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Forecast of useful energy for the TIMES-Norway model

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Summary

A regional forecast of useful energy demand in seven Norwegian regions is calculated based on an earlier work with a national forecast. This forecast will be input to the energy system model TIMES-Norway and analyses will result in forecasts of energy use of different energy carriers with varying external conditions (not included in this report).

The forecast presented here describes the methodology used and the resulting forecast of useful energy. It is based on information of the long-term development of the economy by the Ministry of Finance, projections of population growths from Statistics Norway and several other studies. The definition of a forecast of useful energy demand is not absolute, but depends on the purpose. One has to be careful not to include parts that are a part of the energy system model, such as energy efficiency measures. In the forecast presented here the influence of new building regulations and the prohibition of production of incandescent light bulbs in EU etc. are included. Other energy efficiency measures such as energy management, heat pumps, tightening of leaks etc. are modelled as technologies to invest in and are included in the TIMES-Norway model. The elasticity between different energy carriers are handled by the TIMES-Norway model and some elasticity is also included as the possibility to invest in energy efficiency measures.

The forecast results in an increase of the total useful energy from 2006 to 2050 by 18 %. The growth is expected to be highest in the regions South and East. The industry remains at a constant level in the base case and increased or reduced energy demand is analysed as different scenarios with the TIMES-Norway model. The most important driver is the population growth. Together with the assumptions made it results in increased useful energy demand in the household and service sectors of 25 % and 57 % respectively.

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Contents

1 Introduction

A Norwegian TIMES model has been developed by Institute for Energy Technology (IFE) on commission of the Norwegian Water Resources and Energy Directorate (NVE). The first version of the model had a time horizon until 2010 [1] and it was later extended to 2020. This model had a constant demand of energy services. The TIMES-Norway model is now further developed, including an extension of the time horizon to 2050. It is thus necessary to make a forecast of the demand of energy services in each sub-sector in every region until 2050.

Analyses of future energy demand in Norway as a total was done in 2009 on commission of Enova [2]. The energy system model used in this work was the MARKAL Norway, with Norway as one region. Based on that work, a forecast of useful energy demand in the seven regions of TIMES-Norway is done. The work has been financial supported by Enova and is part of the research project "The future Norwegian energy system in a European context" funded by the Research Council of Norway.

The methodology used in each sector is presented in chapter 2 and the resulting forecast of useful energy demand is presented in chapter 3. Finally a discussion and a short description of further work are included in chapter 0. The TIMES-Norway model is described in Appendix 1.

2 Methodology

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, see description in Appendix 1. 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 forecast described here are therefore mainly useful energy for different energy services such as heat and non-substitutable electricity.

2.1 Industry

Historical energy use in 14 industrial sub-sectors, back to 1980, has been analysed together with the development in value added, production index and, in the cases where it has been possible, also the production volumes in tonnes. Different energy indicators are calculated such as:

$$SEC = \frac{E_{useful}}{P} \qquad (1)$$

$$E_I = \frac{E_{useful}}{VA} \tag{2}$$

$$E_{PI} = \frac{E_{useful}}{PI} \tag{3}$$

Where:

SEC = Specific energy consumption (GWh/tonne)
E_{useful} = useful energy (GWh)
P = production volume (tonne)
E_I = Energy intensity
VA = value added (MNOK)
E_{PI} = Energy intensity corrected for production index
PI = production index

When forecasting energy demand, both the development in the activity, for instance production volumes, and the development of the energy indicators has to be considered. A reduction of the energy indicator may be caused by e.g. more energy efficiency in the sector, technology change or by change in product mix. An increase may in the opposite way indicate a less energy efficient production or changes to products or processes that are more energy consuming. Knowledge of the industries analysed, is necessary to explain the development of energy indicators and estimating the future development in each sub-sector. The energy consumption is based on the energy balances [3]. Energy use and activity figures are collected in a database, used in the Odyssee-project [4].

The forecasting method used is a bottom-up approach, where the industry is divided in 14 sub-sectors. Three different forecasting methods were used, depending on the historical development. The main method is to use the best energy indicator in each sub-sector together with a projection of the activity in order to estimate the future energy demand.

Method I:

$$E_t = I_0 * P_t \tag{4}$$

Where:

E_t = energy demand in year t (GWh)
I_0 = Energy intensity in base year (GWh/tonne or GWh/PI)
P_t = production volume or production index in year t

In sectors where useful energy has a clear trend in the past, whereas the energy indicators do not, the annual change in energy consumption is used in forecasting the energy demand.

Method II:

$$E_t = E_0 * \Delta E_{historical} * \Delta t \tag{5}$$

Where:

E_t = energy demand in year t (GWh)
E_0 = energy demand in base year (GWh)
$\Delta E_{historical}$ = historical change rate
Δt = number of years

Some industrial sectors consist of rather few, large production facilities with a high energy consumption. In these sectors, the knowledge of past and future production measures plays an important role in forecasting the energy demand, together with the analysis of energy indicators and activity level.

Method III:

$$E_t = I_0 * P_t + E_{expected\ expansions} - E_{expected\ close\ down} \quad (6)$$

Where:
E_t = energy demand in year t (GWh)
I_0 = Energy intensity in base year (GWh/tonne or GWh/PI)
P_t = production volume or production index in year t
$E_{expected\ expansions}$ = energy demand due to industry expansions (GWh)
$E_{expected\ close\ down}$ = energy demand due to industry close downs (GWh)

The demand forecast is calculated as useful energy (E_{useful}), since the composition of different energy carriers affect the final energy use. The energy demand forecast is divided into electricity used for specific electrical use, such as motors, and thermal/process energy. Useful energy is calculated with the efficiencies used in the energy balance [3].

2.2 Households and services

The method used for the household and services sectors is mainly a modification of method I:

$$E_t = I_0 * \Delta I * A_0 * \Delta A \quad (7)$$

Where:
E_t = energy demand in year t (GWh)
I_0 = Energy intensity in base year (kWh/household, kWh/m^2 , kWh/capita etc.)
ΔI = change in energy intensity
A_0 = activity in base year (number of households, m^2 , persons etc.)
ΔA = development in activity

The geographical distribution in seven regions is based on the calculations of the base year distribution from the development of the short-time model [1], the forecast of Norway until 2050 as described in [2] and projections of population by Statistics Norway [5]. The connection between the different sources is presented in Figure 1. The calculations of the national forecast is further described in section 3.2.

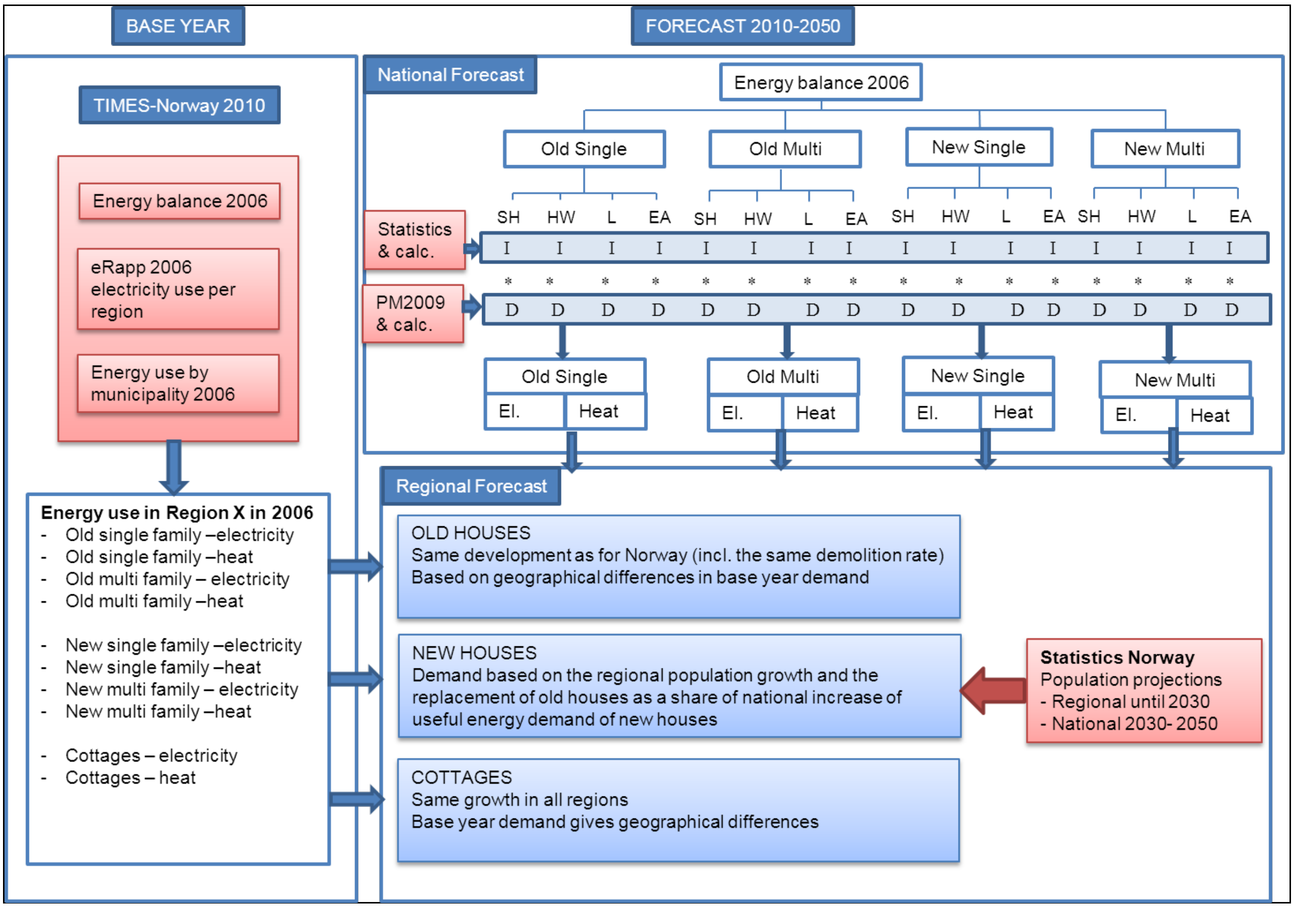

Figure 1 Principal overview of forecast methodology in the household sector; SH=Space Heating, HW=Hot Water, L=Lighting, EA=Electrical Appliances, I=Indicator, D=driver, PM2009 = "Perspektivmeldingen 2009"

2.3 Transportation

The forecast of the demand of transportation is mainly based on the National Plan of Transportation [6]. The increase of different transportation modes of this plan is used to project the future demand of transportation in the TIMES Norway model.

