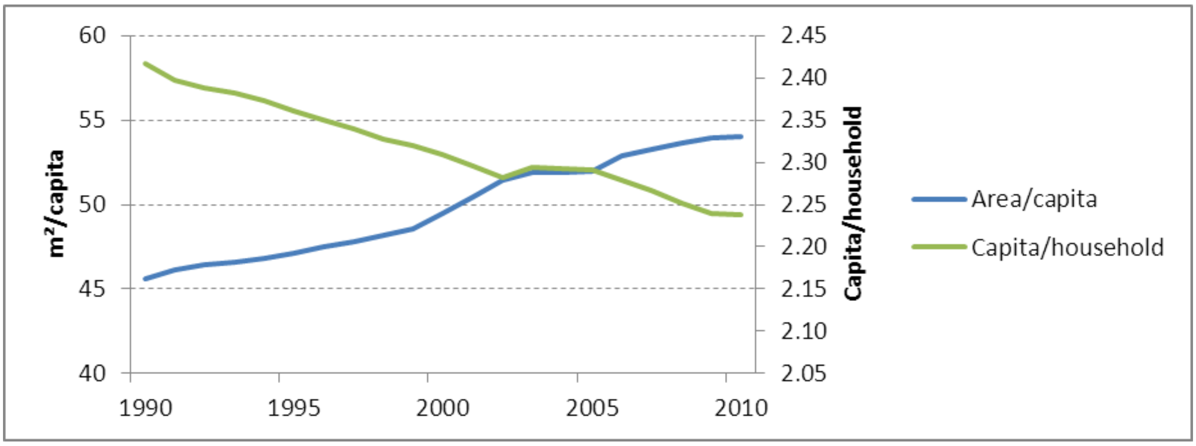

Figure 10 Area per capita and persons per households 1990-2010

The share of multi-family houses is increasing, see Figure 11. In 2000, 27 % of new dwellings were flats, while the share has increased to 47 % in 2009 and 39 % in 2010. In 1990, 80 % of all dwellings were single-family houses and in 2010 this share was about 73 %. An increasing share of flats will contribute to a decrease of energy consumption, since the energy intensity is less for flats compared to single-family houses.

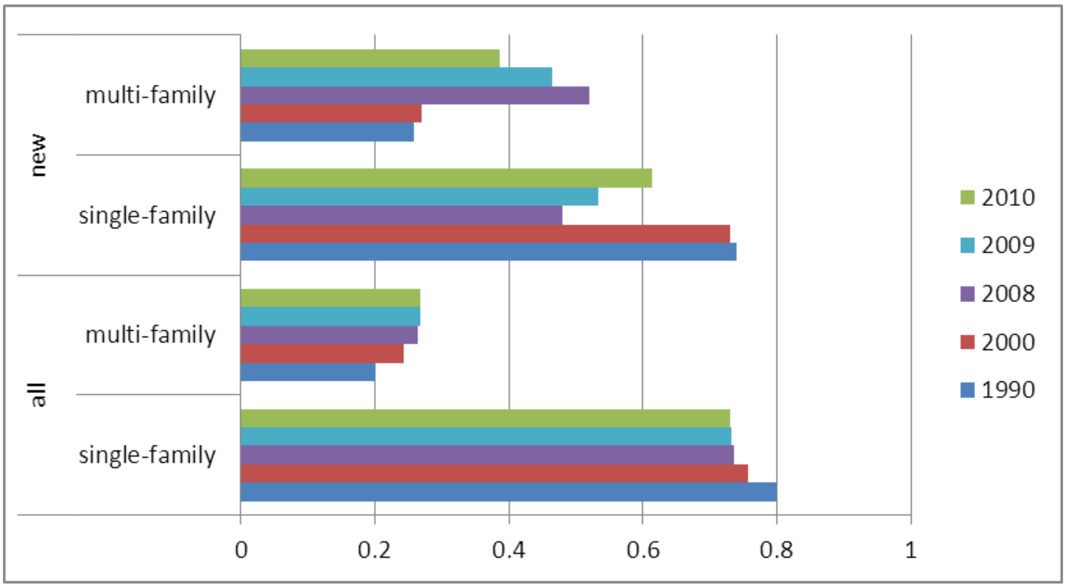

Figure 11 Share of flats and single family houses of total dwellings and of new dwellings 1990, 2000 and 2010

3.1.3 Tertiary sector

Final energy use in the service sector has increased from 23.5 TWh in 1990 to 33.1 TWh in 2010, corresponding to an annual increase of 2 %, see Figure 12 (not climate corrected). From 1996 to 2006 there were a stabilisation, but from 2006 to 2010 the annual increase has been 6 %. The energy statistics of 2009 and 2010 is based on the new standard of classification of branches while the years before are data with the old standard of classification. More activity is included in the service sector in the new classification and this can explain part of the increased use of energy but not all.

The share of electricity varies between 78 % (in 2003 with high electricity prices) and 85 %. The share is slowly decreasing due increased use of district heating. District heating has increased from 0.4 TWh in 1990 to 2.9 TWh in 2010. The increase has been 19 % per year from 2000 to 2010. The share of fuel oil was 10 % in 2010 and the consumption has been about 3-4 TWh the past 20 years. The use of gas also shows a rapid increase, but it is still very small and in 2010 the consumption was 0.4 TWh or 1 % of total energy use. Direct use of biomass has also increased lately and the consumption was 0.3 TWh in 2010. The increase in electricity use from 2006 to 2010 is slightly less than the increase of total energy use in the service sector; respectively 5.7 % electricity and 6.2 % total.

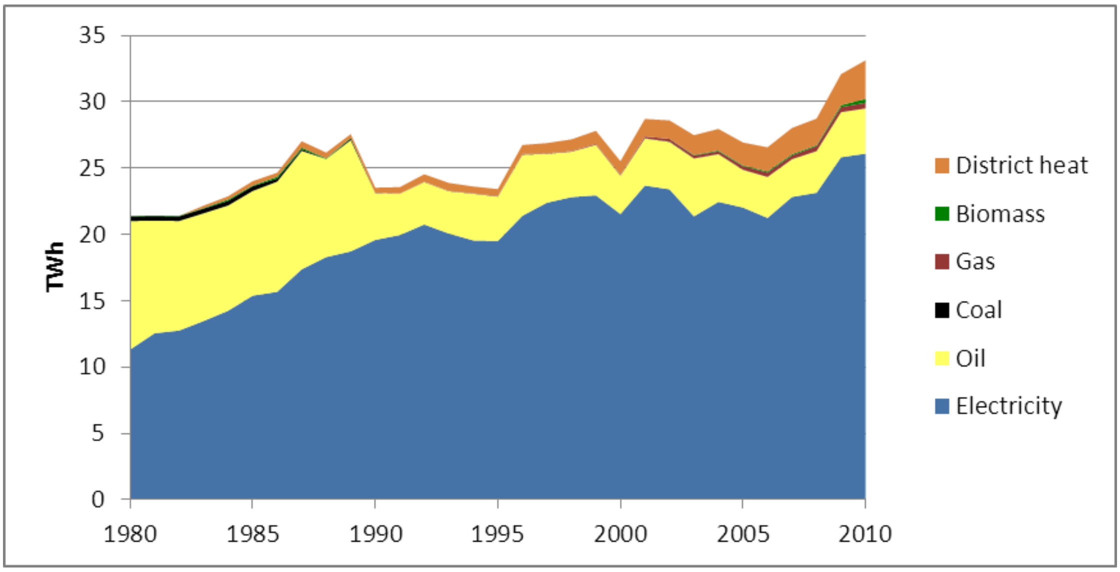

Figure 12 Final energy use by fuel in the service sector (not climate corrected); 1990-2010

Value added of the service sector was 1.8 times higher in 2010 than in 1990, see Figure 13. The energy intensity calculated as energy use per value added has therefore decreased considerably. The trends in building area and number of employees have a more similar development as final energy use, especially from 1990 to 2002.

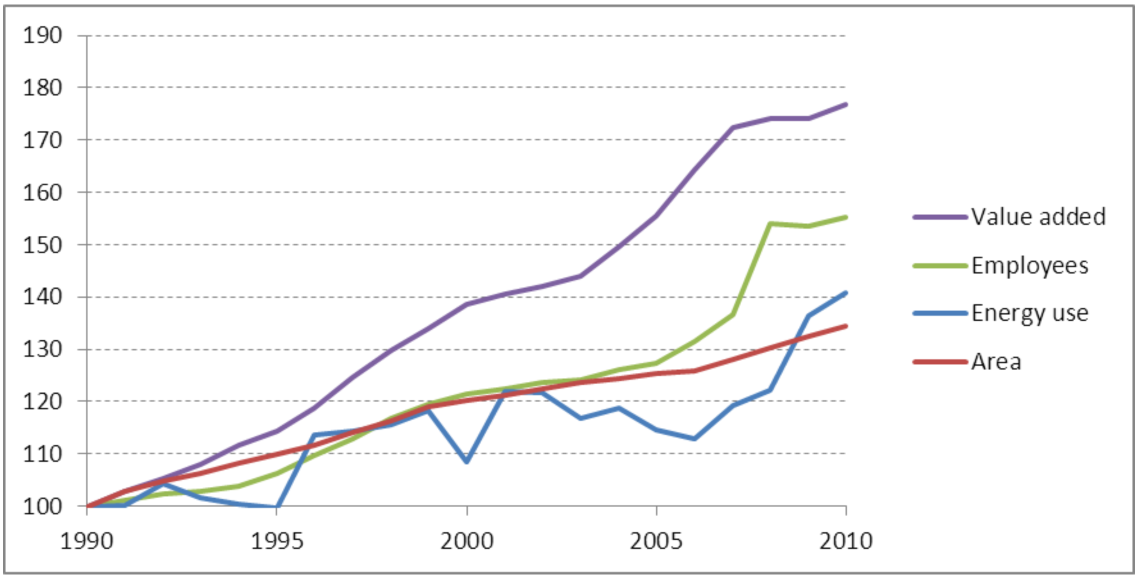

Figure 13 Trends in final energy use, value added, area and number of employees in the service sector 1990-2010

Final energy per employee is 10 % less in 2010 compared to in 1990, see Figure 14. Most of the decrease was from 2001 to 2006 and in 2009/2010 there has been a small increase. Final energy per building area is 5 % higher in 2010 than in 1990, but the statistics of building area is uncertain. The final energy per value added decreased from 1990 to 2006 by 31 % and has increased afterwards, resulting in a decrease of 20 % from 1990 to 2010. From 2006 to 2010 the annual increase in energy per value added has been 2.7 %.

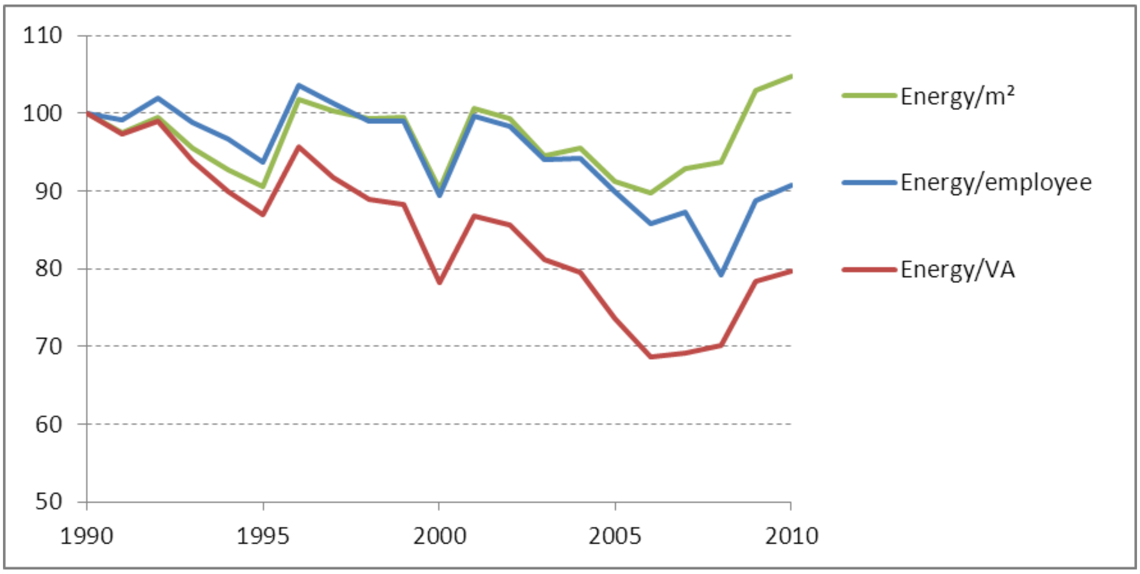

Figure 14 Trends in energy use per area, employee and value added in the service sector 1990-2010

Figure 15 shows energy use for some sub-sectors of the service sector. The sub-sector “other” has now become the one using most energy, 7.0 TWh in 2010, followed by wholesale and retail trade, 6.6 TWh in 2010.

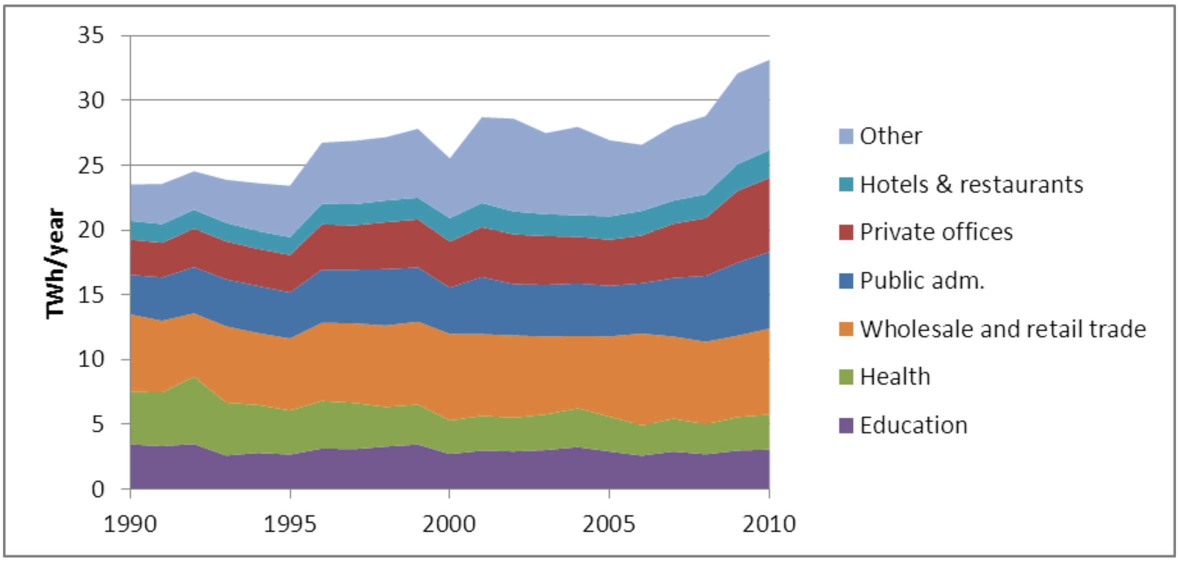

Figure 15 Energy consumption in sub-sectors in the service sector 1990-2010

3.1.4 Transport

The total energy consumption in the transport sector has increased from 45 TWh in 1990 to 62 TWh in 2010, an annual increase of 1.9 %, see Figure 16. The use of diesel oil is more than doubled from 1990 to 2010, while the use of gasoline has decreased by 1.7 % per year. Jet fuel has an annual increase of 2.7 % in this period (domestic air transport).

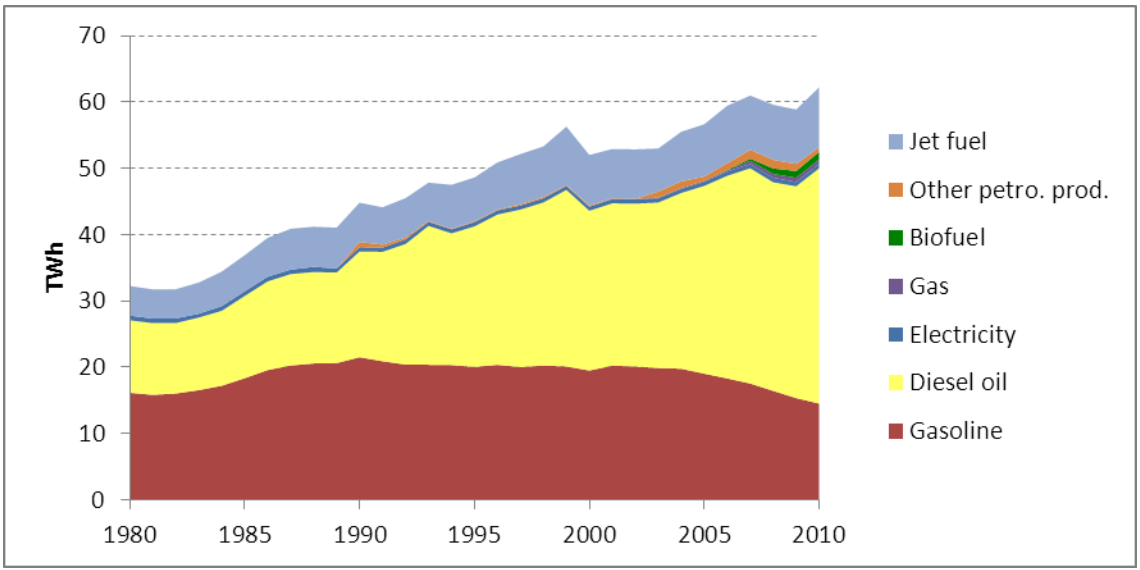

Figure 16 Energy use by fuel type in the transport sector 1980-2010

In person transport, cars are dominating with a share of 80.7 % in 1990 and 79.4 % in 2010, see Figure 17. Domestic air transport has increased most, from 4.9 % in 1990 to 6.2 % in 2010. Buses have decreased from 7.2 % in 1990 to 6.1 % in 2010. Motorcycles have also increased, from 1.3 % in 1990 to 1.8 % in 2010. Transport by railway (train and tram) has increased from 4.5 % to 4.9 % and water transport from 1.3 % to 1.6 %.

