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TIMES-Norway Model Documentation

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Report title

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Summary

TIMES-Norway is a least cost optimization model that represents the entire Norwegian energy system for different energy carriers and technologies. TIMES is a widely applied bottom-up, dynamic, linear programming (LP) optimisation model generator developed in the frame of the implementing agreement IEA-ETSAP.

TIMES-Norway is developed by Institute for Energy Technology (IFE) on commission of The Norwegian Water Resources and Energy Directorate (NVE) and the development started in 2008. The time horizon of the model is from 2006 to 2050, with a flexibility of analysing years within this frame. TIMES-Norway covers all onshore energy use in Norway and the country is divided in seven regions with exchange of electricity between adjacent regions and neighbouring countries.

This report gives an overview of the model, including central model parameters, data and sources, as of January 2013. The model will continuously be developed, and the intention is to update this documentation report regularly.

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1 Introduction

TIMES (an acronym for The Integrated MARKAL-EFOM[1] System) is a bottom-up techno-economic model generator for local, national or multi-regional energy systems, which provides a technology-rich basis for estimating energy dynamics over a long-term, multi-period time horizon. It gives a detailed description of the entire energy system including all resources, energy production technologies, energy carriers, demand technologies and demand sectors. The model assumes perfect competition and perfect foresight and is demand driven. Thus the forecasted energy demand has to be given exogenously to the model, and the TIMES model aims to supply energy services at minimum global cost by making equipment investments, as well as operating, primary energy supply and energy trade decisions.

TIMES is developed by the Energy Technology Systems Analysis Programme (ETSAP), an Implementing Agreement of the International Energy Agency (IEA). It is a least cost optimization model generator, with partial equilibrium (since only the energy part of the entire economy is included). It is the successor of the MARKet ALlocation model (MARKAL). Today over 150 teams in more than 50 countries globally make use of the TIMES family of models [1]. The modelling tools have been used for numerous studies, on a regional, national and global level, with various focus areas [1]. Documentation of TIMES can be down-loaded from:
http://www.iea-etsap.org/web/Documentation.asp

TIMES-Norway is developed by Institute for Energy Technology (IFE) on commission of The Norwegian Water Resources and Energy Directorate (NVE). The original objective was to develop a multi-regional Norwegian model for short-term analysis of the Norwegian energy system. The model should be able to run both separately and in combination with the EMPS-model[2] [2]. The objective of TIMES-Norway was to improve the possibilities to analyse end-use demand and changes in the energy mix with variable electricity prices. The work on TIMES-Norway started in 2008 and the first version with a time horizon of 2006-2010 was delivered in 2009 [3]. In 2010 the time horizon of the TIMES-Norway model was extended to 2020 with support from NVE [4]. In several research projects in 2011 and 2012, IFE extended the model horizon further to 2050.

The project leader at IFE during the development in 2008-2010 was Audun Fidje. Eva Rosenberg, Pernille Seljom and Kari Aamodt Espegren were part of the development team at IFE during this period. In the work with the long-term model (up to 2050) Arne Lind joined the team. NVE by Karen Byskov Lindberg and Ellen Skansaar contributed actively to the development, particularly with load profiles and energy end-use demand.

This report describes the structure and data of the TIMES-Norway model. Information about TIMES parameters and the modelling tool is described in the general TIMES documentation from ETSAP [5-7]. TIMES-Norway is based on the user interface “Answer-TIMES” [8]. Evaluations of results can be made directly in Answer-TIMES, by export to Excel or with the

[1] MARKAL (MARket ALlocation model, Fishboen et al., 1981, 1983), and EFOM (Van Voort et al., 1984) are two bottom-up energy models which inspired the structure of TIMES)
[2] EFI’s Multi-area Power-market Simulator (Samkjøringsmodellen)

user interface "VEDA-BackEnd" [9]. In order to run the model, GAMS has to be installed and a solver such as XPRESS or CPLEX is necessary.

2 Model structure

2.1 Introduction

The structure of the TIMES-Norway model is illustrated in Figure 1. The demand for various energy services, energy price information and resource costs and availability are given exogenously to the model. On the energy supply side, several conversion processes are represented in detail; e.g. electricity and heat production. Transmission and distribution include high and low voltage grids, as well as district heating. Energy carriers used as industrial feed stock (such as natural gas in chemical industry) are included as non-substitutable energy carriers with corresponding CO_2 emissions.