3 Resulting forecast of useful energy demand

3.1 Industry

3.1.1 Forecasting with method I

In the food industry (incl. production of beverage and tobacco) the energy consumption was 4.1 TWh in 2007, which is about the same as in 1992. The energy use and the production index follows the same trend, resulting in rather constant energy intensity measured as energy per production index, see Figure 2. The indicator is assumed to be constant while the development in the production index continuous to drop with the same rate as for the past ten years. This results in a decrease of the energy demand of food industry of 15 % in 2050.

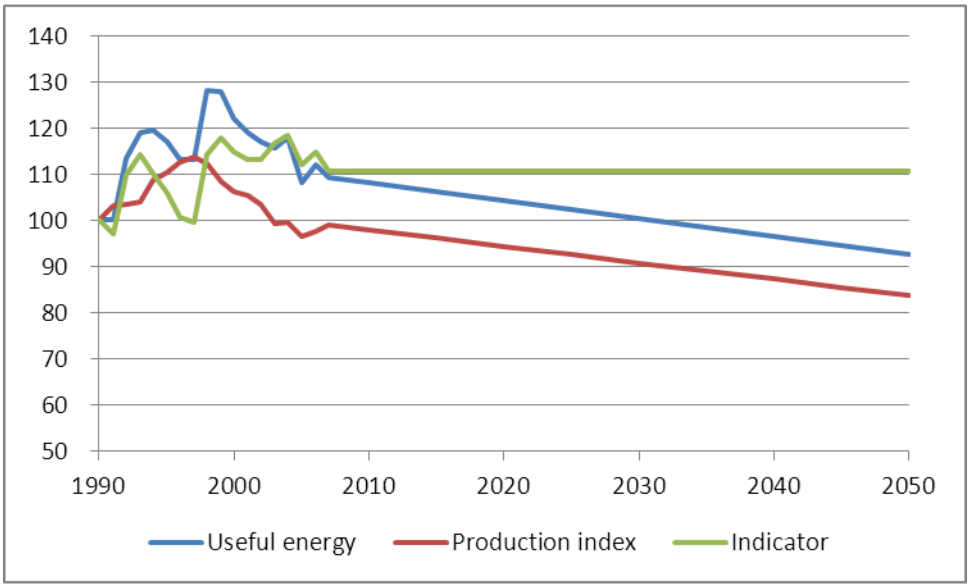

Figure 2 Useful energy, production index and energy indicator in food industry 1990-2050

In 1998 the production of fishmeal, fish oil and animal food increased considerably, but this had little influence on the production index, resulting in a sharp increase in the energy intensity. Such increases in production of energy intensive products, is poorly intercepted in the analysis of energy indicators on a sector level, therefore insight within the sector's processes and products is needed. For the food industry as a whole, the trend is towards more import of products and less domestic production.

Production of non-metallic minerals had an energy use of 4.4 TWh in 2007. Since 1997 the trend of energy use and production index is almost the same, resulting in rather constant energy indicator EPI. The indicator is assumed to be maintained at the same level, while the slight increase in activity continues, resulting in an increased energy use of 6 % by 2050.

Several industrial sectors have a relatively low share of the total energy consumption and the energy indicator has been rather constant over the last decade. These sectors are assumed to maintain their energy demand on the same level as today, with a constant indicator and an activity level based on historical development. The sectors where this forecasting method is applied are mineral mining, textile and leather, wood, printing, rubber and plastics, as well as other industry. The total energy consumption of these sectors was approximately 6 % of total energy consumption in industry in 2007.

3.1.2 Forecasting with method II

Method II is applied to sub-sectors where it is considered as most likely that the trend of energy consumption continues at the same rate as previous and where the development of the driver and indicator is difficult to project. This is the case of fabricated metals industry where the production index has increased considerable while the energy use has been almost constant after 1995, see Figure 3.

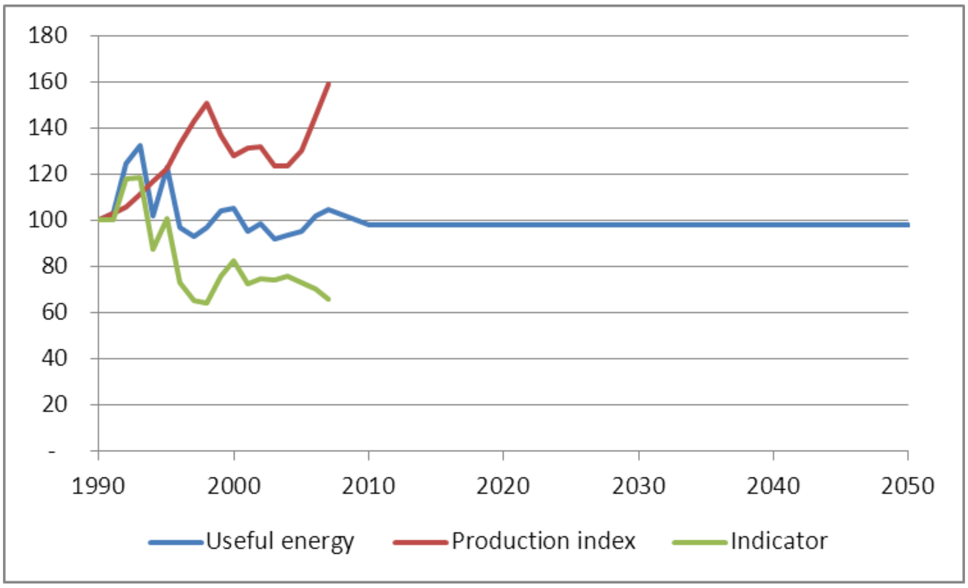

Figure 3 Useful energy, production index and energy indicator of fabricated metal industry 1990-2050

3.1.3 Forecasting with method III

In method III individual plants are evaluated and this method is used for the energy intensive industries. The production of aluminium is used as an example of the methodology.

There are seven plants producing aluminium in Norway and they consumed 23 TWh energy in 2006, of which 22 TWh was electricity. The specific energy consumption (kWh/tonne Al) has decreased by 22% from 1980 to 2004.

In the aluminium industry there has been a technological change from the old Søderberg-technology to the more efficient pre-baked technology. In 2001, 40% of the production was based on the Søderberg-technology, but this share is reduced due to shut down of some production and substituting it by pre-baked technology. After 2006 only two production sites remain based on Søderberg-technology and these have either to be converted to new technology, major improved or shut down by 2013 due to environmental restrictions. In 2002 the Søderberg plant at Sunndalsøra was closed and replaced by a new pre-baked plant in 2004-2005.

In 2004 it was produced 1.4 mill tonnes aluminium in Norway, of which 0.3 mill tonnes were produced with Søderberg-technology. If this production is shutdown, it will result in a reduced energy demand in these plants of approximately 5.4 TWh/year. The industry is continuously working with measures to increase production and this also increases the energy use. Due to this work, it is expected in the base scenario that the production and energy demand will remain on the same level as today even if the plants with Søderberg-technology is closed down, see Figure 4. In a low demand scenario, with low product demand/prices or high electricity prices, one by one of the plants might be shut down and after 2035 only three plants will then remain, see the dotted line in Figure 4.

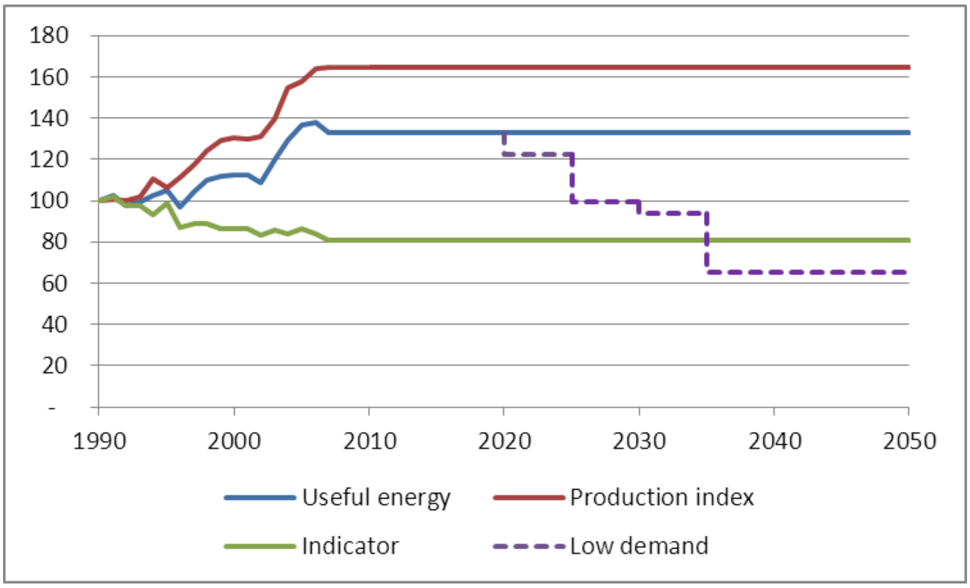

Figure 4 Useful energy, production index and energy indicator in production of aluminium 1990-2050, basic and low demand scenario

The same methodology is used for estimation of future energy demand of the other industry sectors with a high energy use. Since it is very sensitive to close down specific industry plants and in this regional model it will be well known which plants that are suggested to be closed down, this will be treated as scenarios and in the base case the individual plants have a constant energy demand. The effect of the decided close down of known plants after 2006 is included in the calculations.

3.1.4 Summary of the industry sector

The structure of the demand sectors in TIMES-Norway is described in Appendix 1. For each region of TIMES-Norway, the number of plants or groups of plants (marked as “x”) is presented in Table 1. The mining industry includes mineral and petroleum mining onshore, while offshore use of energy is not included, except in the case of electricity from the grid to offshore production platforms in operation in 2006. Refineries only include the use of energy, not use of raw material. The energy use of each plant is confidential data and therefore not presented here, but included in the model. The presence of single plants with high energy use in several of the regions makes it sensitive to forecast the energy use. The consequence is often either to close down single plants, to keep the activity at the present level or considerable increase the activity. In all cases the forecast is strongly connected to the future of single plants and this makes it political sensitive. Therefore the base case is based on a constant energy demand of the individual modelled plants and close down/increases are handled in scenarios.

The energy use in the base year is based on information from Statistics Norway (Energy balance [3] and energy use by municipality [7]), information on electricity use by region and in some cases by plant from NVE [8] and on use of other energy carriers than electricity of companies from the database of the Climate and Pollution Agency [9].