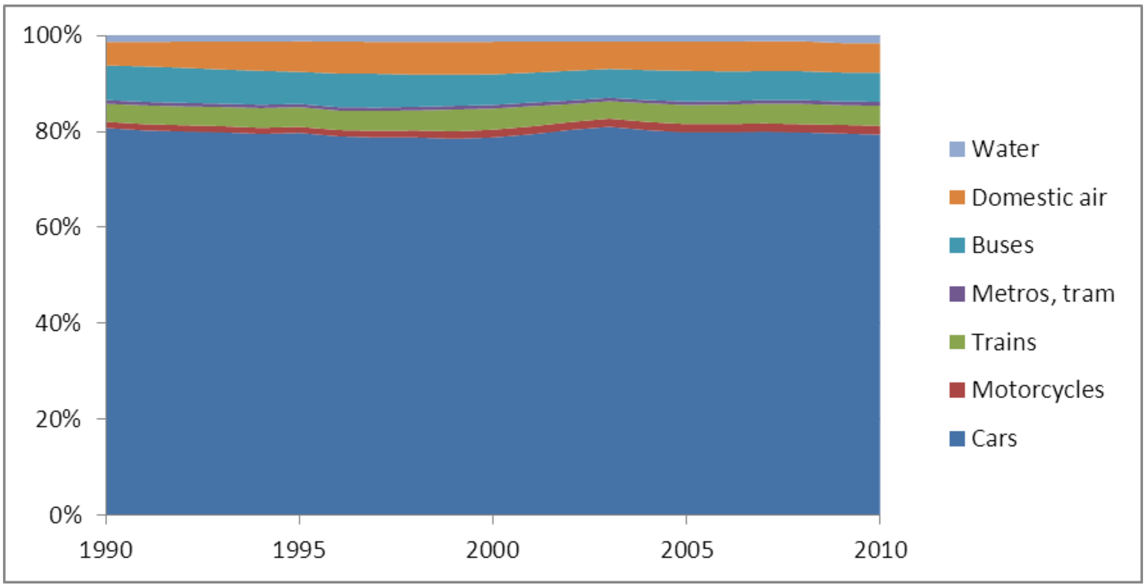

Figure 17 Travel by mode, % of passenger kilometres, 1990-2010

The stock of diesel cars is 16 times higher in 2010 than it was in 1990, see Figure 18. In 1990 the share of diesel cars was only 3 % and in 2010 it has increased to 35 %. The energy efficiency of diesel cars is higher than for gasoline cars and the shift has thus a positive effect on the energy use by cars. The number of electric battery cars was 2068 in 2010 and the number of other cars was 27.

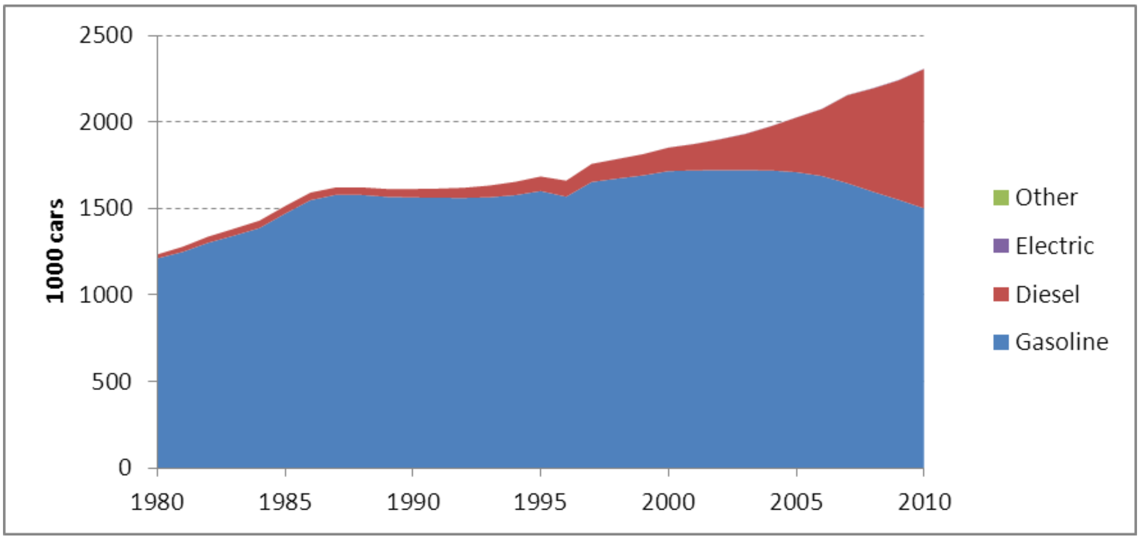

Figure 18 Stock of gasoline and diesel cars 1990-2010

3.2 Energy by end-use in households

Author: Bjørn Bakken, SINTEF Energy Research

SINTEF Energy has worked with electricity demand and user interaction/demand response modelling for many years. Major research projects the last years include Market Based Demand Response (MABFOT), Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe (REMODECE) and Electricity Demand Knowledge (ElDeK). These projects analyse electricity demand primarily from the household sector in great detail down to hourly resolution. In the following chapter, the SINTEF projects REMODECE and ElDeK are described.

3.2.1 REMODECE

The overall objective of the REMODECE project was to contribute to an increased understanding of the energy consumption in the EU-27 households for the different types of equipment, including the consumers' behaviour and comfort levels, and identify demand trends. This should among other things be achieved via a common analysis of the measurement (and survey) campaigns of electricity consumption in households in EU countries.

REMODECE was supported within the Intelligent Energy for Europe Programme of the European community (contract no. EIE/05/124/S12.419657). The total project period was from January 2006 to September 2008.

The objective of REMODECE was to perform a common analysis of the measurement (and survey) campaigns of electricity consumption in households in EU countries. Other countries performing measurement campaigns were Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Portugal and Romania.

The measurement campaigns were performed in about 100 households per country, using monitoring equipment capable to monitor the energy demand every 1 or 10 minutes in a varying number of appliances per household (in Norway 1 minute intervals were used). The measurement period has been approximately two weeks per household. Energy demand is analysed at per household level, estimating yearly energy demand from the two weeks measured. Energy demand on national level and on EU level is estimated based on ownership level of measured appliances. Ownership may be found from national statistics and/or from the survey campaigns.

Figure 19 shows the percentage distribution for different electrical appliances in Norway for 2006/2007. Space heating and hot water use about 75-80 % of the electricity in an average household depending on outdoor temperatures. This value also includes appliances not measured. The remaining appliances use about 20-25 %. Lighting amounts to about 6 %. Cooling devices, like refrigerators and freezers, amounts to 5 %. Other energy carriers, like oil and wood, are not taken into account. Heating is not temperature corrected in this analysis.

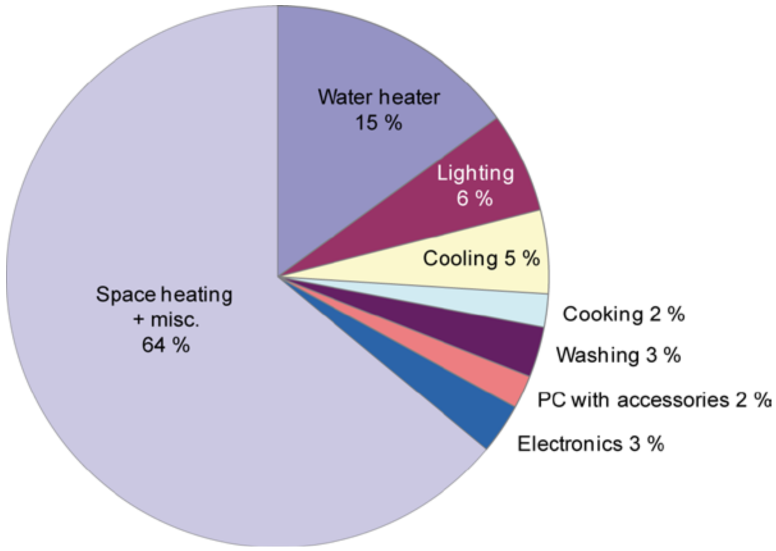

Figure 19 Percent Shares of Electrical End-Uses in Norway 2006/2007

3.2.2 ElDeK

The objective of the ElDeK project is to increase the knowledge concerning electricity demand for different types of customers. This includes knowledge about electricity energy consumption [kWh] and power consumption [kW] – totally for different types of customers and specific for different end-use demands.

The increased knowledge will be achieved through establishing mathematical and statistical methods for calculating both the total electricity demand (bottom-up) and the specific electricity demand for different end-uses (top-down) based on limited metered data. The methods will be developed based on meter data of end-use demand at household customers who already have installed technology for hourly metering of their total electricity consumption.

A total of 75 Norwegian households from four electricity Distribution System Operators (DSOs) participated in the study. The project collected hourly time series of total electricity consumption from the households, and additional high-resolution (one minute) metered data of more than 500 different appliance-specific loads as water heaters, washing machines, television sets etc. The collected data were validated and analysed by use of the software tool Useload (see description in Appendix A1). Based on metered data of the total electricity consumption for the household, the project has developed a statistical method for segmenting the hourly metered consumption data into weather dependent (for example space heating) and weather independent loads. Additionally the weather-independent load has been further segmented into demands from appliances as lighting, refrigeration, water heating etc. Demand patterns of several households have been analysed, resulting in typical group- and household-specific demand profiles.

The new approach provides cost efficient and rapid statistical methods for development of detailed load profiles based essentially on metered data with resolution one hour or higher, collected by smart meters. It allows identifying a potential for goal-oriented energy efficiency actions and later verifying impacts of these. Division of the load between weather-dependent and independent segments identifies potential flexibility in consumption (Demand Response) and creates basis for load forecasts.

3.3 Trends and drivers for energy use in households

Author: Carlo Aall, WNRI

Western Norway Research Institute (WNRI) has recently conducted a study for the Norwegian Water Resources and Energy Directorate (NVE) compiling available knowledge to shed light on changes in the historic (since the 1970s) stationary energy use among Norwegian households in order analysed possible causes for the levelling out of energy use among Norwegian households since 1990 [8].

The energy analysis show that the total, temperature adjusted energy use in Norwegian year-round residences increased by 3 % during 1990-2009 from 42.2 to 44.9 TWh, while the energy use during the previous 20 year period (1970-1990) increased by 55 %. If the development in energy use for the period 1990-2009 had followed the trend of 1970-1990, the energy use in 2009 should have been 73 TWh. Thus, the study has analysed possible reasons for why Norway have experienced a theoretical reduction by 30.8 TWh (42%) in relation to the expected trend in energy use. The figure below sums up the main findings relating to the explanation of this change; namely: (1) A slower increase in per capita living area relating to 55 % of the total reduction from 73 TWh to 42.2 TWh; (2) reduced energy use per m² (relating to 37 % of this reduction); and (3) a milder climate since 1980 (relating to 9 % of the reduction; a contributing factor comparable to the significant transition to heat pumps occurring in Norwegian households at the same period).

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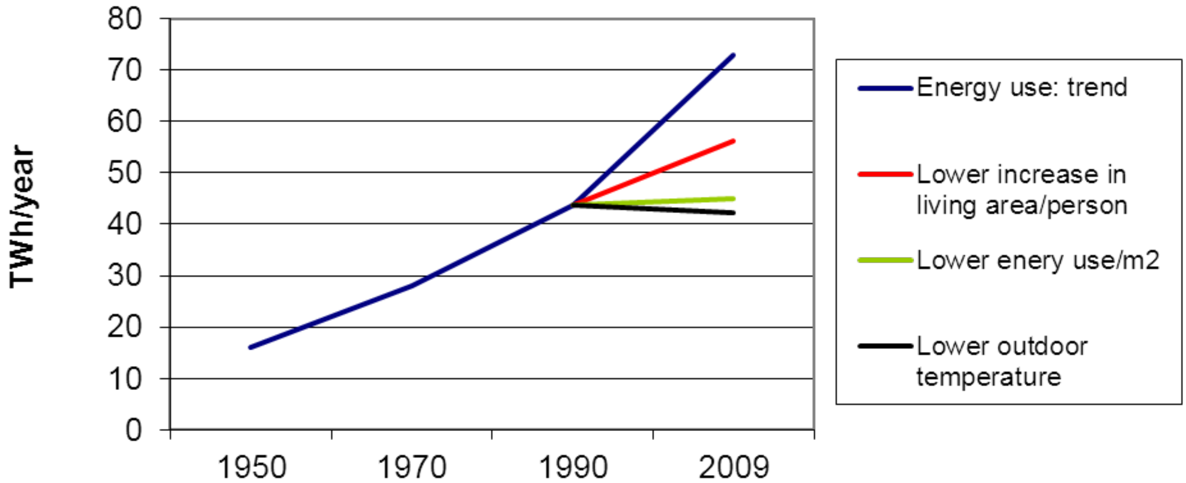

Figure 20 The main explanations for the difference between observed and trend in total stationary energy use in Norwegian households in 2009

The *first* explanation involves changes in per capita living area. The study document a markedly slower increase in per capita living area in the years following 1990, compared to the previous decade. If per capita living area in 1990-2009 had seen a growth rate similar to 1970-1990, the total living area in 2009 would have ended up at 350 million m², or 36 % larger than it actually is. Even considering the higher energy efficiency of newly built houses, the estimated energy use in the households would have been 25 % higher than de facto 2009 figures. Thus the slower increase in per-capita living area is the most significant of all the factors contributing to the levelling out of the graph representing energy use in the households.

The *second* explanation involves changes in energy use per m². The figure below shows how changes within a selection of energy end-use areas have occurred during 1990-2009. These areas, when added up, constitute a reduction equivalent to 41 kWh/m²/year. The grey section of the graphs represents the margin of uncertainty in our estimates, indicating the possibility that data may be combined in several ways to reach an accurate explanation. The most critical factor is incremental changes (as opposed to complete renovation) relating to improvements in the building envelope of older residences. As indicated in the figure, this has contributed to approximately half as much as incremental measures in older houses. On a shared second place are contributions from the implementation of heat pumps and a reduction in heat loss as a result of increased heating efficiency (mainly due to the phasing out of household furnaces). These are followed by the amended building regulations mentioned earlier, affecting new building projects and changes in water heating such as the introduction of water saving shower heads and a transition from manual dish-washing to the use of dishwashers (which heat water more efficiently). As for factors contributing to an increase in specific energy use, there is the issue of the growing number of electrical appliances, and an increased amount of energy-demanding technical operations in blocks of flats (elevators and ventilation systems).The study was not able to identify sufficient data to determine whether indoor temperature has changed over time. Surveys abroad suggest an increase; if this turns out to be the case, several of the entries in the figure below would need somewhat higher values in order to compensate for the increased energy use that higher indoor temperatures would generate.

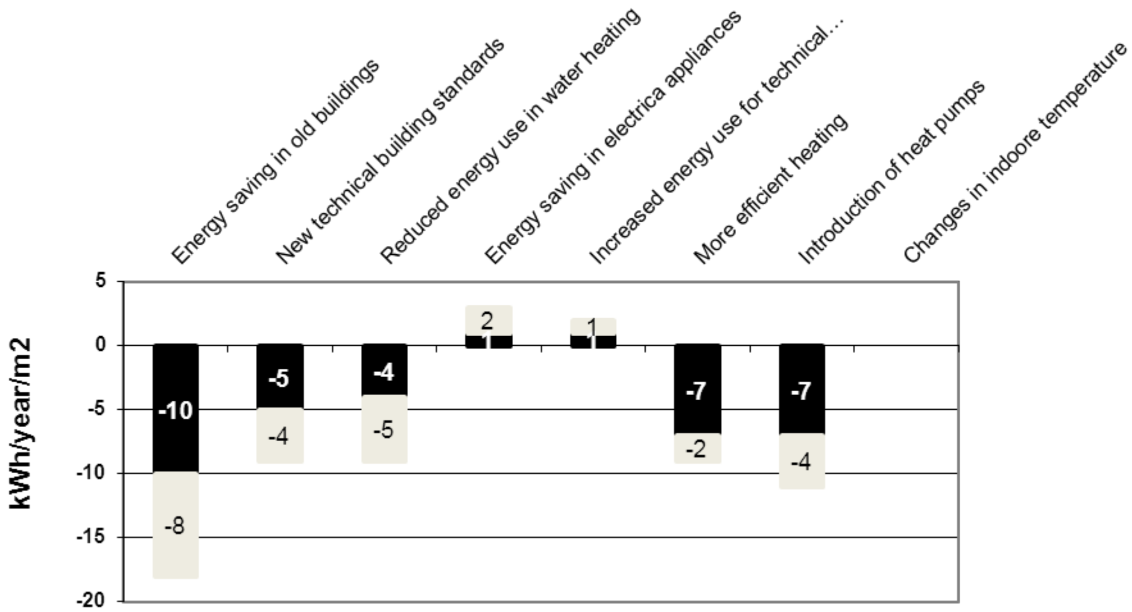

Figure 21 Upper (gray) and lower (black) range for estimated contributions in total reduction of energy use of 41 kWh/year/ m2 from 1990 to 2009 in Norwegian households

4 Norwegian forecasts

In this section some of the current forecasts of interest for the partners in CenSES are described. There are of course several others that could be presented here, but the focus is on forecasts done or used by CenSES partners. First, national Norwegian forecast are presented, followed by international forecasts (in chapter 6) ranging over Nordic, European and global forecasts. Information of some central models used in the studies presented here is presented in Appendix A1.