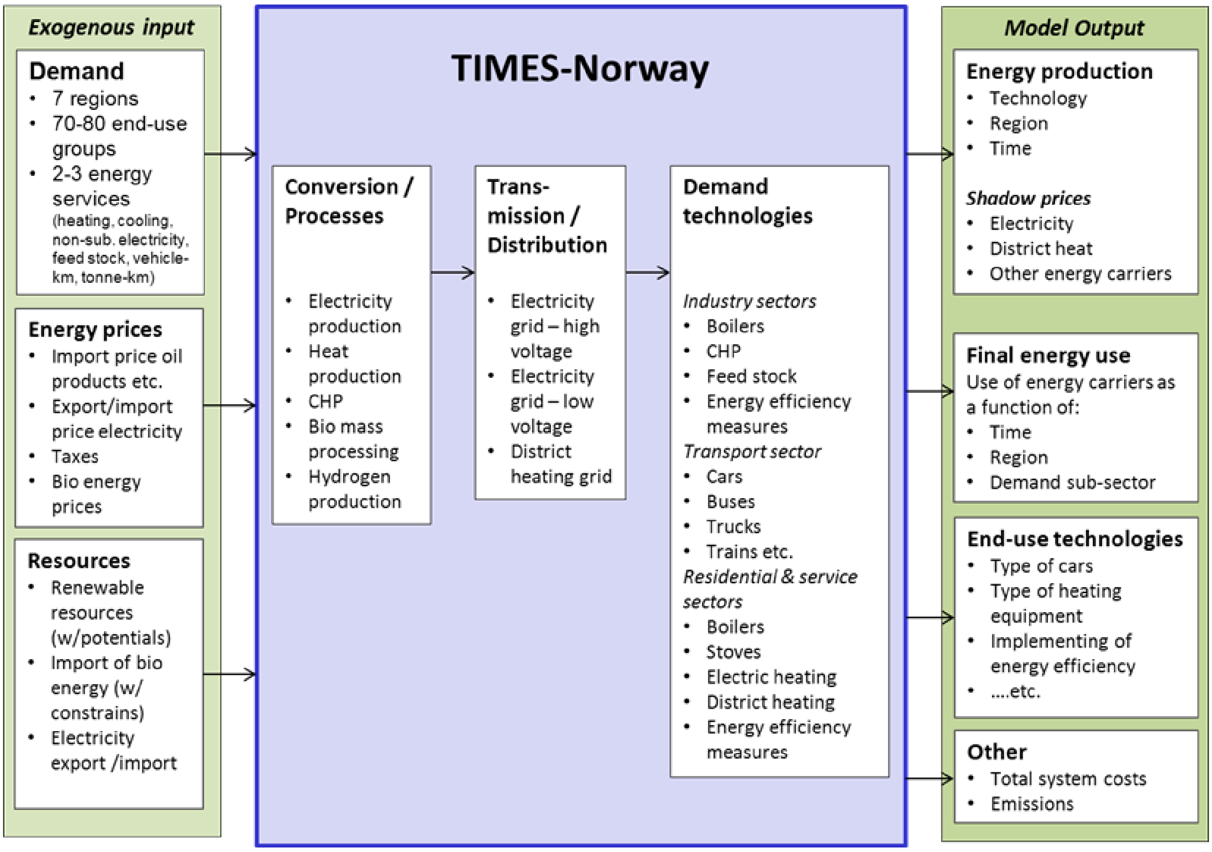

Figure 1: Principal drawing of TIMES-Norway

The overall general discount rate is 7% for all model regions.

2.2 Time slices

In order to use TIMES-Norway in combination with the EMPS-model, a high time resolution was necessary. The year is divided in 52 weeks. Based on the time slices in the EMPS model together with analysis of demand profiles (see paragraph 5.1.2), it was decided to divide each week into five time slices, giving 260 times slices annually. The definition of the weekly time slice periods are shown in Table 1. The fraction of day 1 in week 1 is 0.23% of the annual time and the fraction of day 1 of one week is 12 % (as is the sum of all day 1 in a year), see Table 1.