Table 1 Number of plants or group of plants (x) for each end use category and total energy use per region (TWh in 2006) in TIMES-Norway

Region	South	Central	West	East	Middle	North	Finnmark	Norway
Al plants	1		4		1	1		7
Al rest	X		X		X	X		X
Chemical plants		1	1		1			3
Chemical rest	3	5		2	6	2		18
Metal plants	2		2			1		5
Metal rest		1	3			2		6
Mining	X	X	2	X	X	X	X	X
Pulp & paper plants				4	1			5
Pulp & paper rest	2	3		8	2			15
Refineries		1	1					2
Other industry	X	X	X	X	X	X	X	X
Total (TWh)	6	14	28	11	12	7	0.2	78

The forecast of each industry sub-sector on a national level as it was calculated in [2] is presented in Figure 5. It resulted in a minor decrease of 6 % of the industry sector. When calculating the forecast for each industry subsector in each region of TIMES Norway, the knowledge of individual plants is used as far as possible. The other industry is assumed to have the same development in all regions, being a weighted average of the included subsectors of the previous study, calculated to – 4%. Due to confidentiality, the forecast cannot be presented for each subsector in every region, but is summed as the total industry demand of useful energy in each region, see Figure 6 and Table 6.

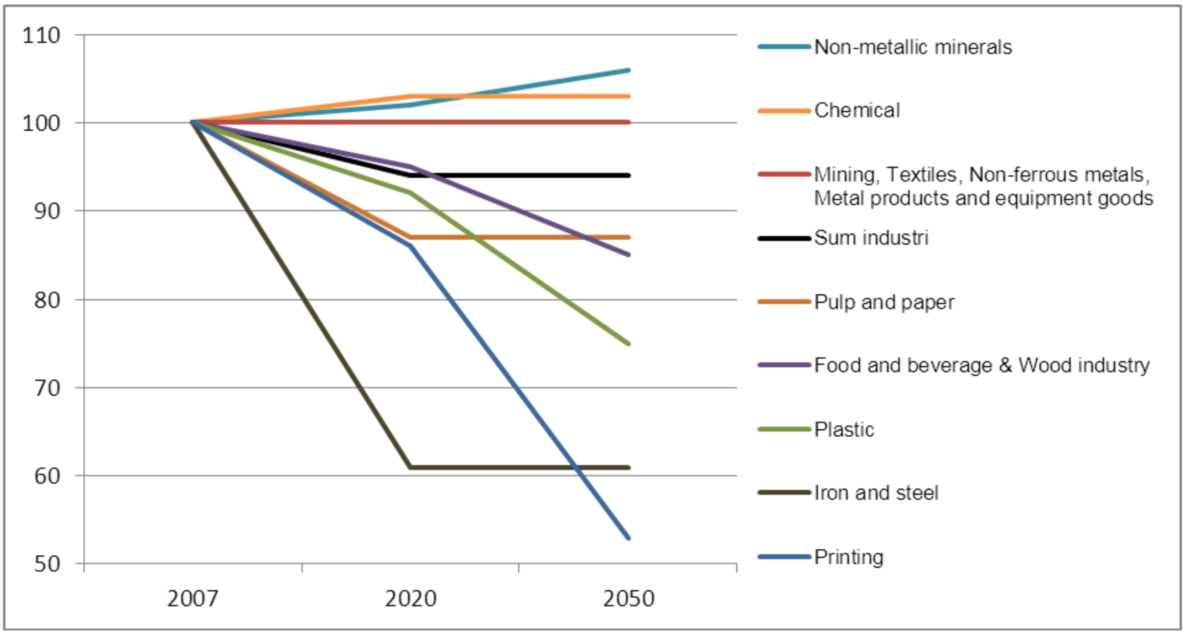

Figure 5 Forecast for each industry sector in Norway [2]

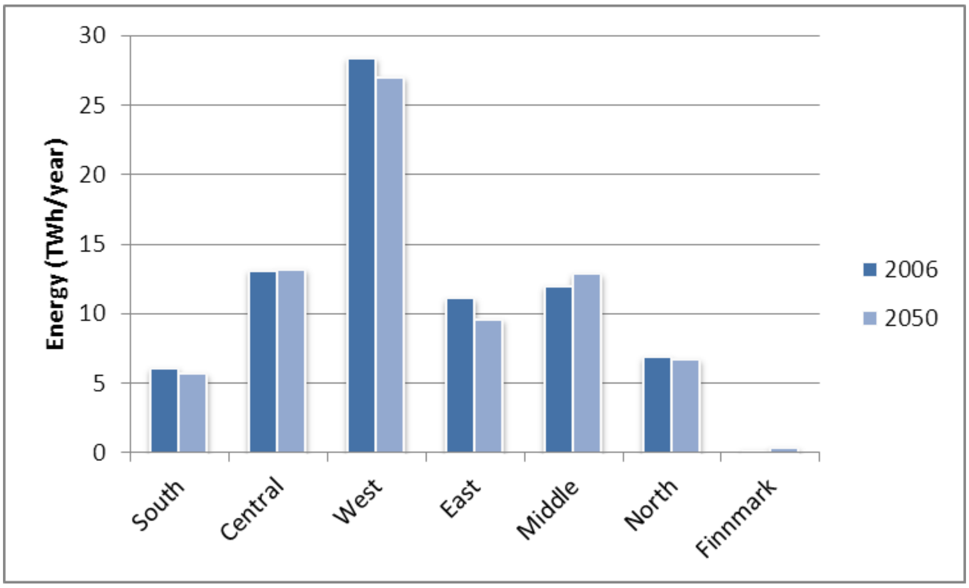

Figure 6 Energy demand in industry by region in 2006 and 2050 (TWh)

3.2 Households

The household sector is divided into four dwelling types; existing (old) single-family houses, existing (old) multi-family houses, new single family houses and new multifamily houses. The definition of "new" is dwellings built after the base year of the model, i.e. 2006.

3.2.1 Drivers in the household sector

The development of the drivers in the household sector is based on statistics of 2005-2007, the white paper "Perspektivmeldingen 2009" of the Department of Finance [10] and several assumptions and calculations. The key figures are presented in Table 2 and discussed below.

Population

The population growth is based on the middle scenario of Statistics Norway (MMMM) resulting in a growth from 4.6 million people in 2005 to 6.5 million people in 2050 in Norway [5], see Figure 7. Statistics Norway also has a forecast per county but it ends in 2030. This county forecast is used for the regional forecast needed in the TIMES-Norway model. The total growth in 2050 in all regions is the same as for the entire country and this growth is distributed to the regions based on the trend for each region from 2020 to 2030. The resulting population growth per region in TIMES-Norway is presented in Figure 8.

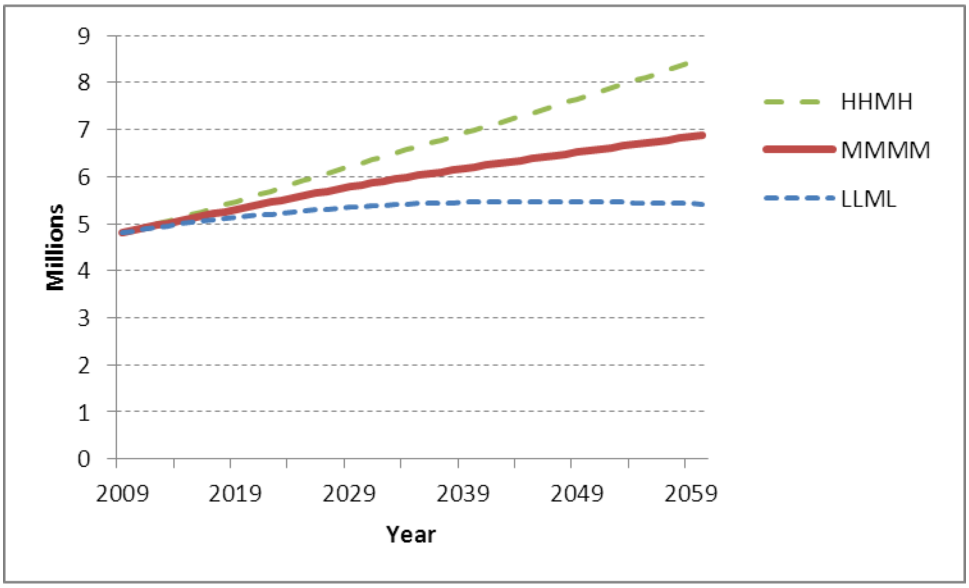

Figure 7 High (HHMH), medium (MMMM) and low (LLML) growth of the main alternatives of population projection of Statistics Norway [5]

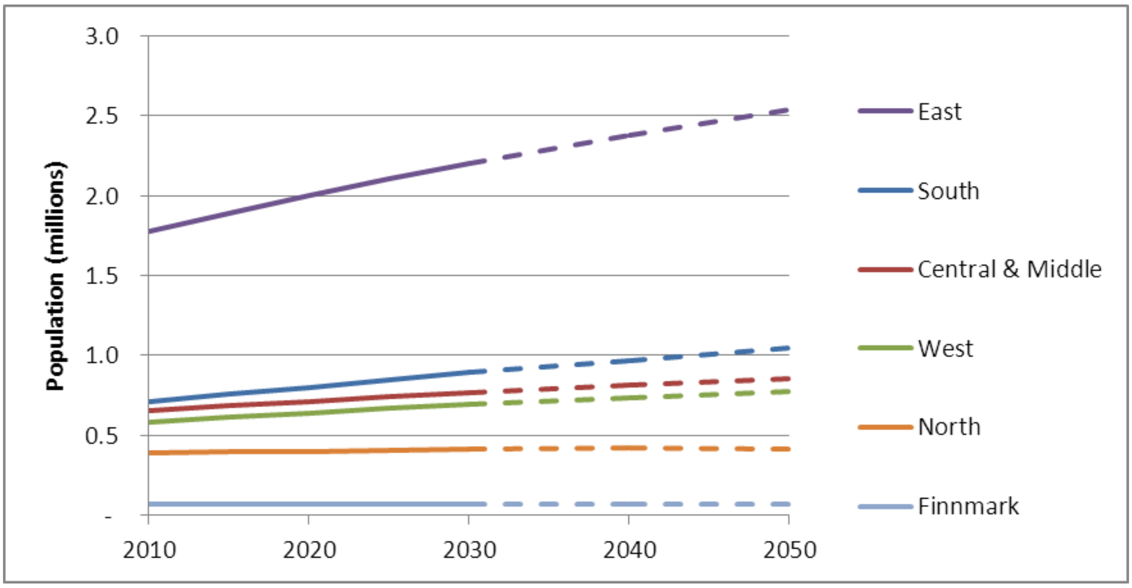

Figure 8 Population growth in the 7 regions of TIMES Norway from 2009 to 2050 (million people)

The most populated area is the region East and the population will increase by 26 % to 2030 according to the projection by Statistics Norway and in 2050 the growth is calculated to 45 % relative to 2009. The growth is highest in region South with 50 % and in the regions North and Finnmark the increase is small, only 7 and 1 % respectively from 2009 to 2050.