4.1 Perspektivmeldingen (White paper on long-term perspectives for the Norwegian economy)

The Ministry of Finance used to present a long-term program every 4th year, describing the Norwegian economy and illustrating the space of action in the future budget policy. These long-term programs included all sectors, among them energy and had a national scope. In the long-term program 2002-2005 a transition of the energy sector was described as well as the supply and use of energy in 2005 to 2020. The time-horizon of the document was 50 years, but for the energy part the horizon was restricted to 20 years due to the difficulties to project the technological development 50 years ahead.

These long-term programs are now replaced by the White papers on long-term perspectives for the Norwegian economy ("Perspektivmeldinger"). They contain no definite policy proposals, as was the case of the former long-term programs, but are just analyses of future possibilities. The first was published in 2004, the second in 2009 and the third was published in February 2013.

The framework and challenges to give a sustainable policy is described in "Perspektivmeldingen 2013" [9], together with opportunities and long-term trends such as an ageing population and petroleum extraction phase out. It is based on an assumption of unchanged electricity consumption of the energy intensive industry and an annual growth of factor productivity of onshore companies of 1.6%. The long-term oil and gas prices from 2014 and onwards are assumed to be 525 NOK/barrel and 1.93 NOK/Sm³ respectively (NOK-2013). The oil and gas production in 2060 is assumed to be respectively 14% and 22% of the 2011-level. The CO_2- price of the ETS[2] is estimated to 100 NOK/tonne CO_2 in 2020, with an annual increase of 4% after 2020.

In "Perspektivmeldingen 2009" [10], it is stated that the main objective of the Government's economic policy is to contribute to high employment, sustainable development, fair distribution of income and well-functioning welfare schemes. The report presents analyses which point out the long-term challenges and the choices faced with. It says that light is shed on how to achieve sustainable development given the challenges in terms of global environmental considerations, an ageing population and increased globalisation. It is an objective to outline some possible courses for Norwegian economy towards 2060.

[2] European Union Emissions Trading System

Based on the macroeconomic projections, the Norwegian Pollution Control Authority calculated new projections of environmentally hazardous emissions to the atmosphere. The projections showed a slight increase in greenhouse gas emissions followed by a gradual decline towards 2030. This development was mainly due to the expected reduction of petroleum activities, peaking some years after 2010 and thereafter falling. The projections assumed continued technological progress and a continued shift towards service industries [11]. The equilibrium model MSG of Statistics Norway is used for the long-term projections (see model description in Appendix A1). It is assumed a constant electricity use by the energy intensive industry in a long-term. The flattening of total consumption of electricity will be followed by an increase on long-term (not quantified in the White paper).

The greenhouse gas emissions by sector in 2009 and 2013 are presented in Table 2 and Table 3. The total greenhouse gas emissions are 1.8 million tonnes less in 2030 in the latest forecast. The emissions from petroleum and electricity production are 4.6 million tonnes higher, while mainland Norway has 6.5 million tonnes less emissions. The emissions of different sectors of mainland Norway are almost constant from 2010 to 2030 in "Perspektivmeldingen 2013", compared to an increase in the previous forecast.

Table 2 Greenhouse gas emissions by sector in "Perspektivmeldingen 2009" (Million tonnes of CO_2 -equivalents)

	1990	2006	2007	2010	2020	2030
Total greenhouse gas emissions	49.7	53.5	55.0	57.3	56.5	54.0
Petroleum and electricity production	8.2	13.7	15.1	16.7	14.1	9.2
Mainland Norway without elec. prod.	41.5	39.8	39.9	40.6	42.5	44.9
- Manufacturing	19.5	15.2		14.7	15.2	16.1
- Domestic transport	4.5	7.7		8.5	9.5	10.9
- Households incl. personal transport	6.1	5.6		5.8	6.2	6.8
- Other activities	11.5	11.3		11.7	11.5	11.1

Table 3 Greenhouse gas emissions by sector in "Perspektivmeldingen 2013" (Million tonnes of CO_2 -equivalents)

	1990	2000	2010	2011	2020	2030
Total greenhouse gas emissions	49.7	54.4	53.9	52.7	54.5	52.2
Petroleum and electricity production	8.2	14.2	15.4	14.9	16.2	13.8
Mainland Norway without elec. prod.	41.5	40.2	38.5	37.8	38.3	38.4
- Industry	19.4	17.4	12.7		12.4	12.6
- Domestic transport	4.4	6.3	8.5		8.8	8.8
- Households incl. personal transport	6.1	5.2	5.3		5.4	5.7
- Other activities	11.5	11.3	11.9		11.7	11.3

4.2 The National Budget of 2011

The National Budget of 2011 from the Ministry of Finance has a reference scenario with the development of the electricity consumption, as presented in Table 4 [12]. This development is based on assumptions of activities and intensities of sub-groups as presented in Table 5.

Table 4 Projection of electricity consumption in different sub-sectors in the reference scenario of the National Budget of 2011 (TWh/year)

	2007	2030	2050
Final electricity consumption	114.9	134.8	153.0
Energy intensive industry	33.8	33.8	33.8
General consumption	81.1	101.0	119.2
Primary industry	2.0	1.4	1.0
Pulp & paper	5.5	5.2	7.9
Other manufacturing industry and mining	9.4	11.4	15.8
Transport	2.2	3.2	4.0
Public service and tertiary industry	15.1	21.4	29.5
Households	34.9	38.2	41.4

Table 5 Annual development rates of production, electricity consumption and electricity intensity of the National Budget 2011, 2007-2050

	Production	Electricity consumption	Electricity intensity
Primary industry	0.7	-1.4	-2.1
Pulp & paper	2.1	0.8	-1.3
Energy intensive industry	1.0	0.0	-1.0
Other industry	2.3	1.2	-1.1
Other consumption goods	2.2	1.9	-0.3
Fish processing	2.7	1.8	-0.8
Processing of meat and milk products	2.4	1.2	-1.1
Textiles	3.4	2.7	-0.7
Wood products	2.4	0.8	-1.5
Printing industry	2.1	0.8	-1.3
Refineries	0.4	0.0	-0.4
Engineering industry	3.4	1.8	-1.6
Building of ships etc.	-0.1	-2.2	-2.2
Building of petroleum platforms etc.	0.0	-0.4	-0.5
Production and transmission of electricity	0.5	0.5	0.0
Oil and gas extraction, intern. sea transport	-1.2	1.7	2.9
Construction	1.9	2.3	0.4
Transport	2.2	1.3	-0.9
Inland transport	2.1	0.9	-1.2
Commodity trade	2.9	1.9	-0.9
Other tertiary industry	1.8	1.1	-0.6
Other private	1.6	1.1	-0.4
Education	1.2	0.5	-0.7
Health care	2.0	1.2	-0.7

4.3 Energiutredningen 2012

The committee "Energiutvalget" was appointed by the Ministry of Petroleum and Energy in March 2011 to evaluate the long term energy policy frames. The objective was to give a better understanding of the considerations in the energy policy and to investigate and evaluate central drivers of the Norwegian energy and power balance of 2030 and 2050 (energy production, energy consumption, grid development and international electricity trade).

In March 2012, the report "NOU 2012:9 Energiutredningen – Verdiskaping, forsynings-sikkerhet og miljø" was delivered [12]. The assumptions used in the calculations are described in a background note [13]. The basis of the economic development is the same as in the National Budget of 2011. Assumptions of international and national development is based on Perspektivmeldingen 2009 [14]. The long-term development path of the National Budget 2011 is calculated with the MSG-model of Statistics Norway, with input from Perspektivmeldingen. The growth in production of goods and services together with the development of energy intensity of different industries, defines the development of energy consumption. The development rate of production, electricity consumption and electricity intensity is presented in Table 6.

Table 6 Annual development rates of production, electricity consumption and electricity intensity used in "Energiutredningen 2012", 2007-2030

	Production	Electricity consumption	Electricity intensity
Primary industry	0.8	-1.4	-2.2
Pulp & paper	2.2	-0.3	-2.4
Energy intensive industry	1.0	0.0	-1.0
Other industry	2.0	0.8	-1.2
Production and transmission of electricity	0.5	0.4	-0.1
Oil and gas extraction, international sea transport	-1.2	5.8	6.6
Construction	1.8	2.3	0.6
Commodity trade	3.1	2.0	-1.1
Transport	2.2	1.6	-0.6
Other tertiary industry	1.8	1.2	-0-6

Calculations based on three different alternatives are presented in "Energiutredningen":

- NB2011 - Development as in the National Budget 2011
- Expansive – a power system with large growth in renewable electricity production
- Tight ("Stram") – a power system with electricity shortage in Norway and the Nordic countries

Assumptions of Norwegian electricity production and consumption in 2030 in the different alternatives are presented in Table 7. "New consumption" in Table 7 is increased consumption in transport, in the petroleum sector and new power intensive production in tertiary industry such as "net sky". The other Nordic countries are modelled based on the scenarios of IEA in WEO 2010 ("NB2011" = "Current policies", "Tight" = "New policy", "Expansive = 450 ppm"). The electricity production and consumption of the other Nordic countries are presented in Table 8.

Table 7 Assumptions of Norwegian electricity production and consumption in 2030 in the different alternatives, TWh

	2007	2010	2030 NB2011	2030 Expansive	2030 Tight
Total production	**137**	**125**	**154**	**183**	**148**
Hydro power	135	118	135	139	134
Small scale hydro			8	12	4
Wind power	1	1	8	29	4
Gas power CHP	2	6	2	3	3
Gas power CCGT			1	1	4
Net export	11	-7	6	17	-3
Gross consumption	**127**	**132**	**148**	**166**	**151**
Losses	12	10	13	17	15
Final consumption	115	122	135	149	136
General consumption	81	91	101	72	89
Energy intensive industry	34	31	34	55	27
New consumption				22	21
Electricity prices (NOK/kWh)	0.292[3]		0.43	0.51	0.74

Table 8 Assumptions of other Nordic countries in the 3 alternatives of “Energiutredningen”, 2030 (TWh)

Country	Alternative	Electricity production	Electricity consumption	Power balance
Sweden	NB2011	183	157	25
	Expansive	182	162	20
	Tight	150	157	-6
Finland	NB2011	105	101	4
	Expansive	101	94	7
	Tight	95	98	-3
Denmark	NB2011	52	46	6
	Expansive	43	44	-1
	Tight	44	45	-1

[3] Average 2002-2011 in Oslo

4.4 The Norwegian Commission on Low Emissions and climate policies

In October 2006 the Norwegian Commission on Low Emissions presented their final report "NOU 2006:18: A climate-friendly Norway" [15]. The MSG-model was used for calculations of future energy use, resulting in the energy use presented in Table 9.

Table 9 Energy use in 2000 and 2050 in the reference case of [15]

Energy carrier	Energy use 2000	Energy use 2050	Annual average change
Gasoline (mill. ton)	2.3	3.2	0.7 %
Auto diesel oil (mill. ton)	3.2	3.4	0.2 %
Fuel oil (mill. ton)	3.1	4.7	0.8 %
Electricity (TWh)	126	197	0.9 %
Total energy use (TWh)	229	333	0.8 %
GDP			1.9 %
Population			2.8 %

This study was followed by the White paper to the Government "St. meld. Nr 34 (2006-2007) Norsk klimapolitikk" [16]. The projection of energy use is not presented in this white paper.

In April 2012 the Government presented the climate policy in a White paper to the Government [17]. Emission projections are done every second year by the Ministry of finance in cooperation with the Climate and Pollution Agency. The White paper on climate policy is based on the emission projection of the National budget 2011. The projections use the macroeconomic model MSG, developed by Statistics Norway. In the projections it is assumed that the use of electricity in the energy intensive industry will remain unchanged in a long-term. The total consumption of electricity will increase slightly in the long-term. The stationary energy use in buildings is assumed to increase slightly to 2020. The transport sector will increase the emissions from 17.3 mill ton CO_2-equivalents in 2010 to 18.7 mill in 2020 and 18.9 mill in 2030. The projection of energy demand per sector and/or energy carrier is not published in the report.

4.5 Climate Cure 2020

Climate Cure 2020 has been tasked with assessing possible measures and instruments for achieving the target of reducing Norway's greenhouse gas emissions by 15 to 17 million tonnes by 2020, including the effect of forests. Several reports of different sectors are available at http://www.klimakur.no/ such as sector reports of:

- Transport
- Oil and gas production
- The capture, transport and storage of CO_2

- Industry
- Buildings
- District heating
- Agriculture, forestry and waste

The calculations of future emissions and energy consumption are done with the equilibrium model MSG-TECH of Statistics Norway. The calculations are made with “Perspektiv-meldingen 2009” as a starting point. The resulting energy forecast by carrier is presented in Table 10. The growth of energy consumption of some sectors are assembled in Table 11 [18].

The sector report on buildings presents a growth of the energy consumption from 45.0 TWh in 2007 to 45.6 TWh in 2020 in households and from 29.4 TWh to 30.2 TWh in non-residential buildings, excl. industry buildings [19]. The forecast is based on a bottom-up analysis of all buildings, with assumptions of future heated area, specific energy consumption for different types of buildings and buildings regulations.

Table 10 Energy forecast by energy carrier, 1990 – 2020 (GWh)

Energy carrier	1990	2005	2007	2020	Annual growth
Coal and coke	771	377	373	494	2.2%
Biomass	9 814	12 547	12 281	15 378	1.7%
Gas	42 505	68 144	78 626	76 871	-0.2%
Gasoline and kerosene	27 382	24 350	22 549	14 881	-3.1%
Fuel oil	40 894	47 697	53 123	69 874	2.1%
Waste	1 637	3 444	3 336	4 224	1.8%
Electricity and district heat	98 619	116 693	117 814	125 700	0.5%
Total (excl. district heat)	220 757	270 800	285 225	300 822	0.4%

Table 11 Annual growth of energy consumption per sector, 2007-2020

Sector	Annual growth
Road transport	1.0 %
Service sector	1.4 %
Households	0.4 %
Energy sectors	0.2 %

4.6 National renewable energy policy

In June 2012 the Ministry of Petroleum and Energy published the report on national renewable energy policy according to the EC Directive 2009/28 [5]. In this report, a study of the energy consumption up to 2020 is presented. The calculations of stationary energy consumption are made by NVE based on calculations of useful energy for different end-use sectors and analyses with TIMES-Norway resulting in consumption of different energy carriers.

The main forecast is based on an estimate of total energy consumption up to 2020 that includes the impact of energy efficiency measures. Estimated total energy consumption will increase from 19 821 ktoe (233 TWh) in 2005 to 21 483 ktoe (252 TWh) in 2020. This is equivalent to a total increase of 8.4 % and an annual increase of 0.4 % in 2010-2020, see Table 12.

Table 12 Expected gross final energy consumption of Norway in heating and cooling, electricity and transport up to 2020 taking into account the effects of energy efficiency and energy saving measures 2010-2020 (ktoe) [5]

Demand sector	2005	2020	
Heating and cooling	4 406 (51.8 TWh)	4 307 (50.6 TWh)	-2.2%
Electricity	10 765 (126.5 TWh)	10 887 (127.9 TWh)	1.1%
Transport as in Art. 3 (4)a	4 029 (47.3 TWh)	4 860 (57.1 TWh)	20.6%
Gross final energy consumption	19 821 (232.9 TWh)	21 483 (252.4 TWh)	8.4%

4.7 Institute for Energy Technology (IFE)

IFE carried out a study of the historical energy use and an analysis of future energy demand up to 2020 on commission of NVE in 2005 [20]. Development of key drivers as growth in GDP and population were based on “Perspektivmeldingen 2004”. Contacts with industry representatives were the foundation of the calculations of industrial development. A bottom-up methodology was applied to the industry, household and service sectors, resulting in a total growth of 10 % of stationary energy consumption from 2005 to 2020.

In 2007 IFE made a forecast of energy demand up to 2050 on commission of Enova, as part of their strategy work [21]. First, a forecast of useful energy demand was made for all final energy consumption sectors. Secondly, the technology choices and consumption of different energy carriers were analysed with MARKAL-Norway. This work was updated in 2009, resulting in the forecast of useful energy demand as shown in Table 13 [22]. Important inputs were growth in GDP, population and man-hours from “Perspektivmeldingen 2009”.

Table 13 Forecast of useful energy demand, 2007 – 2050

	2050
Total stationary use	**+ 16 %**
Industry	**- 6 %**
Aluminium	0 %
Ferro-alloys	- 39 %
Chemicals	+ 3 %
Pulp & paper	- 13 %
Other industry (10 sub-groups)	+ 3 %
Households	**+ 32 %**
Energy per household	‘ - 23 %
Energy per person	- 6 %
Energy per heated area	- 28 %
Tertiary sector (12 sub-groups)	**+ 58 %**
Transport	**+ 37 %**
Buses	+ 14 %
Cars	+ 41 %
Trucks	+ 52 %
Railway	+ 41 %
Sea transport	+ 34 %

Five different scenarios were analysed with MARKAL-Norway and in addition three combinations, see Table 14. The policies at the date of the analyses were included in the base case. In the five main scenarios energy efficiency measures is used to a large extent. To illustrate the effect if these energy efficiency measures not are implemented, three combinations without energy efficiency were included. Energy efficiency measures were included in MARKAL-Norway as technologies with 4 different cost-classes within industry, households and service. The potential was restricted to 22 % of electricity demand and 31 % of heat demand in households, 14 % of electricity and 40 % of heat demand in service and approximately 20 % in industry. In addition to these energy efficiency measures, it was possible to invest in heating equipment with improved efficiency, such as new boilers, heat pumps and solar thermal systems. These latter technologies were available in all analyses.