Table 1: Definition of weekly time slices

YEAR					Definition	Fraction per	
Week 1	**Week 2**	**Week 3**	**....**	**Week 52**	**Hours**	**week**	**year**
DAY 1	DAY 1	DAY 1	DAY 1	DAY 1	Monday - Friday: 07.00 - 11.00	12%	0.23%
DAY 2	DAY 2	DAY 2	DAY 2	DAY 2	Monday - Friday: 11.00 - 17.00	18%	0.34%
DAY 3	DAY 3	DAY 3	DAY 3	DAY 3	Monday - Friday: 17.00 - 23.00	18%	0.34%
NIGHT	NIGHT	NIGHT	NIGHT	NIGHT	Monday: 00.00 - 07.00 Tuesday-Friday: 23.00 - 07.00	23%	0.45%
WEEKEND	WEEKEND	WEEKEND	WEEKEND	WEEKEND	Friday 23.00 - Sunday 24.00	29%	0.56%

2.3 Geographic regions

The model was developed to be used in connection with EMPS, and this resulted in the definition of the seven geographic regions. The regions are more or less unions of the 19 Norwegian counties. With seven regions, the model can be used for identifying bottlenecks between regions, and the need for new generation capacity and/or new grid lines between regions. In reality there are more possible bottlenecks in the grid, e.g. the power market model EMPS has 13 regions, however in order to keep the model size manageably it was decided to have seven regions. On the other hand, the Nordic spot market for electricity is currently divided into five Norwegian regions, indicating that the major bottlenecks in the grid should be covered by the seven regions in TIMES-Norway.

There are big differences between the regions. Region 3 contains several hydro power plants and many energy intensive industries. Region 2 has a surplus of power due to a relative low power demand within all sectors, but considerable power production. Region 4 has the highest population, and has consequently the highest energy demand in households and service sector. The two northernmost regions occupy a very large area with only a modest energy demand (due to low population and little industry).

Figure 2 shows the model division of the country into seven regions. Existing transmission lines for electricity between adjacent regions and neighbouring countries (Netherlands, Denmark, Sweden, Finland, and Russia) are marked as unbroken lines, and potential extensions are marked as dotted lines. From 2012 it is possible to invest in new grid capacity between regions without limitation and between countries as indicated by the dashed line in Figure 2.