Share of dwelling types

Today, 77 % of the Norwegian dwellings are single family houses and 23 % is multi-family houses. The new dwellings of today have a higher share of multifamily houses, 47 %, and it is assumed that this trend will continue. Behind this trend are a concentration of dwellings in the cities and an increasing lack of available areas for new dwellings, resulting in an increase of multifamily houses. It is assumed a share of new multifamily houses of 60 % in the period 2020-2050 in this forecast. The trend is assumed to be the same in all regions, since even if some regions have a smaller population, the same trend of urbanisation is registered all over the country.

Demolition rate

It is assumed that all new dwellings are in use from the day they are built until the end of the model period in 2050. The existing dwellings of 2006 are assumed to have an annual demolition rate of 0.6 % and the rate is assumed to be the same in single family houses as in multifamily houses and in all regions.

Persons per household

In 2005 the number of person per household was 2.29 and in “Perspektivmeldingen 2004” it was assumed to decrease to 1.85 persons per household in 2050 [11]. The development of persons per households is not explicitly expressed in “Perspektiv-meldingen 2009” [12], but the Ministry of Finance assumed it would be the same as in the previous outlook, and hence, the development of “Perspektivmeldingen 2004” is used in this forecast.

Due to the structure of the model and the forecasting method used, figures of number of persons per household of different dwelling types are required. The latest household survey including these figures was based on data of 2001 [13]. The number of persons per single family house can be calculated to 2.5 based on this survey and the number of persons per multifamily house can be calculated to 1.7. It is further assumed that in order to get the overall assumption of 1.85 persons per household, the occupancy of single family houses in 2050 will be 2.1 and of multifamily houses will be 1.5. The occupancy is assumed to be the same in old and new dwellings.

Number of households

The development in number of households is not explicitly expressed in “Perspektiv-meldingen 2009”, but is calculated as a function of the population growth and the assumption of number of persons per household. This results in an increase from 2.0 million households in 2005 to 3.5 million households in 2050. The assumptions of the share of multifamily houses of all new buildings in combination with the demolition rate, results in the number of new/old and multi/single family houses in 2050 presented in Table 2.

Dwelling area

The average dwelling area in 2005 of different types of dwellings are calculated based on data from Statistics Norway [14]. The demolition of existing houses is not assumed to change the average area of existing houses, meaning large and small dwellings are demolished with the same rate, as well as multi and single family houses. The average area of new multi- and single family houses in 2005 were 91 m^2 and 150 m^2 respectively. In 2007 they were 93 m^2 and 155 m^2 respectively, and new households are assumed to have the same average area until 2050.

This results in a total area of households of 228 million m^2 in 2005 and 412 million m^2 in 2050. Of the household area in 2050, 57 % of the area will be constructed after 2005 and 43 % of the area will be in multifamily houses.

Table 2 Key figures of the household sector

	Year	TOTAL	OLD Multi	OLD Single	NEW Multi	NEW Single
Population, k	2005	**4 606**				
	2050	6 548				
Share of house type (number of households)	2005		**23%**	**77%**	**47%**	**53%**
	2050		**23%**	**77%**	60%	40%
Demolition rate, annual			0.6%	0.6%	0%	0%
Number of households						
Persons/household	2005	**2.29**	1.67	2.48	1.67	2.48
	2050	1.85	1.50	2.11	1.50	2.11
Total number, k	2005	**2 011**	**463**	**1 548**	**-**	**-**
	2050	3 539	353	1 181	1 162	843
Household area						
m^2/household	2005	114	73	126	91	150
	2050	117	73	126	93	155
Total area, mill. m^2	2005	228	34	194	-	-
	2050	412	26	148	108	130

Key to Table 2

Statistics
Perspektivmeldingen
Assumptions
Calculations

3.2.2 Indicators in the household sector

The energy use in households is divided into four end uses; space heating, hot water, lighting and electrical appliances. The share of each end use in the base year is based on information from The Norwegian Water and Energy Directorate [15] and is presented in Figure 9.

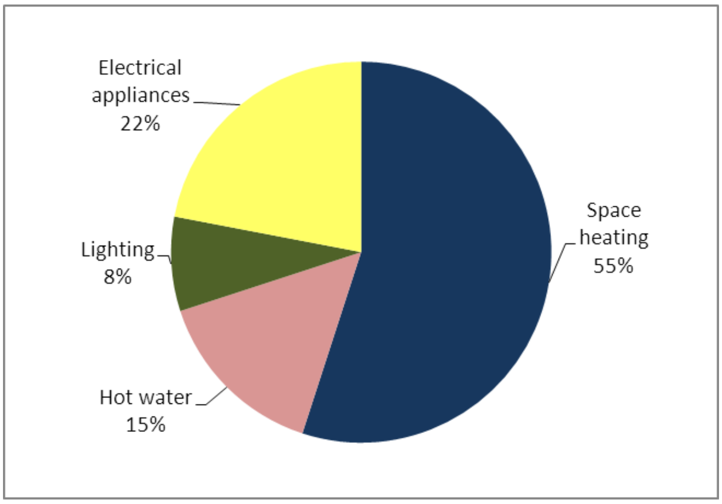

Figure 9 Share of residential end use in the base year [15]

For each of the end uses, a driver is selected, see Table 4. The development in drivers is mainly based on “Perspektivmeldingen 2009” [12]. When the driver is selected, the indicator of the base year is calculated based on statistics, calculations and assumptions defined in Table 2. The development of the indicators are described below and summarised in Table 3.

Space heating

The temperature adjusted useful energy in households was 44.2 TWh in 2005. Assuming 55% for space heating gives a total of 24.3 TWh for space heating. According to Statistics Norway, multifamily houses used 167 kWh useful energy per m² in 2006 [16]. The temperature adjusted useful energy for space heating of multifamily houses in 2006 would then be 100 kWh/m². With a total area of multifamily houses of 34 million m², a total of 3.4 TWh was used for space heating in multifamily houses in 2006. Single family houses then have to use 20.9 TWh if the total is 24.3 TWh, corresponding to 108 kWh/m². The specific energy use in existing houses is assumed to be constant until 2050.

Specific use of useful energy in new houses are calculated based on the building regulations of 2007, see Table 3. The energy efficiency is assumed to increase by 1 % per year, due to new building regulations.

Increased temperature due to climate changes will according to a Norwegian study result in a decrease in energy for space heating by 15 % [17]. The effect of climate change varies along the country, but for simplicity the same reduction is used in all regions. This is not included in the base case scenario, but analysed as a separate scenario.

Table 3 Key figures behind the development of indicators in the household sector

	Year	TOTAL	OLD		NEW	
			Multi	Single	Multi	Single
Space heating kWh/m²	2005	106	100	108	66	74
	2050	71	100	108	42	47
with climate change, kWh/m²	2005	106	100	108	66	74
	2050	60	85	92	36	40

Hot water

The energy use for hot water is assumed to be constant per capita and the useful energy for hot water production will increase from 6.6 TWh in 2005 to 9.4 TWh in 2050 due to the increase in population.

Electrical appliances

The energy use for electrical appliances is affected by e.g. the efficiency of the appliances, the number of appliances and the time of use. The efficiency has been improved lately, but at the same time the number of electrical appliances has increased. It is therefore assumed, that in total the energy use for electrical appliances per capita will remain at the same level as today based on a continued improvement of the efficiency and an increased use of electrical appliances. The growth in population will then result in an increase of useful energy for electrical appliances from 9.8 TWh in 2005 to 13.8 TWh in 2050.

Lighting

The indicator used for lighting is kWh/household and it is assumed to decrease linearly by 30% to 2020 and by 60% to 2030. The reason for the assumption is the prohibition of production of incandescent light bulbs in EU from 2009-2012 and increased efficiencies of other lighting from 2013/2016. If an incandescent light bulb is replaced by CFL or LED, the electricity use will be 80% less. Since more energy efficient lighting already has replaced some incandescent light bulbs, and also other factors such as number of bulbs and operational time, influence the energy use, it is assumed a saving by 60 % in 2030. After 2030 the indicator is assumed to be constant.

Less use of electricity for lighting will also affect the demand of energy for space heating, since it during part of the year make a contribution. This is however not included in the calculations. To illustrate the magnitude of this omission, the decrease in electricity for lighting in 2050 is approximately 2.6 TWh. If half of this is assumed to be contributing to the demand for space heating, it will be approximately 1.3 TWh in 2050 (2 % of total useful energy in 2050).

Table 4 Selected drivers and indicators in the households and their development, and the resulting energy use in 2005 and 2050

	Space heating	**Hot water**	**Electrical appliances**	**Lighting**
Driver	**Households**	**Population**	**Population**	**Households**
2005	2.0 mill.	4.6 mill.	4.6 mill.	2.0 mill.
2050	3.5 mill.	6.5 mill.	6.5 mill.	3.5 mill.
annual growth	1.7%	0.93%	0.93%	1.7%
total growth	76 %	42 %	42 %	76 %
Indicator	**kWh/household**	**kWh/capita**	**kWh/capita**	**kWh/household**
2005	12 089	1 439	2 111	1 758
2050	8 251	1 439	2 111	703
total change	-32%	0%	0%	-60%
Energy use	**TWh/year**	**TWh/year**	**TWh/year**	**TWh/year**
2005	24.3	6.6	9.7	3.5
2050	29.3	9.4	13.8	2.5
total change	21%	42%	42%	-30%

3.2.3 Results

The total useful energy demand of the household sector will with this forecast be as presented in Figure 10. The total demand of useful energy will increase from 44 TWh in 2006 to 55 TWh in 2050. The energy demand of the entire country is divided into the seven regions based on the population growth described in paragraph 3.2.1. The resulting growth per region is illustrated in Figure 11. All regions but North and Finnmark will increase the demand of useful energy to the household sector. The increase is highest in the region “East”.