Table 14 Analysed scenarios with MARKAL-Norway, change in total energy use 2007-2050 (TWh per year)

Short name	Description	Industry	House-holds	Service	Transport	Total
BAU	Business as usual	-2.2	-1.5	+15.2	+6.5	18
WEO2008	Oil and gas prices from World Energy Outlook 2008	-3.0	-2.2	+15.2	+6.6	17
LAV	Low energy demand of industry	-28.4	-1.5	+15.2	+6.5	-8.2
DIR	>= 75 % renewable energy in 2020	-2.2	-1.5	+15.2	+6.5	18
ELBIL	Electrification of cars from 2020	-2.2	-2.2	+15.2	+2.9	14
-EE	No energy efficiency measures possible	+3.2	+8.1	+15.2	+6.5	33
DIR-EE	75 % renewable energy + no energy efficiency measures	+3.2	+8.1	+15.2	+6.6	33
ELBIL-EE	Electrification of cars from 2020+ no energy efficiency measures	+3.2	+8.1	+15.2	+2.9	29

The TIMES-Norway model needs a more detailed forecast of useful energy than provided by the 2009-study. Enova supported a new study to calculated the input values of seven regions based on the former forecast of Norway [23]. The new study included four different scenarios, as presented in Table 15. This is used as input to TIMES-Norway in new analyses of energy consumption by carrier and technology.

Table 15 Comparison of different scenarios as increase/decrease of stationary energy demand in 2050 compared to the base scenario (+/- TWh/year)

Scenario		Base	1	2	3	4
			High population	Low industry demand	Electrification offshore	Industry clusters
Year	2006	2050	2050	2050	2050	2050
Industry	78[4]	78	0	-22	+6	+6
Residential	44	56	+12	0	0	+2
Service & other	32	49	+14	0	0	+2
Total	154	183	+26	-22	+6	+10

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[4] Excl. raw material

4.8 Western Norway Research Institute (WNRI)

A part of the study described in chapter 3.3 was to develop a mathematical model to (a) generate a historical, utilization based data set on the distribution of energy spent within the households, and (b) to create scenarios regarding the development of energy use in Norwegian households over the next 20 years. In Table 24 in Appendix A1 some key data in the excel based scenario model is presented (in Norwegian).

4.9 Nettmeldingen

The White paper on development of the electricity grid in Norway ('Vi bygger Norge – om utbygging av strømnettet') from March 2012 presents the government's policy for expansion and re-investments in the central transmission grid for electricity [24].

The White paper addresses the following parameters, which are regarded of specific interest, when discussing forecast for energy demand:

- Electrification of petroleum sector
- Economic growth
- Population growth
- Energy shifts that in the long term contributes to decreased energy demand (energy efficient technologies, more efficient fuels etc.)
- Increased transmission capacity between Norway and Nordic/Europe
- Green certificates
- EU 20/20/20

The White paper gives no quantitative description of future energy demand, but states that assessments of long term regional and national demand growth need in-depth analysis.

4.10 Statnett

In the development plan for the central grid 2010, Statnett are using one common forecast towards 2015, called Expectation 2015 [25]. Towards 2025 three scenarios are analysed:

- Low end use demand
- Wind power and growth
- Electricity export and exchange

In the central grid plan 2011 Statnett describe the following parameters having an impact on future electricity and power demand:

- Electricity intensive industry
- General demand
- Electrification of petroleum sector
- Transport sector and electric vehicles
- Energy efficiency and consumer flexibility
- Smart grids

Statnett are not projecting a huge increase in the demand for electricity over the next decades. However, the future power demand might increase as a combination of electrification of the transport sector and the petroleum sector, increase of electricity for heating and growth in the energy intensive industry. In addition, the growth in population and economy may reduce the impact of energy efficiency.

The development of the future grid is not designed on the basis of future energy demand, but on the power demand in the maximum load hour.

4.11 Summary of national forecasts of current interest

The national forecasts presented here have different scopes and are not directly comparable. They have different time horizons, geographical areas, energy carriers, end-use demand sectors etc. A summary of the scope of the forecasts is presented in Table 16 and of some results in Table 17. The electricity consumption in 2050 of two official forecasts has been reduced from 197 TWh in the NOU 2006:18 to 153 TWh in the National Budget 2011, a decrease of 44 TWh in five years. These forecasts are made with general equilibrium models (macro-economic models) and as a comparison, a forecast with a bottom-up model (MARKAL-Norway) resulted in a demand of 115 TWh in 2050, when energy efficiency measures were included, close to the actual final electricity consumption of 113 TWh in 2010.

Table 16 Summary of the scope of different forecasts (secondary objectives in brackets)

	Energy carrier	Geographical area	Time horizon	Comments / focus area
Perspektiv-meldingen	GHG emissions	Norway	2060	Norwegian Economy
National Budget	Electricity	Norway	2050	Norwegian Economy
Energiutredningen	Electricity	Norway	2030 / 2050	
Statnett	Electricity	Norwegian regions	2015 / 2025	Power demand
Hydro	Electricity (and other carriers)	Norway (and neighbouring countries)	2035	Electricity price / Industry development
NVE short term	Electricity	Norwegian regions	2020	
NVE long term	All	Norwegian regions (and neighbouring countries)	2050	
IFE	All	Norwegian regions, NordPool areas, Global	2050	

Table 17 Summary of national forecasts

Study	Year	2000	2007	2020	2030	2050
Perspektivmeldingen 2013 Greenhouse gas emissions (Mill ton)	2013	54.4		54.5	52.2	
National Budget 2011 Electricity, final consumption (TWh)	2011		114.9		134.8	153.0
Energiutredningen Electricity, final consumption (TWh)	2012		115	122	135	
Klimakur 2020 El & district heat (TWh)	2010		117.8	125.7		
NOU 2006:18 Electricity (TWh) Total energy use (TWh)	2006	126 229				197 333
Handlingsplan fornybardirektivet (TWh) Heating and cooling Electricity Gross final energy consumption	2012		51.8 126.5 232.9	50.6 127.9 252.4		
IFE Useful stationary energy demand Electricity, Final consumption, (TWh) Base case Electricity, Final consumption, Base case, without energy efficiency	2009		111.7* 111.7	98.1 112.8	101.6 118.9	+ 16 % 115.5 132.3

*) 2005

The relative development of future electricity demand is presented in Figure 22. The studies start and end in different years, and to facilitate the comparison, the values of 2007 are interpolated and used as a starting point with the value of 100. The development in electricity use according to the available studies is related to the value of 2007 with interpolation of missing values.

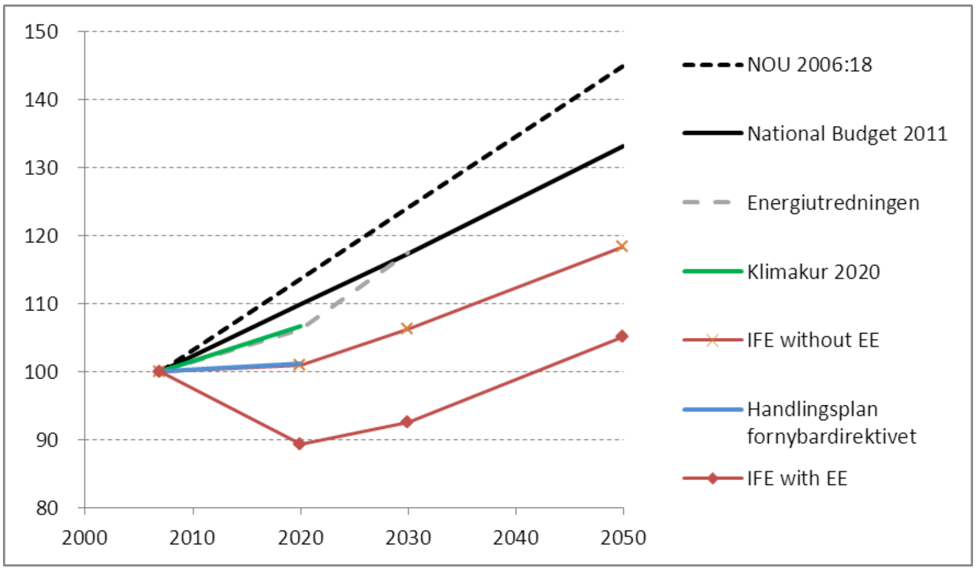

Figure 22 Relative development of future electricity demand of some Norwegian forecasts with 2007=100 (EE = Energy efficiency)

5 International forecasts

In this chapter some international forecast used by or of major interest of the CenSES-partners are presented.

5.1 EU Energy Roadmap 2050

In “Energy Roadmap 2050” the European Commission explores the challenges posed by delivering the EU’s decarbonisation objective while at the same time ensuring security of energy supply and competitiveness. The Energy Roadmap 2050 is the basis for developing a long-term European framework together with all stakeholders. It is worth noting, however, that the analysis is limited to EU27 and does not include Norway or Switzerland.

In the report it is written that forecasting the long-term future is not possible, and further that the scenarios explore routes towards decarbonisation of the energy system. A number of scenarios to achieve an 80% reduction in greenhouse gas emissions implying some 85% decline of energy-related CO2 emissions including from transport, have been examined with the PRIMES energy system model (see model description in Appendix A1). The main scenarios analysed as described in [26] were:

Current trend scenarios

- Reference scenario. The Reference scenario includes current trends and long-term forecasts on economic development (gross domestic product (GDP) growth 1.7% pa). The scenario includes policies adopted by March 2010, including the 2020 targets for RES share and GHG reductions as well as the Emissions Trading Scheme (ETS) Directive. For the analysis, several sensitivities with lower and higher GDP growth rates and lower and higher energy import prices were analysed.

- Current Policy Initiatives (CPI). This scenario updates measures adopted, e.g. after the Fukushima events following the natural disasters in Japan, and being proposed as in the Energy 2020 strategy; the scenario also includes proposed actions concerning the "Energy Efficiency Plan" and the new "Energy Taxation Directive".

Decarbonisation scenarios

- High Energy Efficiency. Political commitment to very high energy savings; it includes e.g. more stringent minimum requirements for appliances and new buildings; high renovation rates of existing buildings; establishment of energy savings obligations on energy utilities. This leads to a decrease in energy demand of 41% by 2050 as compared to the peaks in 2005-2006.

- Diversified supply technologies. No technology is preferred; all energy sources can compete on a market basis with no specific support measures. Decarbonisation is driven by carbon pricing assuming public acceptance of both nuclear and Carbon Capture & Storage (CCS).

- High Renewable energy sources (RES). Strong support measures for RES leading to a very high share of RES in gross final energy consumption (75% in 2050) and a share of RES in electricity consumption reaching 97%.

- Delayed CCS. Similar to Diversified supply technologies scenario but assuming that CCS is delayed, leading to higher shares for nuclear energy with decarbonisation driven by carbon prices rather than technology push.

- Low nuclear. Similar to Diversified supply technologies scenario but assuming that no new nuclear (besides reactors currently under construction) is being built resulting in a higher penetration of CCS (around 32% in power generation).

The underlying analysis of the Energy Roadmap 2050 is presented in [27]. The scenarios were derived with the PRIMES model by a consortium led by the National Technical University of Athens (E3MLab), supported by some more specialised models (e.g. GEM-E3 model that has been used for projections for the value added by branch of activity and PROMETHEUS model that has been deployed for projections of world energy prices).

The Reference scenario is based on the scenarios up to 2030 published in the report “Energy trends to 2030: update 2009”, but extends the projection period to 2050. In this report, the energy trend up to 2030 is presented for each EU country [28]. An example of the tables and the details of data is shown in Table 25 - Table 27 (Norway is not included in this report). Some selected data for EU-27 is presented in Table 18.

Table 18 Selected data for EU-27 from the baseline scenario of EU Energy Trends to 2030

	2000	2010	2020	2030
Population (million)	481.1	499.4	513.8	519.9
Average household size (persons)	2.5	2.3	2.2	2.2
Gross Domestic Product (in 000 M€05)	10 107	11 386	14 164	16 825
GDP Industry (in 000 M€05)	9 017	10 136	12 655	15 051
Gross inland energy consumption (Mtoe)	1723	1764	1822	1807
Gross Electricity Generation (TWh)	2992	3312	3795	4192
Final Energy Demand	1113	1169	1229	1216
Industry	327	313	333	344
Residential	267	309	316	308
Tertiary	160	176	185	185
Transport	339	370	395	379

The following figures that summarize results for European energy demand for the different scenarios are relevant in this report:

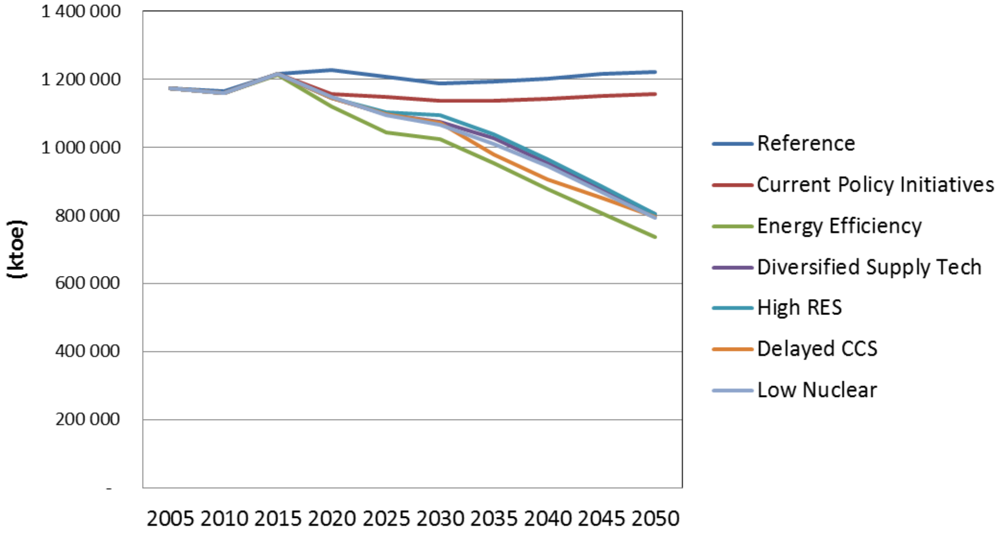

Figure 23 Development of Final energy demand in EU27 in Energy Roadmap scenarios

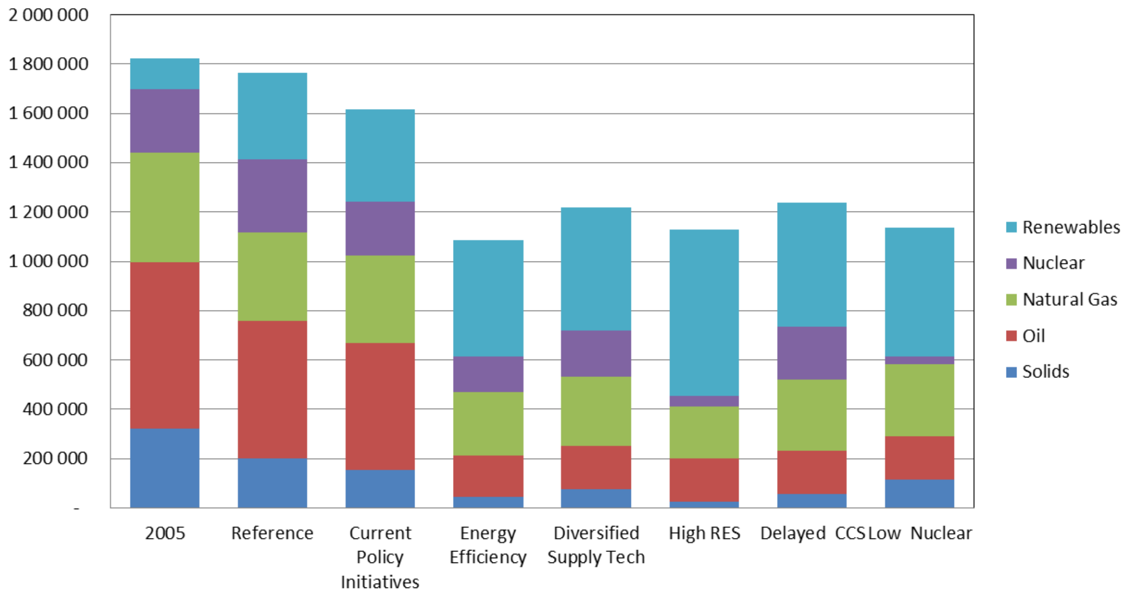

Figure 24 Total primary energy use in EU27 in 2050

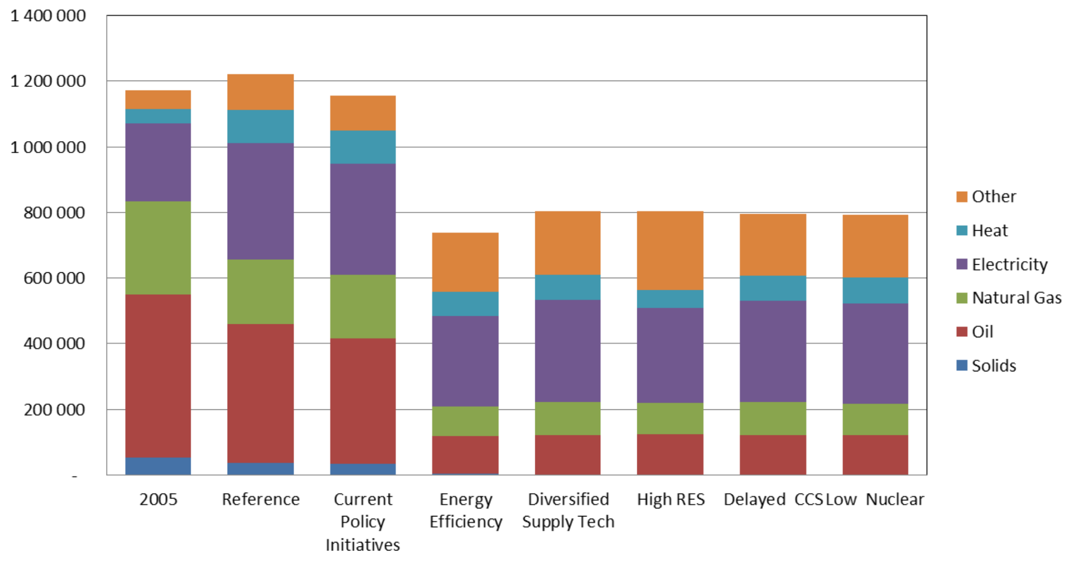

Figure 25 Final energy demand in EU27 in 2050

The main conclusions from the Energy Roadmap 2050 are the following [26]:

- Decarbonisation is possible – and can be less costly than current policies in the long run
- Higher capital expenditure - lower fuel costs
- Electricity plays an increasing role
- Electricity prices rise until 2030 and then decline
- Household expenditure will increase
- Energy savings throughout the system are crucial
- Renewables rise substantially
- CCS has to play a pivotal role in system transformation
- Nuclear energy provides an important contribution
- Decentralised and centralised systems increasingly interact

5.2 World Energy Outlook

The International Energy Agency (IEA) provides energy projections towards 2035 using the World Energy Model (WEM). The model is a large-scale simulation tool designed to model how energy markets function and is used to generate detailed projections for the World Energy Outlook (WEO) scenarios.

In WEO 2011 IEA presents three different scenarios for the energy sector towards 2035:

- Current Policy Scenario
- New Policy Scenario
- 450-Scenario

The most important scenario in WEO 2011 is the New Policy Scenario, which imply that the national energy and climate targets are fulfilled.

Generally, the World Energy Outlooks are considered as a reference source of energy scenarios for political discussions. On the one hand, the WEO are often serving as a basis of national governments to derive their own national energy action plans for the future. On the other hand, political discussions always drive the development of energy scenarios towards their focus. In this context, the process around the development of energy scenarios within the WEO is a result of the intensive communication between the IEA and the national governments accompanied by the interest of relevant stakeholders within the energy sector.

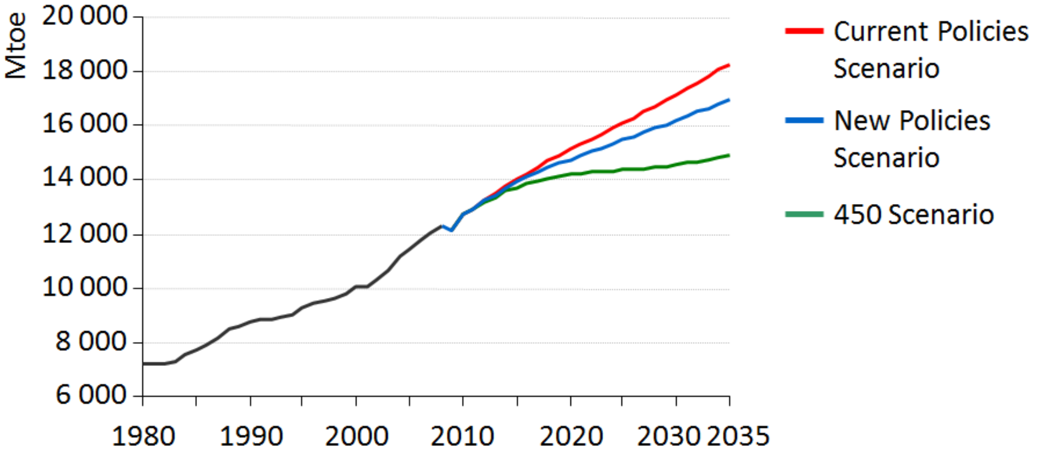

Figure 26 World primary energy consumption by scenario [29].

In the New Policies Scenario energy demand in the world will increase by 40% from 2009 to 2035, and in Current Policies Scenario the growth in energy demand is even larger. In the New Policies Scenario China and India account for 50% of the growth.

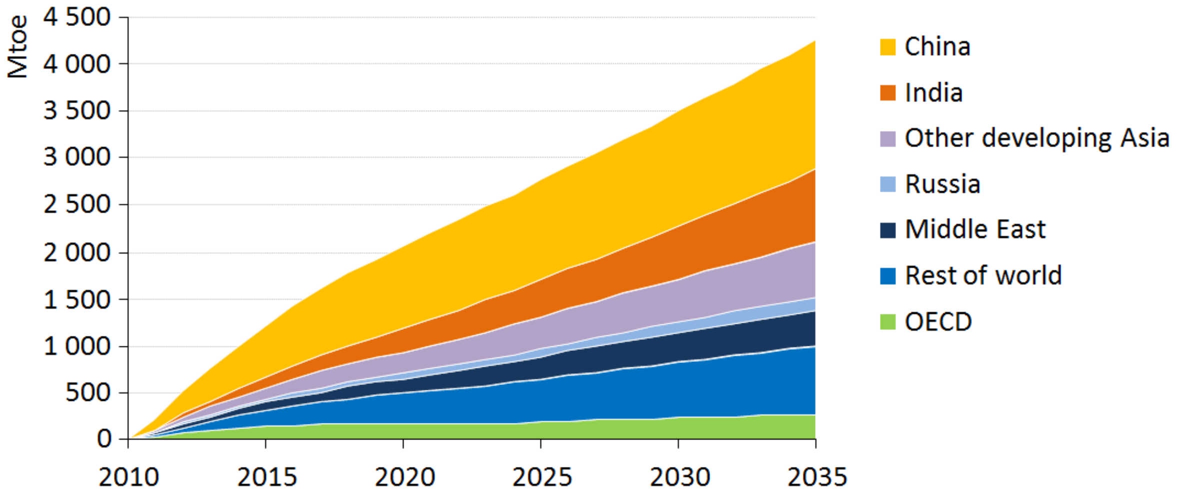

Figure 27 Growth in primary energy demand in the New Policies Scenario [29]

5.3 EIA – International Energy Outlook

The International Energy Outlook 2011 (IEO2011) presents an assessment by the U.S. Energy Information Administration (EIA) of the outlook for international energy markets through 2035 [4]. The IEO2011 consumption projections are divided in:

- OECD Americas (United States, Canada and Mexico/Chile)
- OECD Europe
- OECD Asia (Japan, South Korea, and Australia/New Zealand)
- Non-OECD Europe and Eurasia
- Non-OECD Asia
- Middle East
- Africa
- Central and South America

World total primary energy consumption by region and fuel in 2006-2035 is presented in the report (the energy sources are liquids, natural gas, coal, nuclear and other). Non-marketed energy sources are not included in IEO2011. World total installed generating capacity by region in 2008-2035 is also presented and this is further divided in liquids-fired, natural-gas-fired, coal-fired, nuclear and hydroelectric and other renewable generating capacities (in GW) and electricity generation (in billion kWh). The report also includes projections of population, GDP and intensity by region. Some figures are presented in Table 19. The reference case is a business as usual trend estimate, given known technology and technological and demographic trends. Other scenarios explore the impacts of alternative assumptions such as different macroeconomic growth rates and world oil prices.

Table 19 Example of information on energy projection data from IEO2011 [4]

	2008	2020	2035	Annual change 2008-2035
Primary energy consumption (Quadrillion Btu)				
Total world	481.3	619.5	769.8	1.6 %
United States	100.1	104.9	114.2	0.5 %
OECD Europe	82.2	86.9	93.8	0.5 %
Net electricity generation from central producers (Billion kWh)				
Total world	19 125	25 462	35 175	2.3 %
United States	4 122	4 453	5 167	0.8 %
OECD Europe	3 440	4 040	4 793	1.2 %
Population (millions)				
Total world	6 731	7 609	8 453	0.9 %
United States	305	342	390	0.9 %
OECD Europe	544	567	580	0.3 %
GDP per capita (2005 dollars per person)				
Total world	9 773	13 258	19 123	2.6 %
United States	43 349	50 938	65 862	1.5 %
OECD Europe	27 568	32 158	41 762	1.5 %

The Annual Energy Outlook 2012 was prepared by the U.S. Energy Information Administration (EIA) and it presents long-term projections of energy supply, demand and

prices through 2035, based on results from EIA's National Energy Modelling System, NEMS [30]. The analysis focuses primarily on a reference case, low and high economic growth cases, and low and high oil price cases. The report presents projection of the U.S. as total and 9 regions of the U.S. and is presented for different energy carriers every year from 2009 to 2035. The demand is divided in residential, commercial, industrial, transportation and the power sector. Key indicators of the U.S. as a whole are also available, e.g. numbers of households (single-family, multi-family and mobile homes), energy by end-use for every energy carrier (e.g. space heating, space cooling, cooking, refrigeration etc.) and heating degree days for the 9 regions. These tables can be downloaded at:
http://www.eia.gov/oiaf/aeo/tablebrowser/

5.4 Energy Technology Perspectives

IEA releases every second year the Energy Technology Perspectives (ETP). The 2012 edition is called Pathways to Clean Energy Systems. ETP 2012 have three central scenarios; the 6°C scenario (6DS), the 4°C scenario (4DS) and the 2°C scenario (2DS) [31].

Energy demand projections differ in the three scenarios. In the 6DS which is mainly a continuation of current trends, the world's energy demand is almost twice as high as in 2050 as in 2009. The 4 DS takes into account the countries intentions to limit emissions, and the efforts to improve energy efficiency. The main scenario in ETP2012 is the 2DS which describes an energy system where energy-related CO_2 emissions are less than half in 2050 compared with 2009. The 2 DS correspond to the WEO 450 Scenario through 2035. The projections in ETP to 2050 are shown in the figure.

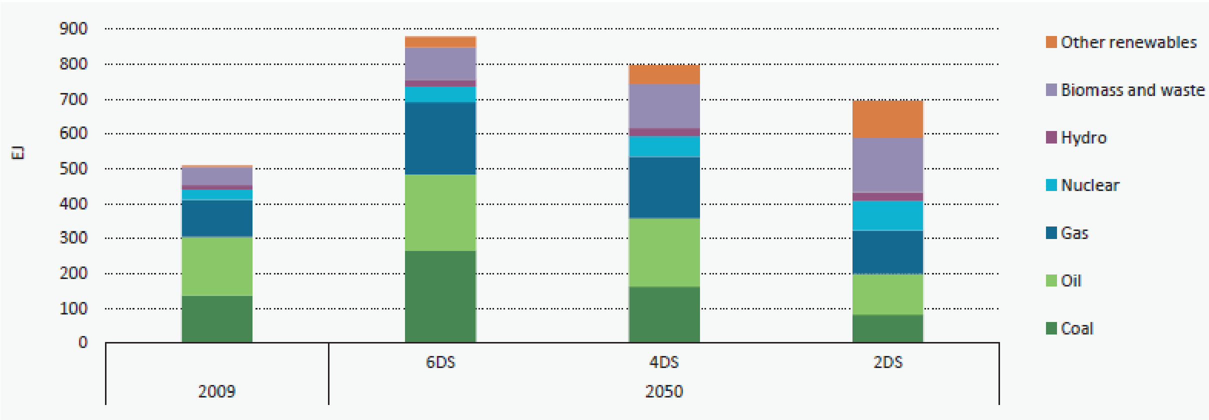

Figure 28 World primary energy supply by scenario [31].

The impact of energy efficiency measures is the far most important parameter in reducing future energy demand (and the need for future energy supply) in the 2DS. Success is dependent on significant decoupling of energy use from economic activity. This requires changes in individual behaviour and in technology development.

5.5 Nordic Energy Technology Perspectives

In January 2013, the International Energy Agency published the report *Nordic Energy Technology Perspectives: Pathways to a Carbon Neutral Energy Future (N-ETP)* [32]. The scenarios in N-ETP are based on the global ETP scenarios. In the global 2°C scenario (2DS) from ETP 2012, energy-related carbon dioxide (CO_2) emissions in the Nordic region is reduced by almost 70% in 2050 compared to 1990. In the Nordic ETP a Carbon-Neutral Scenario is analysed, in which the emissions are reduced by 85%. International carbon credits are used to offset the remaining 15% of the emissions.

In the projections of future energy demand it is assumed that the industrial sector in the Nordic region will remain relatively stable. In the building sector future energy demand is driven by a number of factors including population, income, number and size of households, geographic region, climatic conditions, energy prices, services sector value added, and floor area of service sector. It is assumed an increase in all these parameters. The reduced energy demand in 2DS includes improvements in space heating, lighting and appliances. In the transport sector measures to increase efficiency and reduce CO_2 emissions is grouped in five main categories which are included in the projections; avoid, improve, switch technology, switch fuel and shift modes.

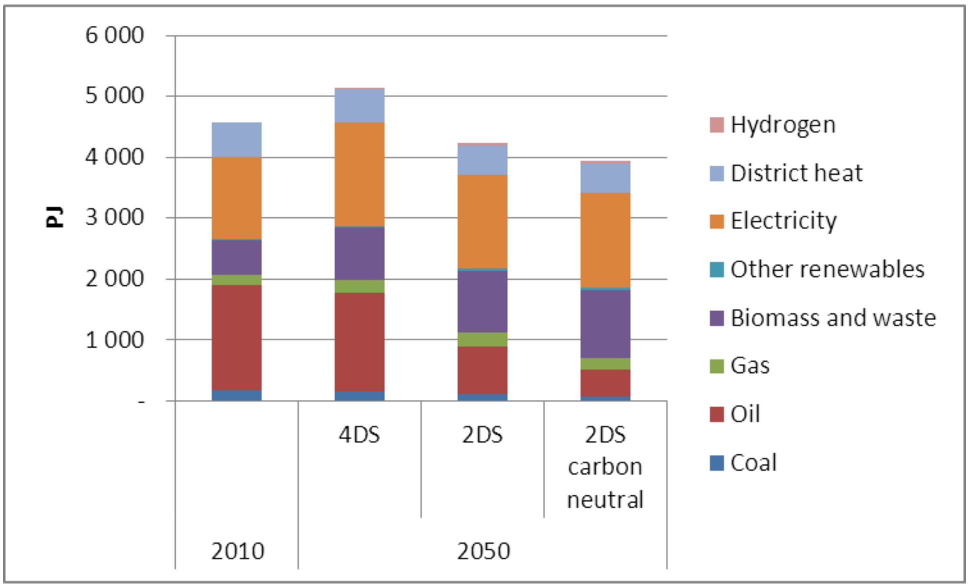

Figure 29 Final energy consumption in the Nordic countries, PJ/year [32]

One message from the report is that changes in energy demand and supply must be considered simultaneously across the different sectors. The synergies that exist among systems for district heating, power generation, electric transport, municipal waste management and industrial energy use must be further utilized.

5.6 Summary of international forecast of current interest

The scope, time horizon and areas of the international forecasts presented in this report are summarized in Table 20 and Table 21. The annual global growth in electricity use varies from 2.4% in WEO 2011 to 3.1% in ETP 2012, compared to the European growth of 1.3% in EU Energy Roadmap and 0.8% in IEO 2011 (with different scenarios and time horizons, see Table 21). The growth in electricity, final energy demand and primary energy supply is highest on a global level, less on a European level and smallest for the Nordic countries.

Table 20 Summary of scope of global/regional forecasts

	Regions	**Time horizon**	**Model**	**Objective**
EU Energy Roadmap 2050	EU	2050	PRIMES	Decarbonisation
WEO 2011	Global	2035	World Energy Model (WEM)	Climate targets
IEO 2011	Global with 8 regions	2035		
ETP	Global with 7 regions + selected countries	2050	TIMES	Pathways to clean energy systems
N-ETP	Nordic countries	2050	TIMES	Carbon neutral

Table 21 Summary of development in global/regional forecasts

			Annual growth		
Study	Region	Years	Electricity	Final energy demand	Scenario
EU Energy Roadmap 2050	EU-27	2010-2030	+1.3%	+0.2%	Baseline
WEO 2011	World	2009-2035	+2.4%	+1.5%	New Policies
IEO 2011	World	2008-2035		+1.6%	
IEO 2011	OECD Europe	2008-2035	+0.8%	+0.5%	
ETP	World	2009-2050	+3.1% +2.5%	+1.6%[5] +0.9%	4DS 2DS
N-ETP	Nordic countries	2010-2050	+0.6% +0.3%	+0.3% -0.2%	4DS 2DS

[5] Total Primary Energy Supply

6 Conclusion and further work

Many user partners and research partners of CenSES are dependent on energy demand forecasting in their work with energy systems analyses and planning. The type of forecast needed differs e.g. concerning geographical area, energy carriers, demand sectors and time levels. The lack of an official Norwegian energy demand forecast with a transparent view of assumptions is a drawback for many partners.