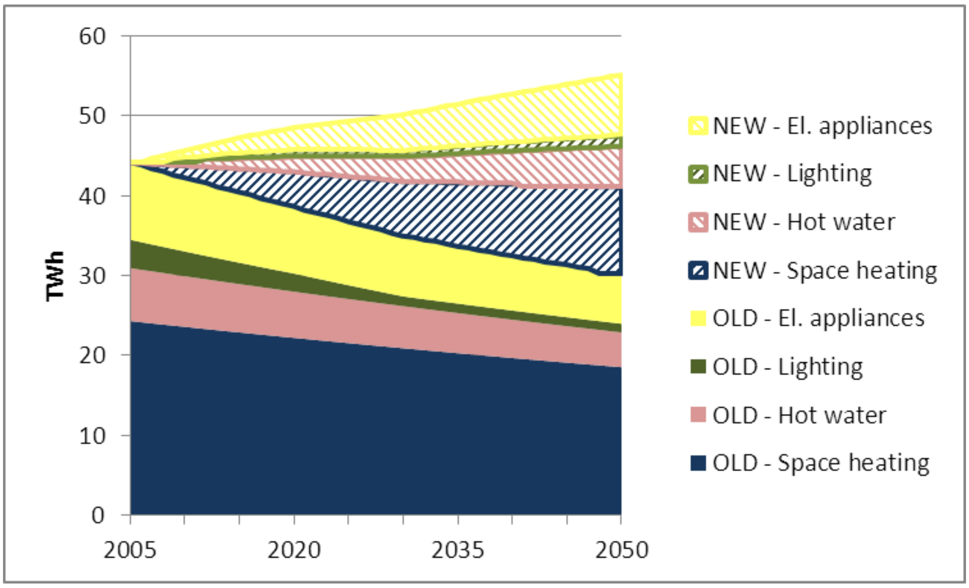

Figure 10 Energy use in households 2005-2050 (TWh/year)

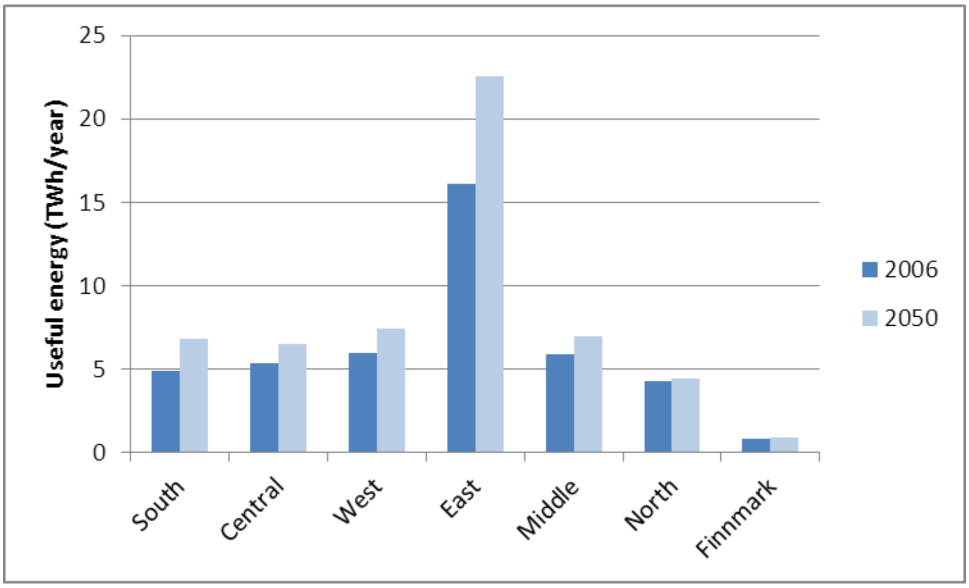

Figure 11 Useful energy demand in each region in 2006 and 2050 (TWh/year)

3.3 Service and other end uses

The forecast of the service sector is based on a model with 12 subsectors of the service sector and each subsector has seven end-uses. The future demand of useful energy is calculated as for the household sector with a driver, development of the driver, the belonging indicator and the development of the indicator. The seven end-uses are:

- Space heating
- Ventilation
- Hot water
- Pumps & fans
- Lighting
- Cooling
- Other

The subsectors and the selected driver of each subsector are presented in

Table 5. In this case, the same driver is used for all end-uses in a subsector. The development in number of employees per subsector is based on the information of the “Perspektivmeldingen 2009” [12]. The indicator kWh/employee is assumed to be constant throughout the period of analyse. The subsectors “Trade” and “Other” are modeled with the value added as the driver, and the annual increase of the driver is from the “Perspektivmeldingen 2009”. The indicator kWh/value added is assumed to decrease by 1.4 % per year in “Trade” and by 1.0 % per year in “Others. The subsector “Leisure” is considered to be closest linked to the private consumption. The annual growth in private consumption is 3.2 % and the expected reduction in the indicator is 1 % per year.

Table 5 Drivers and development of drivers and indicators in the service sector

Subsector	**Driver**	**Annual increase of driver**	**Annual change in indicator**
Trade	Value Added	3.4 %	-1.4 %
Hotel & restaurants	Number of employees	0.5 %	0 %
Transports	Number of employees	0.9 %	0 %
Post & telecom.	Number of employees	0.5 %	0 %
Financial services	Number of employees	0.5 %	0 %
Other com. services	Number of employees	0.5 %	0 %
Public services	Number of employees	1.0 %	0 %
Education	Number of employees	1.0 %	0 %
Health	Number of employees	1.0 %	0 %
Leisure	Private consumption	3.2 %	-1.0 %
Other personal services	Value Added	2.3 %	-1.0 %
Other personal services, rest.	Value Added	2.3 %	-1.0 %

Based on the assumptions above, the demand of useful energy in the service sector will increase from 32 TWh in 2006 to 49 TWh in 2050, equal to 55 % increase. In TIMES Norway the service sector is divided in the eight subsectors, including construction and road lighting.

Each subsector is divided in demand for heating, cooling and electricity. The development per subsector is presented in Figure 12.

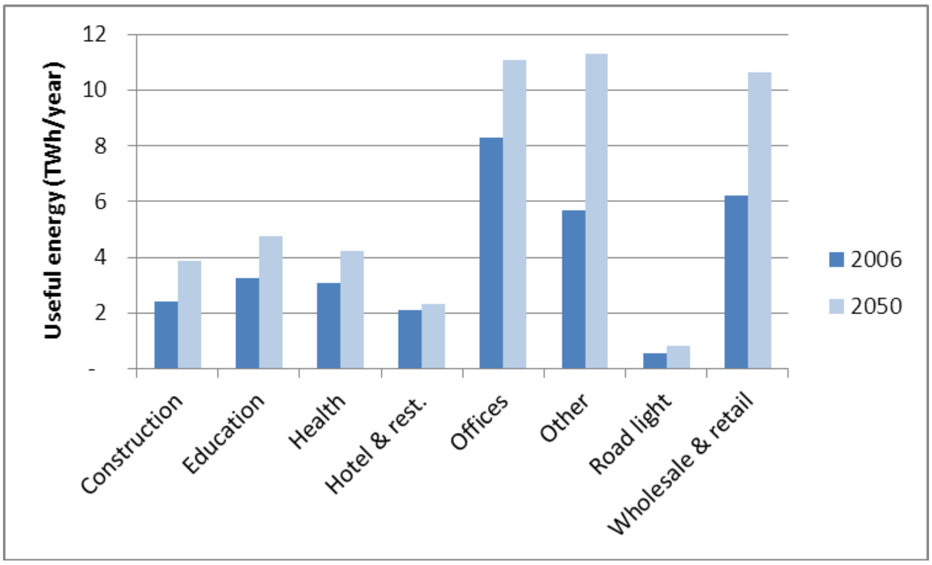

Figure 12 Useful energy per subsector of services in the TIMES Norway model in 2006 and 2050 (TWh/year)

The total demand of useful energy for Norway for each service subsector is divided into the seven regions of TIMES Norway by use of the development in population per county as forecasted by the middle scenario of Statistics Norway. This is based on the same method as for the household sector, see paragraph 3.2.1. The resulting demand of useful energy in each region is presented in Figure 13.

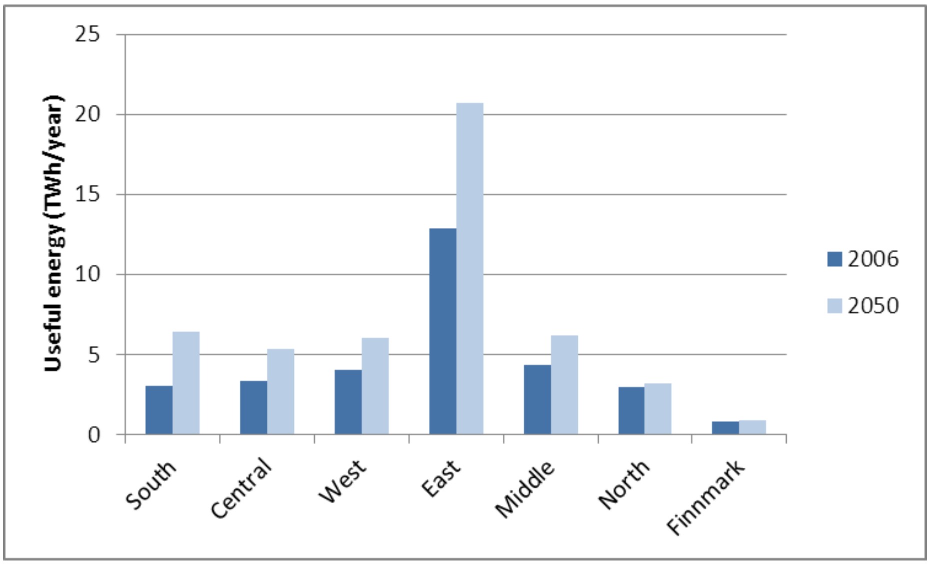

Figure 13 Useful energy in the seven regions of TIMES Norway in 2006 and 2050 (TWh/year)

The useful energy demand of the primary sector was 2.6 TWh in 2006 and is calculated to 5.0 TWh in 2050 based on the development of value added in this sector in “Perspektivmeldingen 2009”. The relative increase is assumed to be the same in all regions.

3.4 Transportation

The transportation sector is divided in:

- Air transport – useful energy demand
- Cars long distance – demand of vehicle-km
- Cars short distance – demand of vehicle-km
- Freight transport – useful energy demand
- Other transport– useful energy demand
- Buses– demand of vehicle-km
- Train– useful energy demand
- Sea transport – useful energy demand

The energy demand is based on the energy consumption by municipality [7] and this deviate from the national energy balance [3] in the way that transportation by air and sea are only included to a smaller content (within a certain distance). Hence the energy use by municipality does not add up to the same consumption as in the national energy balance. The difference is categorised as "other" together with use of energy for tractors, small boats, tools, generators etc. The energy use by sub-sector in 2006 as modelled in TIMES-Norway is presented in Figure 14.