A common interest for energy demand forecasting and the necessarity of common assumptions in comparative analyses of future energy systems is identified within CenSES. The work with methodologies, transparency and common assumptions will be continued in CenSES and will also be an important part of the scenario activities of Research Area 5 (Energy scenario development) of CenSES.

We suggest continuing this work with development of a common CenSES forecast of Norwegian energy demand towards 2050. To be able to make this common forecast a close cooperation between research partners and user partners in CenSES is needed. The common forecast can be used as a basis for new analysis in future research projects and in the work with CenSES scenarios.

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Appendix

A1 Models

The main focus of this report is long-term energy demand forecasts. To better understand the different need and possibilities of different models, some more information of relevant models is included below. An interesting comparison of positive and negative attributes of the three major energy modelling approaches of the residential sector is presented in [33] and in Table 22

Table 22 Positive and negative attributes of the three major residential energy modelling approaches [33].

	Top-down	Bottom-up statistical	Bottom-up engineering
Positive attributes	• Long term forecasting in the absence of any discontinuity	• Encompasses occupant behaviour	• Model new technologies
	• Inclusion of macroeconomic and socioeconomic effects	• Determination of typical end-use energy contribution	• "Ground-up" energy estimation
	• Simple input information	• Inclusion of macroeconomic and socioeconomic effects	• Determination of each end-use energy consumption by type, rating, etc.
	• Encompasses trends	• Uses billing data and simple survey information	• Determination of end-use qualities based on simulation
Negative attributes	• Reliance on historical consumption information	• Multicollinearity	• Assumption of occupant behaviour and unspecified end-uses
	• No explicit representation of end-uses	• Reliance on historical consumption information	• Detailed input information
	• Coarse analysis	• Large survey sample to exploit variety	• Computationally intensive
			• No economic factors

A1.1 **MSG**

Most of the foresight work financed by the Ministries includes the use of an equilibrium model developed by Statistics Norway (MSG). This model is often used as a base in combination with scenario methodologies. The scenarios are often based on fundamental uncertainties that might have vital influence on the future energy use and/or production. These uncertainties are important inputs to the model and the model results are the basis of the scenario analysis.

MSG is an Applied General Equilibrium (AGE) model of the Norwegian economy developed at Statistics Norway. It is designed in order to calculate consistent long run projections of the Norwegian economy, as well as effects of changes in economic policy instruments and other exogenous variables. In particular, MSG has been designed in order to address issues such as the efficiency effects of changes in taxation, trade policy, various types of industry subsidies, environmental and energy policies. The Norwegian National Accounts (NA) constitute the main empirical data source for both calibration and estimation of behavioural and technology parameters. Major driving forces for the economic development, as the growth in productivity, demographic trends, employment, international capital return and the development in income from the petroleum sector has to be stated outside the model.

Several of the driving forces that have to be exogenously given to the model are discussed in the project organisations and there are often alternative development analysed for e.g. energy prices, international level of interest rates, growth in productivities, demographic trends, hours worked, labour force participation and elderly health state. Use of energy in the MSG model is connected to an economic variable described in the National Accounts. One parameter that is of great importance in the Norwegian energy balance is the business structure, and this is an external parameter that is specified within the project group based on historical development and discussions of future possibilities. Assumptions are made concerning future electricity production in the analysis with the model.

A1.2 **PRIMES**

The following description of the PRIMES model is from [27]:

The PRIMES model simulates the response of energy consumers and the energy supply systems to different pathways of economic development and exogenous constraints and drivers. It is a modelling system that simulates a market equilibrium solution in the European Union and its member states. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply match the quantity consumers wish to use. The equilibrium is forwarding looking and includes dynamic relationships for capital accumulations and technology vintages. The model is behavioural formulating agents' decisions according to microeconomic theory, but it also represents in an explicit and detailed way the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market competition economics, industry structure, energy /environmental policies and regulation. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing.

PRIMES is a partial equilibrium model simulating the entire energy system both in demand and supply; it contains a mixed representations of bottom-up and top-down elements. The PRIMES model covers the 27 EU Member States as well as candidate and neighbour states (Norway, Switzerland, Turkey, and South East Europe). The timeframe of the model is 2000 to 2050 by five-year periods; the years up to 2005 are calibrated to Eurostat data. The level of detail of the model is large as it contains:

- 12 industrial sectors, subdivided into 26 sub-sectors using energy in 12 generic processes (e.g. air compression, furnaces)
- 5 tertiary sectors, using energy in 6 processes (e.g. air conditioning, office equipment)
- 4 dwelling types using energy in 5 processes (e.g. water heating, cooking) and 12 types of electrical durable goods (e.g. refrigerator, washing machine, television)
- 4 transport modes, 10 transport means (e.g. cars, buses, motorcycles, trucks, airplanes) and 10 vehicle technologies (e.g. combustion engine, hybrid cars)
- 14 fossil fuel types, new fuel carriers (hydrogen, biofuels) 10 renewable energy types
- Main Supply System: power and steam generation with 150 power and steam technologies and 240 grid interconnections
- Other sub-systems: refineries, gas supply, biomass supply, hydrogen supply, primary energy production
- 7 types of emissions from energy processing (e.g. SO_2, NO_x, PM)
- CO_2 emissions from industrial processes
- GHG emissions and abatement (using IIASA's marginal abatement cost curves for non CO_2 GHGs).

For more information see
http://www.e3mlab.ntua.gr/e3mlab/index.php?option=com_content&view=section&id=8&Itemid=56&lang=en

A1.3 **GCAM**

GCAM, short for *Global Change Assessment Model*, is an integrated assessment model of moderate complexity focused on energy and agriculture sectors. It is a global energy system simulation model and of the CenSES participants it is used by Sintef Energy Research. The GCAM model has no markets for labour and capital and it is specifically designed to address issues associated with global change. The GCAM model can be conceptualized as consisting of four modules (see Figure 30). The GCAM projects economic activity, energy consumption, and emissions in 5-year time steps from 1990 through 2095. It has global coverage in the form of 14 distinct regions (United States, Canada, Western Europe, Japan, Australia & New Zealand, Former Soviet Union, Eastern Europe, Latin America, Africa, Middle East, China [& Asian Reforming Economies], India, South Korea, Rest of South & East Asia).

The main driver of energy demand is population together with a productivity growth factor and based on this, GDP is calculated for each end use sector and the 14 regions of the world. End use demand of three demand sectors, industry, buildings and transportation (without further splitting), is calculated from GDP and elasticities of price and income. End use demand is not easy to extract from the model. Changes in end use demand have to be included as changes in population and/or productivity growth rates.

More information of the model is available in [34] and [35].

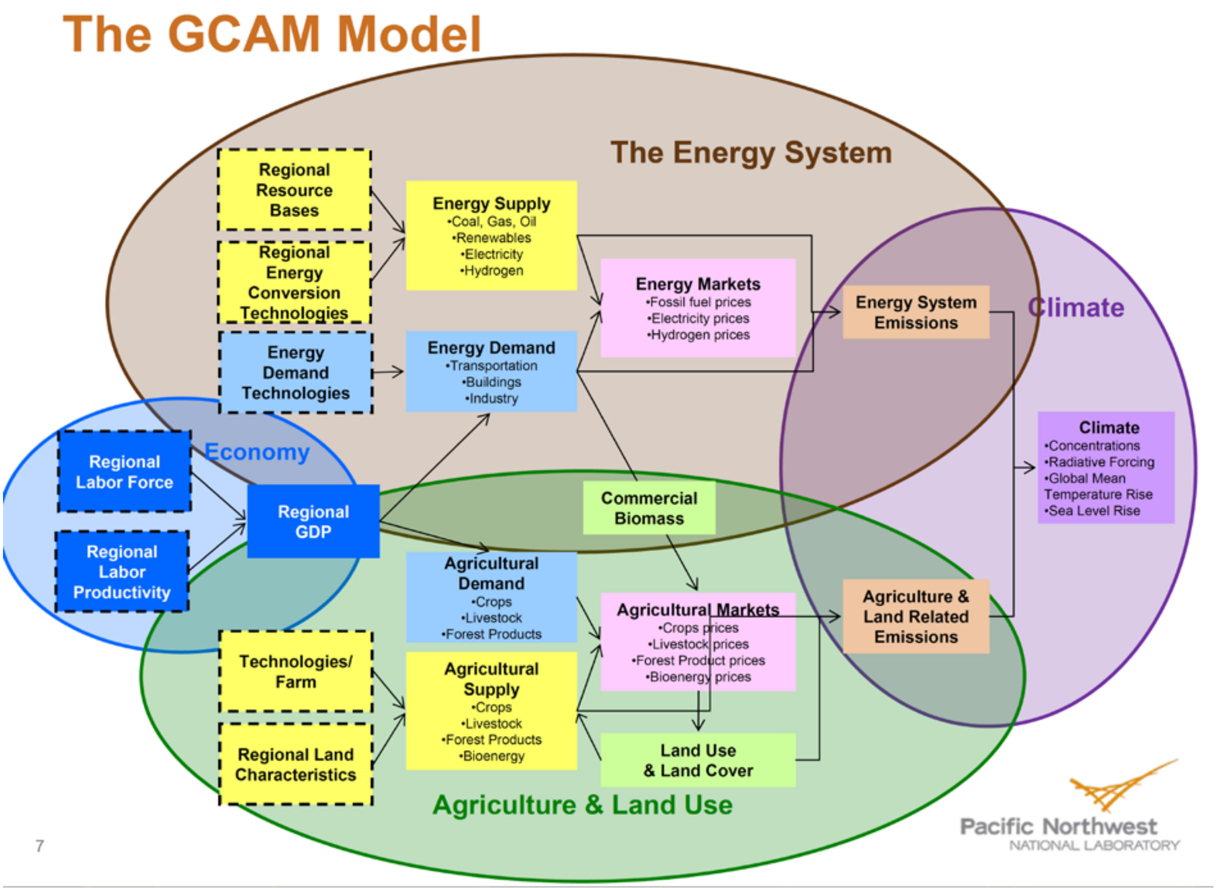

Figure 30 GCAM overview (From [34])

A1.4 **eTransport**

eTransport has many modules and the data is stored in a database which is read by the tool. Changes apply via the graphical interface which also starts the optimization. An example multi-carrier network with electricity and heat networks, fed by the marked, waste and gas, is shown in Figure 31.

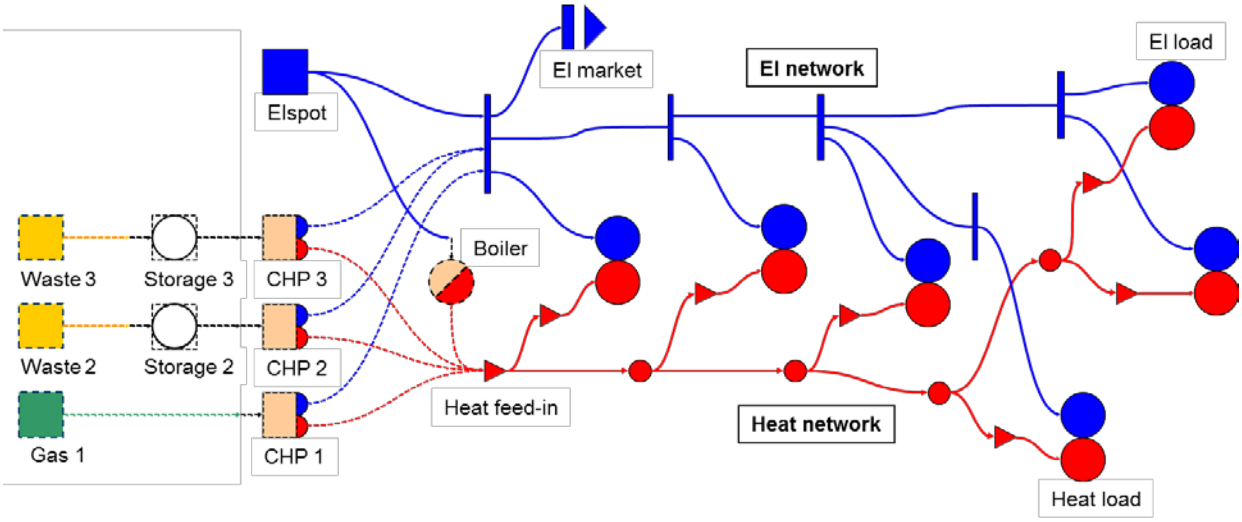

Figure 31 Example model in eTransport [36]

- Optimizes the construction of infrastructure for the most common energy carriers like electricity, district heating, cooling, gas, waste and biomass (including conversions between these)
- Beside continuous transport via lines, it may also include discrete transport with e.g. ship, truck or train
- Uses flexible, multi-layer time resolutions (hourly profiles, days, variable seasons, years, investment periods, planning horizon)
- Representation of geographic infrastructure and distance
- Modular design enables rather easy modification and addition of technology models

For more information, see www.sintef.no/etransport

A1.5 **EMPS**

The following Figure 32 shows the model concept of EMPS. They are different inputs and interactions for the data which then finally is calculated in the market simulation. The solutions lead to a result and depending on this the whole market data might be recalculated resulting in a new simulation of the system. This is necessary, if large changes in the model (data set, power plants…) are made.

- Mid- and long-term optimization of system operation on weekly basis
- Socio-economic market simulator assuming a perfect market using linear programming (LP)
- Optimal unit commitment and generation dispatch

- Results are area prices for energy and water-values for the reservoirs (using stochastic dynamic programming (SDP))
- Usage of historical time series for water inflow with a very detailed hydro-course description
- Includes stochastic weather prediction and historical data

The need for energy demand forecasts of EMPS is electricity load per area with flexible time resolution (from 5-12 load levels per week down to hourly resolution) per year, split into price-dependent and inflexible load. The model runs one single year with various data sets up to 2050.

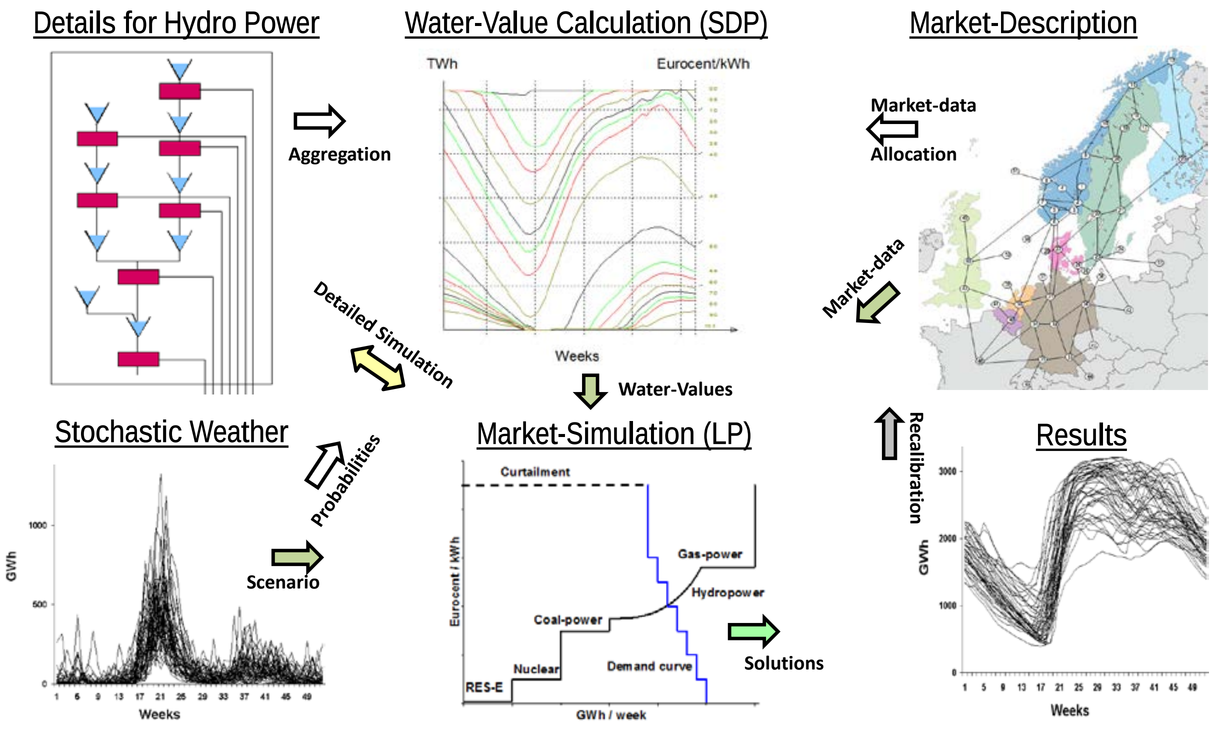

Figure 32 Overview of the model concept in EMPS [37]

A1.6 **SHOP (Short-term Hydro Operation Planning)**

The tool for short-term operation scheduling is used internationally for optimal hydro scheduling. It covers also other system models and thus it can co-ordinate different types of power production systems. The results are detailed production schedules for user-defined time periods (typically 7-14 days) and time resolutions (typically 1 hour or 15 minutes) based on reservoir inflow, market prices and loads. SHOP takes dependencies within the water course (e.g. between boundary conditions from longer-term scheduling and time intervals) into account and includes all main components (e.g. reservoirs, hydro units, discharge gates, junctions)

- Uses iterations of linear programming to find optimal result
- Can handle any number of cascaded water courses

- Based on an optimization formulation for complex hydraulic configurations of water courses
- Optimization is based on successive linear programming and may include mixed integer formulation
- Head optimization and start-up costs for hydro plants is modelled
- Hydro units are defined by individual power-production/discharge-curves
- Operational constraints are for example reservoir levels for pumping, min/max values (production, reservoirs, gates…), user defined schedules, limitations in production units/reservoirs/gates…

SHOP needs timeseries for electricity demand down to 15-minute time intervals for 7-14 days. For more information, see http://www.sintef.no/shop

A1.7 **USELOAD**

The tool is used to calculate electrical load profiles and divide it into costumer groups or end-uses like households or industry. The speciality of USELOAD is great flexibility, basic development of methods and great applicability for different kinds of purposes. The model constitutes as an interesting tool for different parties in the power market like network owner (net & energy planning, design of tariffs, analysis of customers), power supplier (market analysis, energy services), system operator (power analysis, forecasts) and authorities (DSM analyses, design of policy instruments towards customers).