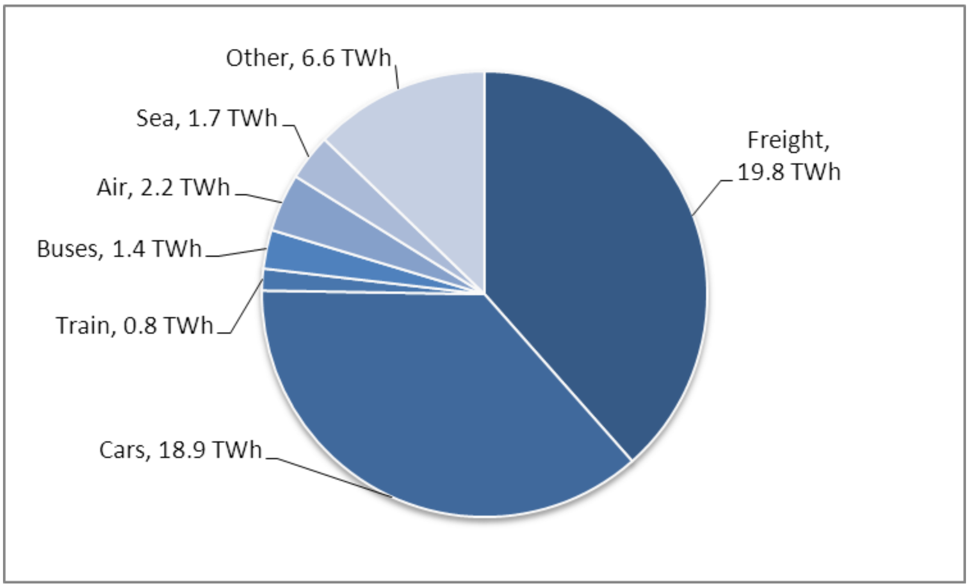

Figure 14 Energy use in transportation in 2006 (TWh)

The future demand for transport is based on the national transport plan in the White paper No. 16 2008-2009 [6]. The resulting forecast of the transport subsectors is presented in Figure 15. The development in the different regions of TIMES Norway is the same as for the whole country, expect for freight and cars, see Figure 16.

The total increase in use of cars will be 58 % while the increase in population only will be 42 % toward 2050, according the sources used for this forecast. This indicates that the car use per capita increases by 64 %. The population growth per region is used to calculate the future demand of vehicle-km by cars. The regional development of the freight sector is calculated based on data from a study of TØI [18].

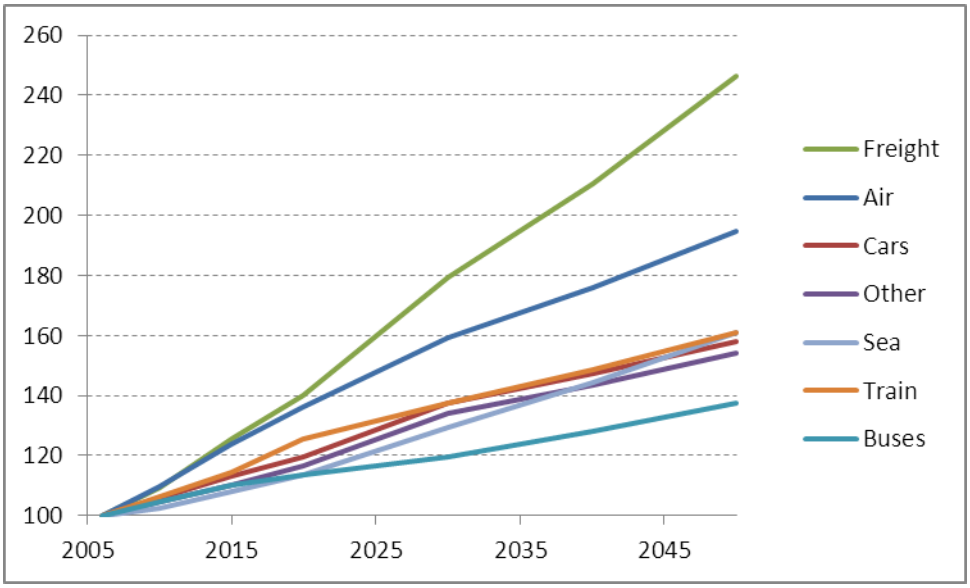

Figure 15 Relative development in national transport modes

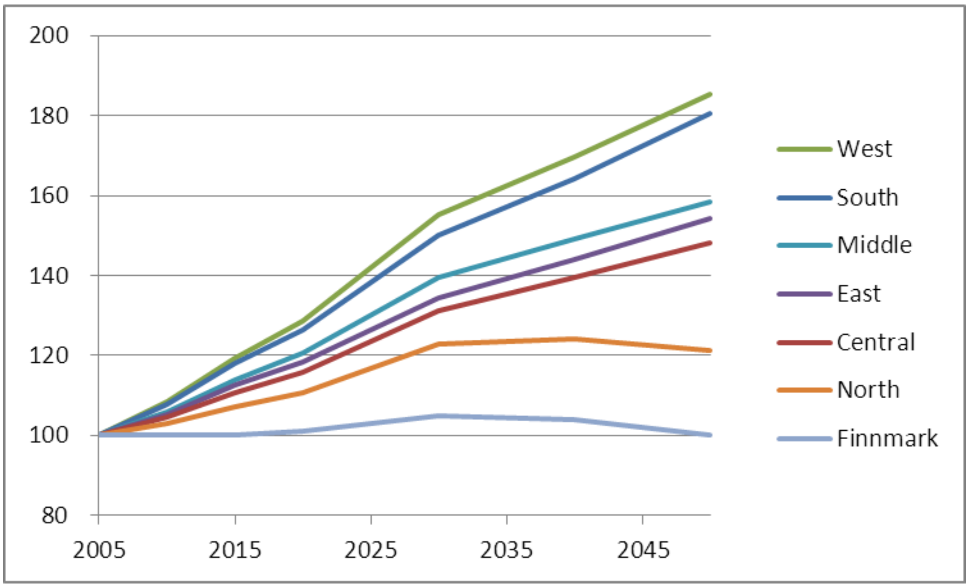

Figure 16 Regional development of cars from 2006 to 2050

Transport by cars is divided in short and long distance. To estimate the population in urban and rural areas, statistics of population in communities with more than 10 000 inhabitants is used. The population of urban and rural areas in each region in the base year is as presented in Figure 17. To roughly divide the transport by cars in long and short distance, it is assumed that the need for short distance transport is the same share as the population in urban areas and long distance transport is like the share of inhabitants in rural areas.

The modelling of the transport sector in TIMES-Norway needs to be improved. Not all sub-sectors have different technology options. Possibilities for modal shift is not included in the model, but is handled as different scenarios where the effect of modal shifts may be analysed.

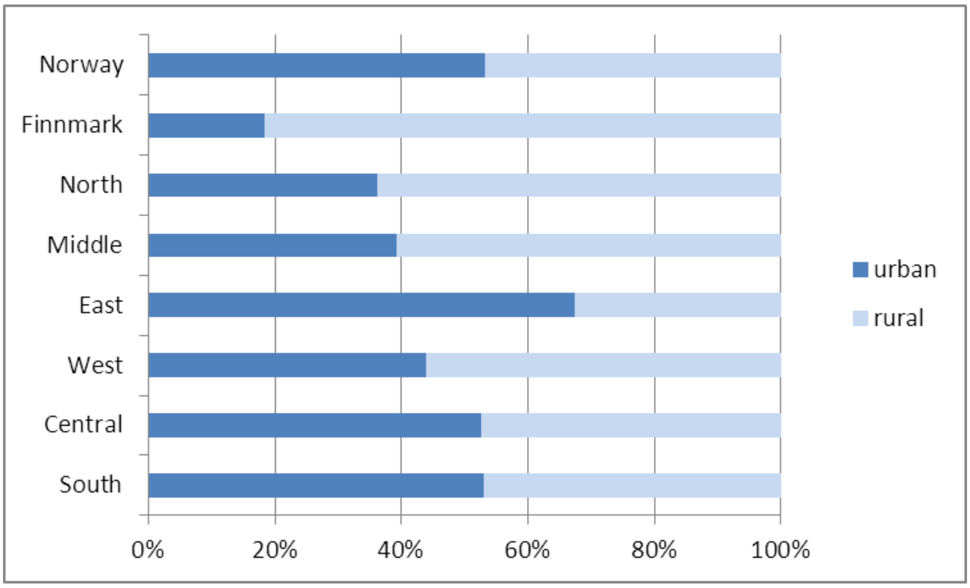

Figure 17 Population in urban and rural areas in each region

3.5 Summary

Since the transportation subsectors has different units – both GWh and mill. vehicle-km – it is impossible to add them directly. The summary in this section will therefore focus on stationary energy use and also exclude the use of raw materials. The demand of useful energy for stationary use will increase in all regions. The growth rate is highest in East and South and in total the growth is 18 % according to this forecast, see Table 6 and Figure 18.

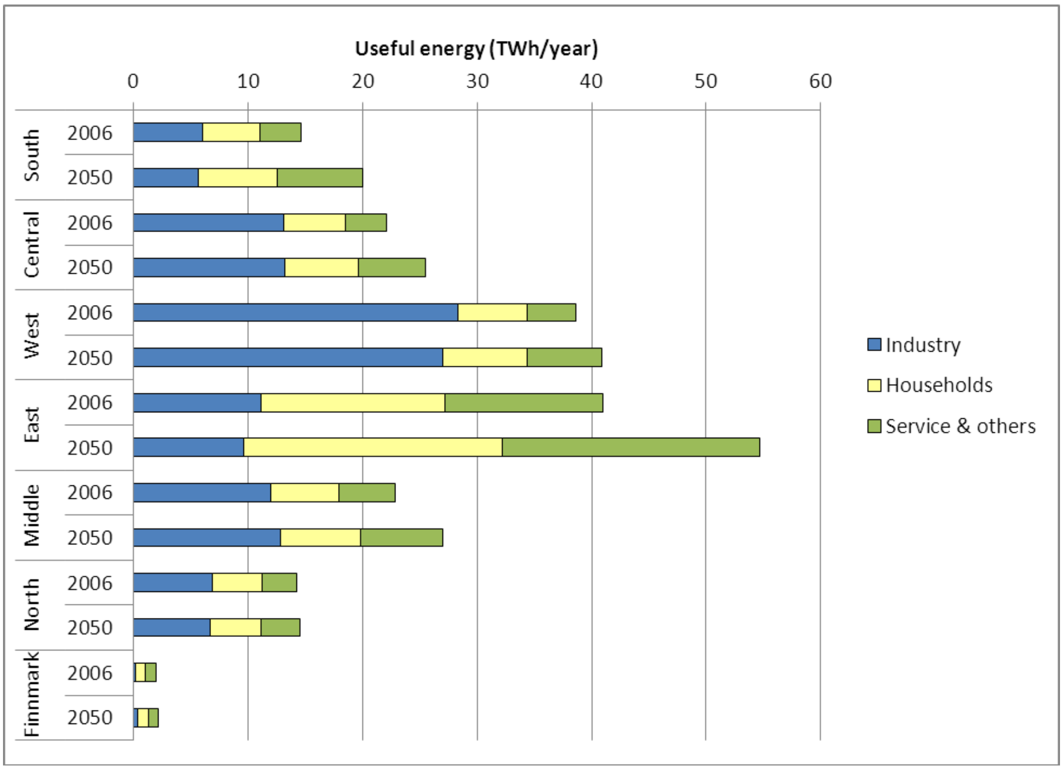

Figure 18 Projection of useful energy for stationary use in 2006 and 2050 (TWh/year)