- Based on load curves from national load research projects
- Segmenting metered time series into end-use or different customers
- Uses statistical methods and handles climatic dependencies
- Detailed input data (like daily load curves for i.e. lighting, heating, ventilation, hot water and other electrical appliances) is important before the model is operative for a specific region
- Climate correction of energy and power with hour's division
- Detailed calculation of network losses
- Detailed energy and power forecasts at all voltage levels

For more information, see http://www.sintef.no/useload

A1.8 **PSST (**Power System Simulation Tool)

The simulation tool is based on a market model with a DC load flow grid representation. The modelling method involves an explicit computation of the power flow in the high voltage transmission grid of Europe, using simplified grid equivalents of the Nordel, UCTE and UK/Ireland power systems. The simulation tool is implemented as a collection of Matlab functions. It minimizes the total production costs of an energy system regarding the production at each generation, including grid constraints. The tool is mainly used for large scale wind power studies in the European grid.

- Hourly time series for load profiles and wind data

- Weekly data for water values and inflow
- Monthly data for nuclear revisions
- Input data is stored mostly in plain text, Excel or MATLAB files
- Includes a simple user-interface
- Visualisation in Google-Earth

For more information, see Magnus Korpås, Leif Warland; "Description of the PSST Tool", Project Memo, Sintef Energy Research, February 2009

A1.9 **ETSAP-TIAM**

The TIMES model generator was developed and is maintained by the Energy Technology Systems Analysis Program (ETSAP), an implementing agreement under aegis of the International Energy Agency (IEA). The TIMES integrated assessment model (ETSAP-TIAM) is the global multiregional incarnation of the TIMES model generator and of the CenSES participants it is used by IFE.

The model aims to supply energy service at minimum global cost (more accurately at minimum loss of total surplus) by simultaneously making decisions on equipment investment, equipment operation, primary energy supply, and energy trade. TIAM is a vertically integrated model of the entire extended energy system. The model is described in detail in [38] and [39].

ETSAP-TIAM is a global long-term linear optimization model with 15 regions. The annual time distribution is winter, summer, intermediate and day/night. The drivers of the model are:

- GDP – Gross Domestic Product
- GDPP – Gross Domestic Product per capita
- HOU – Households
- POP – Population
- SPROD-X – Production of sector X related to GDP

Demand = (K * Driver) ^ elasticity

The demand sectors are:

- Transportation
    a. Automobile travel
    b. Bus travel
    c. 2 & 3 wheelers
    d. Rail passenger travel
    e. Domestic aviation travel
    f. International aviation travel
    g. Trucks
    h. Freight rail
    i. Domestic navigation
    j. Bunkers
- Residential
    a. Space heating
    b. Space cooling
    c. Water heating
    d. Lighting

e. Cooking
f. Refrigeration and freezing
g. Washers
h. Dryers
i. Dish washers
j. Other appliances
k. Other

- Commercial
    a. Space heating
    b. Space cooling
    c. Water heating
    d. Lighting
    e. Cooking
    f. Refrigeration and freezing
    g. Other electric demands
    h. Other
- Agriculture
- Industry
    a. Iron and steel
    b. Non-ferrous metals
    c. Chemicals
    d. Pulp and paper
    e. Non-metal minerals
    f. Other industries

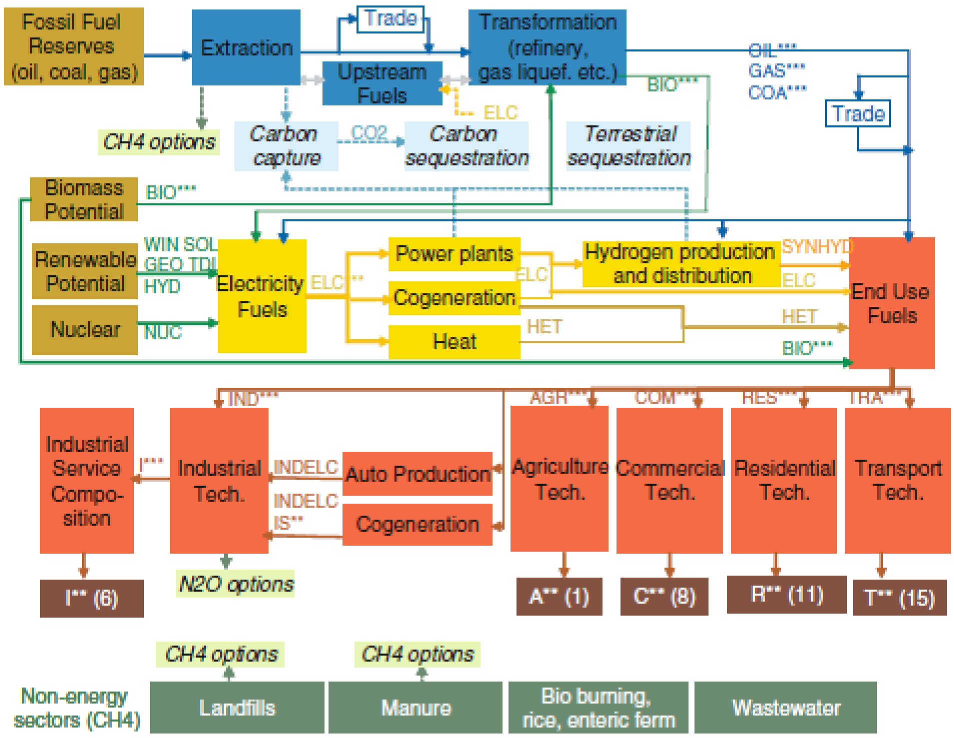

Figure 33 A sketch of the ETSAP-TIAM model's Reference Energy System [38]

A1.10 **TIMES-Norway**

Table 23 List of end use demands for each of the seven regions of TIMES-Norway

Sector	Sub-sector	Demand type
Agriculture		Electrical, Heating, Raw material
Commercial	Construction	Electrical, Heating
	Education	Electrical, Heating, Cooling
	Health services	Electrical, Heating, Cooling
	Hotel and restaurant	Electrical, Heating, Cooling
	Office buildings	Electrical, Heating, Cooling
	Other	Electrical, Heating, Cooling
	Road light	Electrical
	Wholesale and retail	Electrical, Heating, Cooling
Industry	Aluminium plant A-D	Electrical, Heating, Raw material
	Aluminium other	Electrical, Heating, Raw material
	Chemical plant A	Electrical, Heating, Raw material
	Chemical other	Electrical, Heating, Raw material
	Metal industry plant A	Electrical, Heating, Raw material
	Metal industry other	Electrical, Heating, Raw material
	Mining	Electrical, Heating, Raw material
	Pulp & paper large	Electrical, Heating, Raw material
	Pulp & paper small	Electrical, Heating, Raw material
	Refineries	Electrical, Heating, Raw material
	Residual industry	Electrical, Heating, Raw material
Residential	Cottages	Electrical, Heating
	Multi-family houses – new	Electrical, Heating
	Multi-family houses – old	Electrical, Heating
	Single family houses – new	Electrical, Heating
	Single family houses – old	Electrical, Heating
Transport	Air transport	Useful energy
	Personal cars – long distance	Vehicle-km
	Personal cars – short distance	Vehicle-km
	Freight	Useful energy
	Other mobile combustion	Useful energy
	Public transport – bus	Vehicle-km
	Public transport – train	Useful energy
	Sea transport	Useful energy
Total per region	33-36	75-78
Total TIMES-Norway	267	534

A1.11 **WNRI Household scenario model**

Table 24 Key data for the scenario model on future residential energy use (in Norwegian).

Egenskap	Utgangsverdi	Prosentvis årlig vekst
Areal	Areal per person	0,5%
	Rivingsrate	0,0 %
Boliger	Person per hushold	-0,2
Lys	kWh per m^2	-15% (2015), -2% (2030)
	Spillvarmefaktor	0%
Hvitevarer	kWh per m^2	-1,5% (Teknologi-indeks)
		0,5% (Bestand-indeks)
	Spillvarmefaktor	-5% (2015) 0% (2030)
Elektronikk	kWh per m^2	-3% (2030) (Teknologi-indeks)
		2,5% (Bestand-indeks)
	Spillvarmefaktor	-5% (2015) 0% (2030)
Vannoppvarming	kWh per m^2	-0,5% (Teknologi-indeks)
Beredertap	kWh per m^2	-1,5% (Teknologi-indeks)
Teknisk drift	kWh per m^2	0% (2030)
Fordeling areal	Enebolig, % areal	-6% (2015) , 0% (2030)
	Rekkehus, % areal	0% (2030)
	Blokker, % areal	20% (2030)
Fordeling boliger	Enebolig, % boliger	-3% (2030)
	Rekkehus, % boliger	0% (2030)
	Blokker, % boliger	3% (2030)
Fordeling folketall	Enebolig, % boliger	0% (2030)
	Rekkehus, % boliger	0% (2030)
	Blokker, % boliger	0% (2030)
Oppvarming energibærer, nye boliger 3,5 %	Fast brensel, %-andel	0,0 % (2030)
	Oljeprodukt, %-andel	0,0 % (2030) [6]
	Fjernvarme, %-andel	20,0 % (2030)
	Gass, , %-andel	0,0 % (2030)
	Elektrisitet, %l	0,0 % (2030)
Omgivelsesvarme, nye boliger	Enebolig, kWh per m^2	7% (2012)(Teknologi-indeks)
	Rekkehus, kWh per m^2	80% (2012)(Teknologi-indeks)
	Blokker, kWh per m^2	200% (2012)(Teknologi-indeks)
Brutto varmebehov, nye boliger	Enebolig, kWh per m^2	-0,5 (2015), -0,2 (2030)
	Rekkehus, kWh per m^2	-0,5 (2015), -0,2 (2030)
	Blokker, kWh per m^2	-0,5 (2015), -0,2 (2030)
Brutto varmebehov, eksisterende	Enebolig, kWh per m^2	-0,7 (2030)
	Rekkehus, kWh per m^2	-0,7 (2030)
	Blokker, kWh per m^2	-0,7 (2030)
Oppvarming energibærer, eksisterende	Fast brensel, %-andel	0,0 % (2030)
	Oljeprodukt, %-andel	-5,0 % (2030)
	Fjernvarme, %-andel	1,0 % (2030)
	Gass, %-andel	0,0 % (2030)
	Elektrisitet, %-andel	0,0 % (2030)

[6] Utgangspunktet for nye boliger er 0 slik at oljeprodukt ikke brukes som energibærer i nye boliger.

A2 Example of data from “EU Energy Trends to 2030”

Table 25 EU Energy Trend to 2030; Example of data available in [28]

BASELINE SCENARIO EU-27: Key Demographic and Economic Assumptions	1990	2000	2010	2020	2030	'90-'00	'00-'10	'10-'20	'20-'30	1990	2000	2010	2020	2030
						Annual % Change				% Structure of total value added				
Main Demographic Assumptions														
Population (Million)	470.4	481.1	499.4	513.8	519.9	0.2	0.4	0.3	0.1					
Average household size (persons)	2.7	2.5	2.3	2.2	2.2	-0.8	-0.7	-0.4	-0.3					
Number of households (Million)	176.2	195.1	216.8	231.3	240.8	1.0	1.1	0.6	0.4					
Gross Domestic product (in 000 M€05)	**8142.7**	**10107.2**	**11385.6**	**14164.0**	**16824.7**	**2.2**	**1.2**	**2.2**	**1.7**					
Households expenditure (in 000 M€05)	**4714.3**	**5853.9**	**6495.6**	**8077.2**	**9423.1**	**2.2**	**1.0**	**2.2**	**1.6**					
Gross Value Added (in 000 M€05)	**7304.8**	**9017.0**	**10135.9**	**12655.5**	**15051.1**	**2.1**	**1.2**	**2.2**	**1.7**					
Industry	1370.8	1597.2	1690.2	2059.6	2409.1	1.5	0.6	2.0	1.6	18.8	17.7	16.7	16.3	16.0
iron and steel	54.1	56.4	53.8	61.7	68.5	0.4	-0.5	1.4	1.0	0.7	0.6	0.5	0.5	0.5
non ferrous metals	23.4	33.1	28.9	34.2	39.1	3.5	-1.3	1.7	1.4	0.3	0.4	0.3	0.3	0.3
chemicals	116.2	154.8	186.3	229.0	271.9	2.9	1.9	2.1	1.7	1.6	1.7	1.8	1.8	1.8
pharmaceuticals and cosmetics	39.5	57.4	79.3	106.4	137.2	3.8	3.3	3.0	2.6	0.5	0.6	0.8	0.8	0.9
non metallic minerals	65.6	73.9	71.4	83.9	96.3	1.2	-0.4	1.6	1.4	0.9	0.8	0.7	0.7	0.6
paper, pulp, printing	126.9	146.8	143.2	170.6	199.8	1.5	-0.2	1.8	1.6	1.7	1.6	1.4	1.3	1.3
printing and publishing	80.2	91.0	94.1	115.7	139.6	1.3	0.3	2.1	1.9	1.1	1.0	0.9	0.9	0.9
food, drink, tobacco	180.5	203.3	214.9	263.1	316.2	1.2	0.6	2.0	1.9	2.5	2.3	2.1	2.1	2.1
textiles and leather	99.8	86.1	64.7	63.6	60.9	-1.5	-2.8	-0.2	-0.4	1.4	1.0	0.6	0.5	0.4
engineering	524.1	648.0	722.5	905.7	1060.5	2.1	1.1	2.3	1.6	7.2	7.2	7.1	7.2	7.0
other industries	180.2	194.9	204.7	247.9	295.9	0.8	0.5	1.9	1.8	2.5	2.2	2.0	2.0	2.0
Construction	542.7	554.0	561.7	707.6	829.8	0.2	0.1	2.3	1.6	7.4	6.1	5.5	5.6	5.5
Services	4963.3	6365.3	7398.6	9359.8	11235.8	2.5	1.5	2.4	1.8	67.9	70.6	73.0	74.0	74.7
Agriculture	175.4	190.7	182.3	197.6	217.4	0.8	-0.5	0.8	1.0	2.4	2.1	1.8	1.6	1.4
Energy sector	252.7	309.8	303.1	330.8	358.9	2.1	-0.2	0.9	0.8	3.5	3.4	3.0	2.6	2.4

Table 26 EU Energy Trend to 2030; Example of data available in [28]