Table 6 Useful stationary energy demand (excl. raw material) in each region and sector of TIMES Norway in 2006 and 2050 (TWh/year)

Region	Year	Total	Industry	Households	Service & others
South	2006	14.6	6.1	4.9	3.6
	2050	20.0	5.7	6.8	7.5
	change	37 %	-7 %	38 %	108 %
Central	2006	22.1	13.1	5.4	3.6
	2050	25.5	13.2	6.5	5.8
	change	15 %	1 %	21 %	61 %
West	2006	38.7	28.3	6.1	4.3
	2050	40.9	27.0	7.4	6.5
	change	6 %	-5 %	22 %	51 %
East	2006	41.7	11.1	16.8	13.8
	2050	54.7	9.6	22.6	22.5
	change	31 %	-14 %	34 %	63 %
Middle	2006	22.9	12.0	6.0	4.9
	2050	27.0	12.8	7.0	7.2
	change	18 %	7 %	17 %	47 %
North	2006	14.3	6.9	4.3	3.1
	2050	14.5	6.7	4.4	3.4
	change	2 %	-2 %	3 %	10 %
Finnmark	2006	1.9	0.15	0.9	0.9
	2050	2.1	0.35	0.9	0.9
	change	11 %	127 %	2 %	0 %
Total	2006	156.2	77.6	44.4	34.2
	2050	184.7	75.3	55.6	53.8
	change	18 %	-3 %	25 %	57 %

An overview of sources used in the calculations is presented in Figure 19. The energy balance, energy use by municipality and the projections of population growth, both on a national level to 2060 and by county until 2030, are information from Statistics Norway [3, 7]. The white paper on the long-term development (PM2009) is from the Ministry of Finance [12] and the national plan of transportation is from the Ministry of Transportation [6]. Electricity data is from NVE [8]. The Climate and pollution agency (Klif) make public information on energy use and emissions from companies with a requirement of discharge permit and this an important source of information in the industry sector [9]. The ending year of the sources used for forecasting is added after each of the sources in Figure 19.

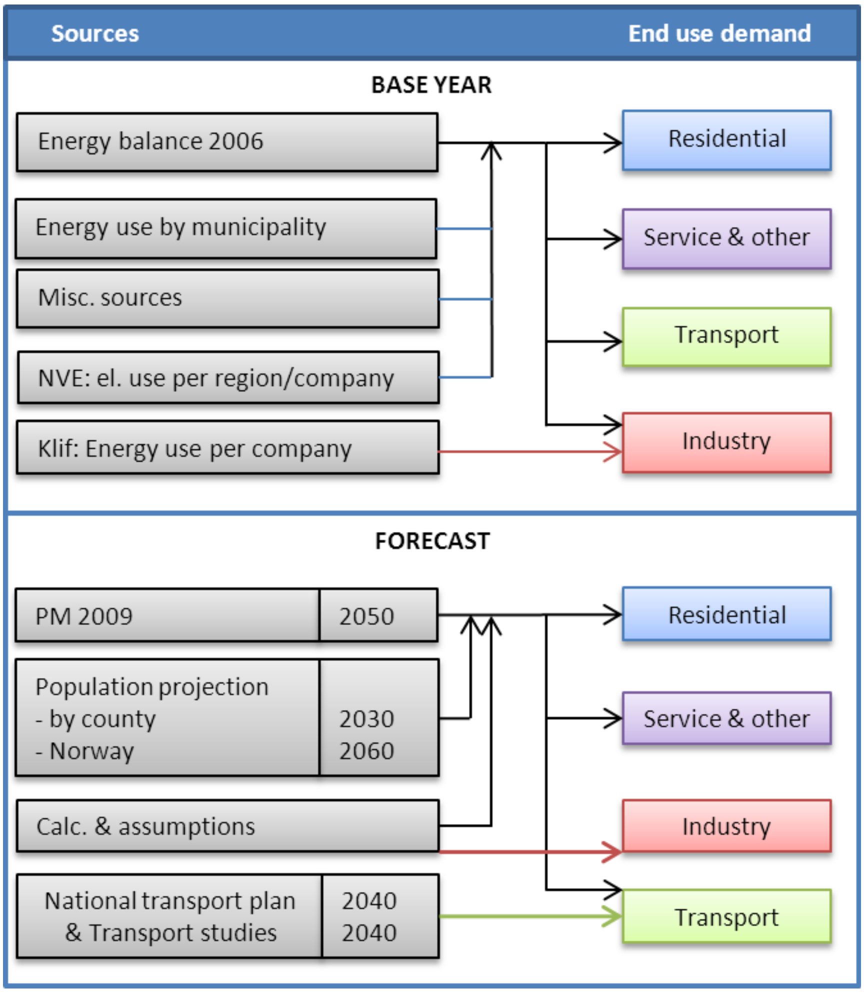

Figure 19 Overview of sources used for calculation of future energy demand with the ending year of each forecasting source (PM2009 = Perspektivmeldingen 2009)

4 Discussions and further work

The definition of a forecast of useful energy demand is not absolute, but depends on the purpose. One has to be careful not to include parts that are a part of the energy system model, such as energy efficiency measures. In the forecast presented here the influence of new building regulations and the prohibition of production of incandescent light bulbs in EU etc. are included. Other energy efficiency measures such as energy management, heat pumps, tightening of leaks etc. are modeled as technologies to invest in and are included in the TIMES-Norway model.

The effect of a changing climate is not included in the forecast here, but will be analysed as a scenario where the effect on space heating/cooling and changes in hydro power production is included.

TIMES-models have a possibility to use elastic demand, but it is not used in this case. The elasticity between different energy carriers are handled by the TIMES-Norway model and some elasticity is also included as the possibility to invest in energy efficiency measures. The electricity price in each of the Norwegian regions will be calculated by TIMES-Norway, but the export/import price is exogenously given to the model. The TIMES-Norway model is described in Appendix 1.

The energy demand of energy services is an important input of the TIMES-Norway model, together with prices of different energy carriers and constraints of the model, see Figure 20. One interesting output of the model is the use of different energy carriers in different end-use sectors, regions and at the time of interest. The next step is to do different analyses with the TIMES-Norway model and analyse the effect of the energy forecast presented here with different assumptions of energy prices, constraints and maybe also different technology costs. Scenarios with different forecasts of energy demand will also be carried out, such as the effect of a much higher increase in the demand either in all regions or in one selected region and/or the effects of a low increase in energy demand.

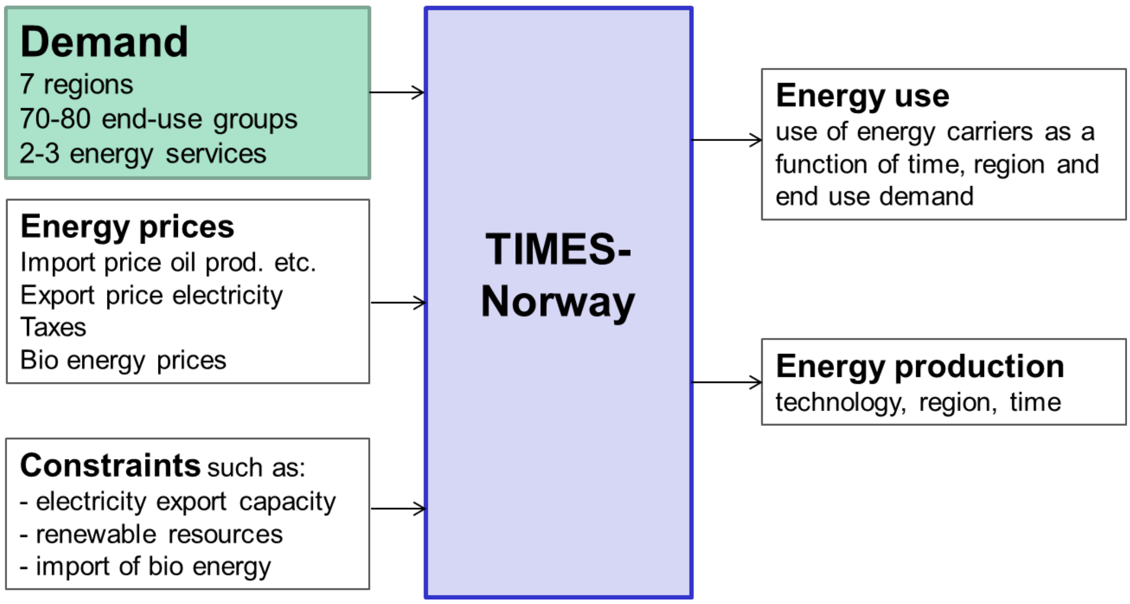

Figure 20 Principal drawing of input and output parameters of TIMES-Norway

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Appendix 1 Description of the TIMES-Norway model

Overall description

TIMES is a model generator developed in the frame of the implementing agreement IEA – ETSAP [19]. It is a linear programming model that represents the entire energy system for different energy carriers and can include extraction, transformation, distribution, end-uses and energy trade. The model consists of many technologies describing the different sectors and characterized by its economic and technological parameters. TIMES is implemented in GAMS and may use different types of solvers such as CPLEX and XPRESS.

The structure of the Norwegian TIMES model is illustrated in Figure 21. Heat and power can be produced in central plants (CHP in Figure 21) or in local plants in industry (cogeneration in Figure 21). Energy carriers used as industrial feed stock (such as natural gas in chemical industry) are included as non-substitutable energy with emission of CO_2. Energy efficiency measures are modelled as investment options with several costs classes and potentials. The investment in gas power plants is limited, due to political reasons.