EU27: Baseline 2009										SUMMARY ENERGY BALANCE AND INDICATORS (A)			
ktoe	1990	1995	2000	2005	2010	2015	2020	2025	2030	'90-'00	'00-'10	'10-'20	'20-'30
										Annual % Change			
Production	**936047**	**950181**	**941880**	**900328**	**821886**	**773670**	**741237**	**740892**	**781416**	**0.1**	**-1.4**	**-1.0**	**0.3**
Solids	366477	277810	213423	196277	167556	155202	142314	135565	130849	-5.3	-2.4	-1.6	-0.8
Oil	129551	171052	173006	134290	102864	74348	49906	40875	37276	2.9	-5.1	-7.0	-2.9
Natural gas	162447	188965	207559	188677	164144	129067	111437	91972	75504	2.5	-2.3	-3.8	-3.8
Nuclear	202589	223028	243761	257360	238990	241310	237685	247463	268042	1.9	-0.2	-0.1	1.2
Renewable energy sources	74984	89326	104111	123722	148430	173644	199895	225016	249745	3.3	3.6	3.0	2.3
Hydro	25101	28054	30374	26395	27808	28531	29145	30041	30533	1.9	-0.9	0.5	0.5
Biomass & Waste	46473	57201	67982	85129	97599	109508	120092	128067	132313	3.9	3.7	2.1	1.0
Wind	67	350	1913	6061	13862	23145	34332	44744	55375	39.8	21.9	9.5	4.9
Solar and others	153	274	421	807	3259	6238	9054	11542	13804	10.7	22.7	10.8	4.3
Geothermal	3190	3447	3421	5331	5903	6222	7271	10622	17719	0.7	5.6	2.1	9.3
Net Imports	**768079**	**738800**	**826299**	**988048**	**992633**	**1083828**	**1133566**	**1130608**	**1100891**	**0.9**	**1.8**	**1.3**	**-0.3**
Solids	81846	79338	98645	126639	117225	133831	144964	139939	129086	1.9	1.7	2.1	-1.2
Oil	535645	512185	533039	599851	578981	616263	629909	619167	596780	0.0	0.8	0.8	-0.5
- Crude oil and Feedstocks	508460	494000	513725	581995	577908	617339	635745	628717	611939	0.1	1.2	1.0	-0.4
- Oil products	27185	18185	19314	17856	1073	-1076	-5836	-9550	-15159	-3.4	-25.1		
Natural gas	135121	145288	192531	257366	292834	328261	351250	361451	363741	3.6	4.3	1.8	0.4
Electricity	3323	1508	1686	971	99	-613	-1684	-1781	-1867	-6.6	-24.7		
Gross Inland Consumption	**1680168**	**1662517**	**1723099**	**1826889**	**1764488**	**1806307**	**1822167**	**1817870**	**1807228**	**0.4**	**0.2**	**0.3**	**-0.1**
Solids	452940	364248	321007	319922	284781	289033	287278	275504	259935	-3.4	-1.2	0.1	-1.0
Oil	631058	650858	658727	676859	631793	638720	627180	606313	578976	0.4	-0.4	-0.1	-0.8
Natural gas	294905	333268	393417	445998	456978	457327	462688	453423	439245	2.9	1.5	0.1	-0.5
Nuclear	202589	223028	243761	257360	238990	241310	237685	247463	268042	1.9	-0.2	-0.1	1.2
Electricity	3323	1508	1686	971	99	-613	-1684	-1781	-1867	-6.6	-24.7		
Renewable energy forms	75343	89606	104501	124880	151825	179530	209011	236749	262896	3.3	3.8	3.2	2.3
as % in Gross Inland Consumption													
Solids	27.3	21.9	18.6	17.5	16.1	16.0	15.8	15.2	14.4				
Oil	38.0	39.1	38.2	37.1	35.8	35.4	34.4	33.4	32.0				
Natural gas	17.8	20.0	22.8	24.4	25.9	25.3	25.4	24.9	24.3				
Nuclear	12.2	13.4	14.1	14.1	13.5	13.4	13.0	13.6	14.8				
Renewable energy forms	4.5	5.4	6.1	6.8	8.6	9.9	11.5	13.0	14.5				
Gross Electricity Generation in GWh_e	**2582823**	**2712209**	**2981720**	**3274121**	**3311797**	**3563832**	**3786426**	**4012817**	**4191841**	**1.8**	**1.0**	**1.4**	**1.0**
Self consumption and grid losses	358053	383048	408040	429777	397688	423813	459082	508456	559012	1.3	-0.3	1.4	2.0
Fuel Inputs for Thermal Power Generation	**383482**	**382334**	**382813**	**424208**	**412202**	**424846**	**438317**	**438371**	**421060**	**0.0**	**0.7**	**0.8**	**-0.4**
Solids	263837	230040	223012	229245	215200	220489	217961	207758	195041	-1.7	-0.4	0.1	-1.1
Oil (including refinery gas)	54404	51463	39294	29780	14439	15668	15338	14881	11627	-3.2	-9.5	0.6	-2.7
Gas	56754	67806	102408	134637	143087	142250	151161	149621	137481	6.1	3.4	0.6	-0.9
Biomass & Waste	5724	10033	14960	25901	34378	41212	47833	54980	60675	10.1	8.7	3.4	2.4
Geothermal heat	2774	2992	2939	4645	5098	5227	6024	9131	16226	0.6	5.7	1.7	10.4
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0				
Fuel Input in other transformation proc.	**838073**	**814864**	**827088**	**842976**	**782479**	**806731**	**803472**	**786038**	**781688**	**-0.1**	**-0.4**	**0.1**	**-0.5**
Refineries	679426	705954	735244	758152	715356	727057	719440	701980	680140	0.8	-0.3	0.1	-0.6
Biofuels and hydrogen production	2	202	610	3129	11802	17450	22015	24357	25886	79.6	34.5	6.4	1.6
District heating	32960	23240	19323	16212	17469	16126	16308	15050	14118	-5.2	-1.0	-0.7	-1.4
Others	126685	85258	71921	65482	47853	46097	45710	43651	41543	-5.5	-4.0	-0.5	-1.0
Energy Branch Consumption	**82379**	**88896**	**88176**	**98033**	**92143**	**90907**	**90860**	**90911**	**90395**	**0.7**	**0.4**	**-0.1**	**-0.1**
Non-Energy Uses	**97931**	**110641**	**112485**	**117477**	**111384**	**114987**	**117036**	**117712**	**118706**	**1.4**	**-0.1**	**0.5**	**0.1**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173678**	**1168688**	**1210934**	**1229094**	**1228680**	**1216372**	**0.4**	**0.5**	**0.5**	**-0.1**
by sector													
Industry	365650	328513	326949	326308	312835	322764	332858	338776	344251	-1.1	-0.4	0.6	0.3
- energy intensive industries	234722	214526	213112	210991	193474	196112	199186	198981	199197	-1.0	-1.0	0.3	0.0
- other industrial sectors	130928	113987	113837	115317	119361	126652	133672	139796	145053	-1.4	0.5	1.1	0.8
Residential	264307	280418	286784	308104	309162	317167	316393	312180	308327	0.8	0.8	0.2	-0.3
Tertiary	158484	160442	159866	176859	176247	182813	184951	185570	184652	0.1	1.0	0.5	0.0
Transport	280269	300617	339389	362405	370345	388190	394892	390035	379143	1.9	0.9	0.6	-0.4
by fuel													
Solids	125031	84977	61454	54486	43786	43604	44549	43790	41747	-6.9	-3.3	0.2	-0.6
Oil	444429	456959	478880	495857	475706	482351	474707	459585	440902	0.7	-0.1	0.0	-0.7
Gas	227902	245996	265552	283524	284203	285314	279405	269861	264868	1.5	0.7	-0.2	-0.5
Electricity	184145	193367	216403	237537	241167	260056	276708	291201	302437	1.6	1.1	1.4	0.9
Heat (from CHP and District Heating) [A]	48610	44616	40061	44441	59596	66270	71982	75208	77637	-1.9	4.1	1.9	0.8
Renewable energy forms	38592	44073	50639	57830	64103	73290	81679	86850	88719	2.8	2.4	2.5	0.8
Other	0	0	0	0	27	48	64	65	64			9.2	-0.1
RES in Gross Final Energy Consumption [B]			**87370**	**104826**	**131767**	**169868**	**187413**	**212017**	**231888**		**4.2**	**3.8**	**2.2**
TOTAL GHGs Emissions (Mt of CO_2 eq.)	**5632.3**		**5063.6**	**5129.8**	**4823.4**	**4833.1**	**4764.0**	**4683.1**	**4226.4**	**-0.9**	**-0.6**	**-0.1**	**-1.2**
of which ETS sectors GHGs emissions				2438.2	2166.5	2176.8	2168.5	2038.9	1780.5			0.0	-2.0
CO_2 Emissions (energy related)	**4030.8**	**3800.1**	**3810.8**	**3948.8**	**3728.4**	**3769.1**	**3892.0**	**3488.2**	**3161.8**	**-0.8**	**-0.2**	**-0.1**	**-1.8**
Power generation/District heating	1484.3	1321.2	1320.8	1381.1	1292.7	1311.8	1285.1	1159.9	911.3	-1.2	-0.2	-0.1	-3.4
Energy Branch	152.2	171.0	170.2	181.6	158.2	148.5	141.5	132.7	123.4	1.1	-0.7	-1.1	-1.4
Industry	781.4	678.1	623.0	581.9	492.4	488.0	488.2	475.9	468.0	-2.2	-2.3	-0.1	-0.4
Residential	499.4	481.6	466.2	486.7	481.0	476.7	450.9	425.6	406.1	-0.7	0.3	-0.6	-1.0
Tertiary	300.5	275.3	242.0	262.2	253.4	246.8	233.5	221.8	212.2	-2.1	0.5	-0.8	-1.0
Transport	812.7	872.9	988.5	1053.1	1050.6	1087.2	1092.8	1070.4	1030.8	2.0	0.6	0.4	-0.6
CO_2 Emissions (non energy related)	**329.6**	**306.8**	**299.3**	**304.6**	**279.6**	**291.1**	**306.0**	**314.6**	**318.2**	**-1.0**	**-0.7**	**0.9**	**0.4**
Non-CO_2 GHGs Emissions	**1172.1**		**953.7**	**878.5**	**815.4**	**782.9**	**798.1**	**782.2**	**766.4**	**-2.0**	**-1.6**	**-0.8**	**-0.1**
TOTAL GHGs Emissions Index (1990=100)	**100.0**		**91.5**	**82.7**	**87.2**	**87.4**	**88.1**	**82.6**	**78.4**				

Source: PRIMES

Table 27 EU Energy Trend to 2030; Example of data available in [28]

SUMMARY ENERGY BALANCE AND INDICATORS (B)										EU27: Baseline 2009			
	1990	1995	2000	2005	2010	2015	2020	2025	2030	'90-'00	'00-'10	'10-'20	'20-'30
										Annual % Change			
Main Energy System Indicators													
Population (Million)	470.388	477.010	481.072	489.211	499.389	507.727	513.838	517.811	519.942	0.2	0.4	0.3	0.1
GDP (in 000 MEuro'05)	8142.7	8748.4	10107.2	11063.1	11385.6	12750.3	14164.0	15503.7	16824.7	2.2	1.2	2.2	1.7
Gross Inl. Cons./GDP (toe/MEuro'05)	203.9	190.0	170.5	165.1	155.0	141.6	128.6	117.2	107.4	-1.8	-0.9	-1.8	-1.8
Carbon intensity (t of CO_2/toe of GIC)	2.43	2.29	2.21	2.16	2.11	2.08	2.03	1.92	1.74	-0.9	-0.5	-0.4	-1.5
Import Dependency %	44.6	43.5	46.8	52.5	54.7	58.3	60.5	60.4	59.1				
Total Energy-related Costs (*) (in 000 M€05)			994.8	1160.9	1214.0	1409.7	1687.2	1871.2	1934.4		2.0	3.3	1.4
as % of GDP			9.8	10.5	10.7	11.1	11.9	12.1	11.5				
Energy intensity indicators													
Industry (Energy on Value added)	130.3	115.2	100.0	95.1	90.4	84.5	79.0	73.9	69.8	-2.6	-1.0	-1.3	-1.2
Residential (Energy on Private Income)	114.4	113.2	100.0	97.5	97.2	88.6	80.0	72.9	66.8	-1.3	-0.3	-1.9	-1.8
Tertiary (Energy on Value added)	126.5	117.0	100.0	99.4	95.3	87.5	79.4	72.4	66.1	-2.3	-0.5	-1.8	-1.8
Passenger transport (toe/Mpkm)	39.6	39.5	40.3	39.5	38.0	35.4	33.6	31.1	28.4	0.2	-0.6	-1.2	-1.7
Freight transport (toe/Mtkm)	47.1	46.8	46.3	46.5	46.1	45.8	44.3	42.6	40.3	-0.2	-0.1	-0.4	-0.9
Carbon Intensity indicators													
Electricity and Steam production (t of CO_2/MWh)	0.46	0.40	0.37	0.35	0.31	0.29	0.27	0.23	0.17	-2.1	-1.9	-1.5	-4.2
Final energy demand (t of CO_2/toe)	2.24	2.16	2.08	2.03	1.95	1.90	1.84	1.79	1.74	-0.7	-0.7	-0.6	-0.6
Industry	2.14	2.06	1.91	1.78	1.57	1.51	1.47	1.40	1.36	-1.1	-1.9	-0.7	-0.8
Residential	1.89	1.72	1.63	1.58	1.56	1.50	1.43	1.36	1.32	-1.5	-0.4	-0.9	-0.8
Tertiary	1.90	1.72	1.51	1.48	1.44	1.35	1.26	1.20	1.15	-2.2	-0.5	-1.3	-0.9
Transport	2.90	2.90	2.91	2.91	2.84	2.80	2.77	2.74	2.72	0.0	-0.3	-0.2	-0.2
Indicators for renewables (excluding industrial waste) (%) (**)													
RES in gross final energy demand (%)			7.6	8.6	10.9	12.8	14.8	16.7	18.4				
RES in transport (%)			0.5	1.4	4.2	5.9	7.4	8.4	9.3				
Gross Electricity generation by fuel type (in GWh)			2991720	3274121	3311797	3553832	3795426	4012917	4191941		1.0	1.4	1.0
Nuclear energy			944823	997519	926827	937076	928666	988723	1083694		-0.2	0.0	1.6
Coal and lignite			944939	980774	890887	935613	946907	935050	931460		-0.6	0.6	-0.2
Petroleum products			169709	133406	67162	72349	69690	63637	49457		-8.9	0.4	-3.4
Gas (including derived gases)			507154	693902	791522	804857	864690	862066	783674		4.6	0.9	-1.0
Biomass & waste			44772	84256	127487	163885	191352	217775	241293		11.0	4.1	2.3
Hydro			353183	306916	323347	331760	338900	349313	355032		-0.9	0.5	0.5
Wind			22246	70473	161188	269127	399210	520277	643895		21.9	9.5	4.9
Solar, tidal etc.			116	1447	16933	31941	45802	59649	75070		64.6	10.5	5.1
Geothermal and other renewables			4778	5427	6445	7225	10209	16427	28365		3.0	4.7	10.8
Net Generation Capacity in MW_e			654126	715734	816096	901048	944473	1011270	1098178		2.2	1.6	1.6
Nuclear energy			133923	134409	127038	126752	123566	122895	134278		-0.5	-0.3	0.8
Renewable energy			112878	147262	206951	265009	326186	384504	443051		6.2	4.7	3.1
Hydro (pumping excluded)			99714	104505	107334	110498	113356	114943	116323		0.7	0.5	0.3
Wind			12793	40584	84096	126192	172303	216847	260783		20.7	7.4	4.2
Solar			371	2172	15272	27744	38885	49721	61073		45.0	9.8	4.6
Other renewables (tidal etc.)			0	1	249	575	1642	2993	4873			20.8	11.5
Thermal power			407324	434063	482106	509286	494720	503870	520849		1.7	0.3	0.5
of which cogeneration units			77070	84892	100061	110539	114967	122882	125821		2.6	1.4	0.9
of which CCS units			0	0	0	0	5394	13967	35253				20.6
Solids fired			194165	186620	183740	182938	165993	154522	165236		-0.6	-1.0	0.0
Gas fired			129444	167173	217761	249765	250328	266936	269382		5.3	1.4	0.7
Oil fired			71058	62082	55837	45963	41813	38933	35750		-2.4	-2.9	-1.6
Biomass-waste fired			12051	17502	24041	29882	35767	42262	48322		7.1	4.1	3.1
Fuel Cells			0	0	0	0	0	0	0				
Geothermal heat			605	686	727	738	820	1216	2158		1.9	1.2	10.2
Load factor for net electric capacities (%)			49.1	49.1	44.1	42.9	43.7	42.9	41.0				
Efficiency for thermal electricity production (%)			37.6	38.5	39.3	40.1	40.8	41.2	41.4				
CHP indicator (% of electricity from CHP)			11.4	11.7	15.1	17.4	17.6	17.9	17.5				
CCS indicator (% of electricity from CCS)			0.0	0.0	0.0	0.0	1.4	3.7	8.7				
Non fossil fuels in electricity generation (%)			45.8	44.8	47.2	49.0	50.4	53.6	57.9				
- nuclear			31.6	30.5	28.0	26.4	24.5	24.6	25.9				
- renewable energy forms and industrial waste			14.2	14.3	19.2	22.6	26.0	29.0	32.1				
Transport sector													
Passenger transport activity (Gpkm)	4880.7	5317.7	5892.2	6240.3	6511.3	7138.1	7598.9	8018.2	8424.4	1.9	1.0	1.6	1.0
Public road transport	544.0	504.0	517.6	526.0	545.0	574.9	602.2	624.6	643.0	-0.5	0.5	1.0	0.7
Private cars and motorcycles	3501.1	3986.3	4428.1	4686.5	4866.1	5300.8	5576.3	5809.6	6041.2	2.4	0.9	1.4	0.8
Rail	472.5	421.7	447.9	461.0	482.5	522.5	563.9	603.9	641.7	-0.5	0.7	1.6	1.3
Aviation	317.3	361.3	456.9	527.3	576.9	696.6	812.7	935.0	1052.1	3.7	2.4	3.5	2.6
Inland navigation	45.8	44.4	41.7	39.5	40.8	42.4	43.8	45.1	46.3	-0.9	-0.2	0.7	0.6
Freight transport activity (Gtkm)	1848.4	1942.4	2195.7	2494.6	2662.8	2965.0	3149.5	3311.4	3460.1	1.7	1.9	1.7	0.9
Trucks	1060.4	1288.7	1518.7	1800.3	1940.3	2178.6	2308.6	2426.1	2538.2	3.7	2.5	1.8	1.0
Rail	526.3	386.1	403.7	414.1	440.5	487.9	525.2	554.6	579.0	-2.6	0.9	1.8	1.0
Inland navigation	261.6	267.6	273.3	280.2	281.9	298.6	315.7	330.7	342.9	0.4	0.3	1.1	0.8
Energy demand in transport (ktoe)	280269	300617	339389	362405	370346	388190	394882	390036	379143	1.9	0.9	0.6	-0.4
Public road transport	5197	4732	4914	5039	5179	5318	5306	5215	5086	-0.6	0.5	0.2	-0.4
Private cars and motorcycles	154395	166321	182974	187736	186470	185222	182702	174691	164762	1.7	0.2	-0.2	-1.0
Trucks	74969	79037	90951	105104	111593	123875	127520	129191	128901	2.0	2.1	1.3	0.1
Rail	9560	9452	9600	9436	9653	10185	10056	9698	8523	0.0	0.1	0.4	-1.6
Aviation	29038	34112	45395	49703	51984	57901	63353	65037	65485	4.6	1.4	2.0	0.3
Inland navigation	7110	6963	5555	5386	5466	5688	5964	6203	6385	-2.4	-0.2	0.9	0.7

Source: *PRIMES*

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