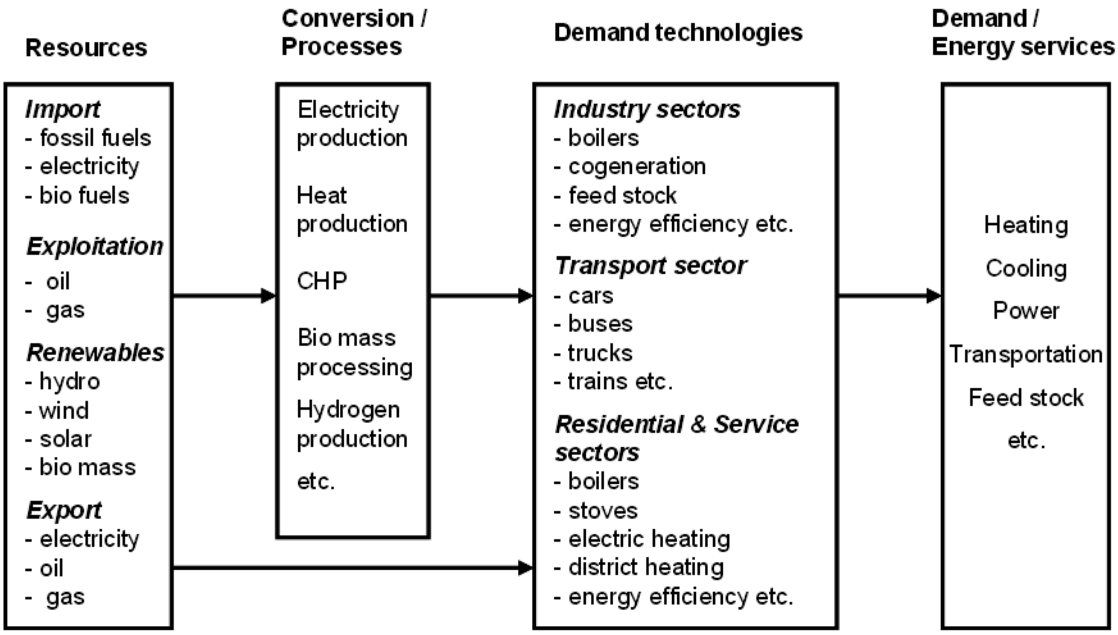

Figure 21 Principal drawing of the Norwegian TIMES model

In order to develop a model that could be used in iteration with the Multi-area Power-market Simulator (EMPS) [20], a so-called hydropower/power market model, it was necessary to increase the time resolution to cover all weeks during each year with five time slices per week, giving 260 time slices annually. The definition of the weekly time slice periods are shown in Table 7.

Table 7: Definition of weekly time slices

Time slice	Hours
DAY 1	07.00 -11.00
DAY 2	11.00 – 17.00
DAY 3	17.00 – 23.00
NIGHT	23.00 – 07.00
WEEKEND	Saturday 07.00 – Monday 07.00

Geographic regions

The TIMES-Norway model covers seven regions in Norway with exchange of electricity between regions (except between regions 3 and 4) and with neighbouring countries (Netherlands, Denmark, Sweden, Finland, and Russia), see Figure 22. The model was developed to be used in connection with the Multi-area Power-market Simulator (EMPS) and this resulted in the definition of the seven geographic regions. The regions are more or less a union of the different Norwegian counties (19 in total).

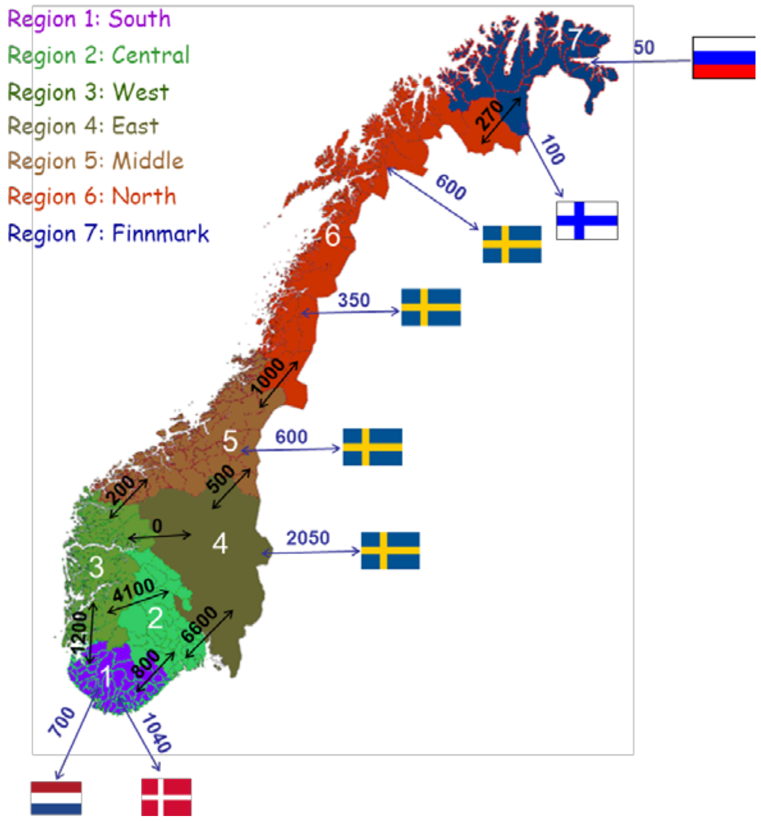

Figure 22 The regions of the Norwegian TIMES model and existing exchange capacities in MW between regions and countries

Energy end use demand structure

Energy end-use demand is an exogenous input to the model and elastic demand functions are not used. The base year of the model is 2006, since this was the newest available energy statistics when the model was first developed. The model has a wide range of demand sectors; especially the industry is modelled in detail. The Norwegian industry used 43 % of total energy and 65 % of electricity in 2006, see Figure 23 and Figure 24. A few big manufacturing industry plants, have an electricity consumption almost at the same level as the entire building sector (residential and service together). This domination of the industry made it interesting to model parts of the industry sector on a plant level. In general the industry is divided in pulp & paper, aluminium, other metal production, chemical industry, refineries and other industry. Most major electricity consuming plants are modelled as individual units and the rest are either a group of well-defined plants or the rest of that industry sector. The commercial sector is modelled as eight sub-sectors and the residential sector consists of five sub-sectors. Additionally, there is agriculture and transport divided in eight sub-sectors.

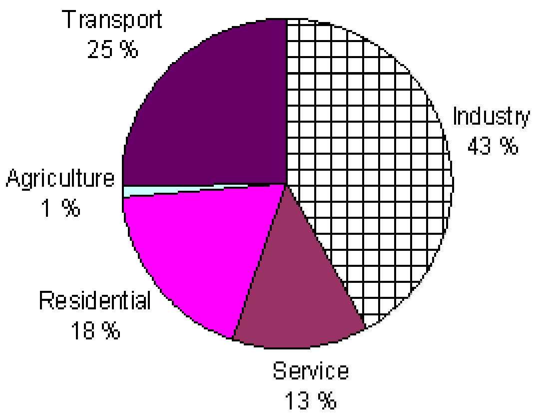

Figure 23 Total Norwegian energy end-use by sector in 2006

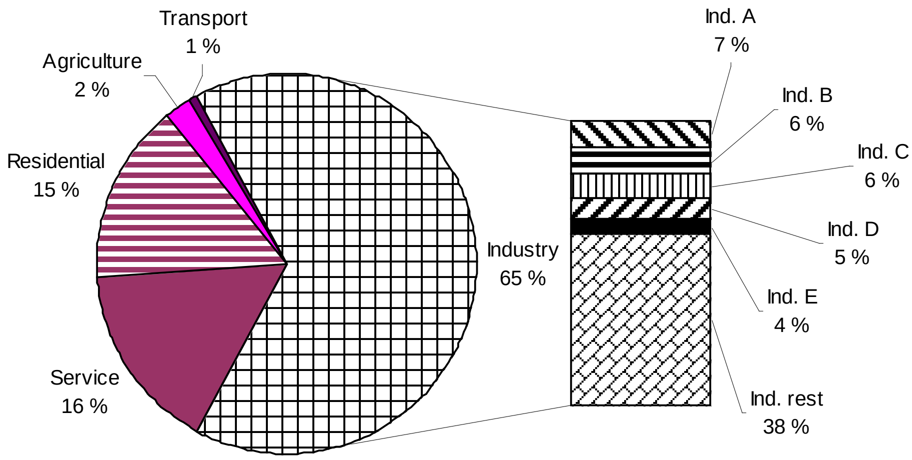

Figure 24 Norwegian electricity consumption by end-use in 2006

A major challenge was to develop load profiles for thermal and electricity demand for the demand sectors considered. In the literature several load profiles are available, but none of these could fit directly into the sectors or time resolution chosen for the model. Therefore, the load profiles have been developed based on measurements and modelling of sector specific load profiles and measured electricity data.

Table 9 lists the end use demands in the model by sub sector and demand type. Each demand sector is divided into sub sectors and demand types; electrical, heating, cooling and raw material. The demand of the personal cars is divided into short and long distances to achieve a better representative transportation sector. In total there are 75-78 end use demand categories in each of the seven regions and in total 534 demand data per year is needed, see Table 8. Some of the demand data is zero since not all type of industries are present in all regions or since cooling data not is available in all sectors were it is possible.

In the model, parts of the transportation sector (including railways, shipping, aviation and fishing boats) do not have an option to substitute existing technologies and energy carriers. Transportation by person cars is modelled with 17 different technologies, including hybrids, electric, fuel cells, plug-in hybrids and combustion engines with different fuels.

Electricity statistics were available at a very detailed level both regarding end-use sector and geographically divided in communities. In addition consumption of most large industry plants were specified. This is a very important source, since electricity use is approximately half of the Norwegian total final energy use and 2/3 of final stationary use.

The energy statistics of other energy carriers are not as detailed and it has been both time consuming and difficult to find statistics on the level of detail required. Statistics Norway has energy statistics on a detailed sub-sector level for the whole country and aggregated for a few sectors on a community level. In addition the Climate and Pollution Agency has plant specific data for industries with emission permission [9]. By a combination of sources and the use of qualified estimates in some cases, all the figures for end-use demand have been calculated.

Table 8 Number of demand data per sector in TIMES Norway

Sector	# sub-sectors	Demand type	# demand data per region	Sum # demand data
Industry	11-14	Electricity, heat, raw material	33-42	231-240
Households	5	Electricity, heat	10	70
Tertiary	8	Electricity, heating, cooling	21	147
Primary	-	Electricity, heat, raw material	3	21
Transport	8	Vehicle-km, tonne-km, useful energy demand	8	56
Total	**33-36**		**75-78**	**534**

Table 9 List of end use demands for each of the seven regions

Sector	Sub sectors	Demand type
Agriculture (3)		Electrical, Heating, Raw Material
Commercial (21)	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 (33-36)	Aluminium group A-D	Electrical, Heating, Raw Material
	Aluminium group Rest	Electrical, Heating, Raw Material
	Chemical Industry group A	Electrical, Heating, Raw Material
	Chemical Industry group Rest	Electrical, Heating, Raw Material
	Metal industry group A	Electrical, Heating, Raw Material
	Metal industry group Rest	Electrical, Heating, Raw Material
	Mining	Electrical, Heating, Raw Material
	Pulp and paper group A	Electrical, Heating, Raw Material
	Pulp and paper group Rest	Electrical, Heating, Raw Material
	Refineries	Electrical, Heating, Raw Material
	Residual Industry	Electrical, Heating, Raw Material
Residential (10)	Cottages	Electrical, Heating
	Multi family house - new	Electrical, Heating
	Multi family house - old	Electrical, Heating
	Single family house - new	Electrical, Heating
	Single family house - old	Electrical, Heating
Transport (8)	Air Transport	
	Personal cars – long distance	
	Personal cars – short distance	
..	Freight	
	Other mobile combustion	
	Public transport – bus	
	Public transport – train	
	Sea transport	