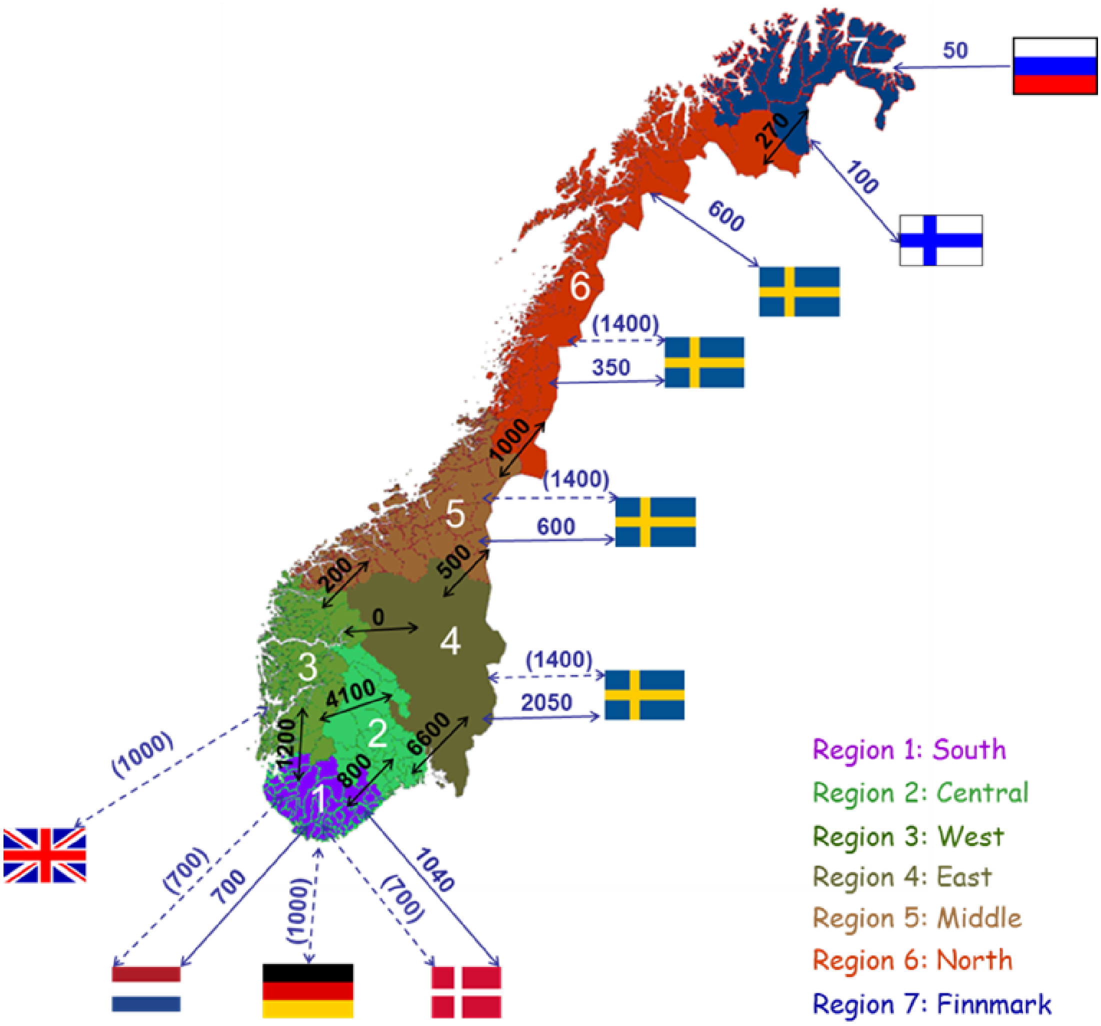

Figure 2: The regions of the TIMES-Norway and existing exchange capacities in MW between regions and countries (dotted lines indicate potential extensions based on [10])

2.4 Interaction with the Nordic Power market model (EMPS)

TIMES-Norway was initially developed to be used together with the Nordic Power market model (EMPS). The iteration procedure (see Figure 3) starts by supplying electricity prices from each of the seven regions in EMPS to TIMES-Norway. Based on this, the electricity consumption is determined in TIMES-Norway. This consumption is then input to EMPS. The iteration procedure will continue as long as there are significant changes in either electricity prices or electricity consumption from one iteration to the next.

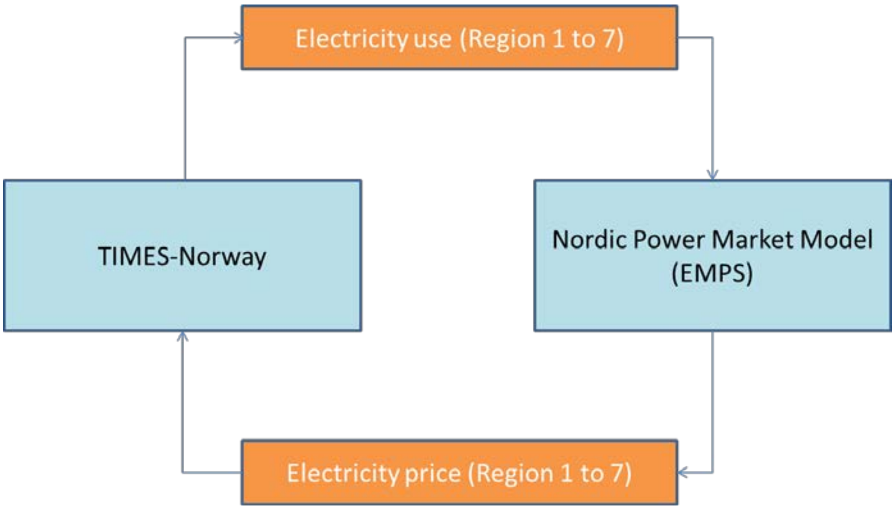

Figure 3: Interaction with EMPS

The iterations with EMPS show reasonable response from the TIMES model to changes in electricity prices. However, different responses in different regions due to existing stock of alternatives are experienced. The iteration process has been tested for selected cases and the results show that both electricity prices and demand converge after a few iterations.

2.5 Base year

The base year of TIMES-Norway is 2006, and consequently, the model is calibrated with statistical values for 2006. The energy balance and energy use by municipality from Statistics Norway were used for this purpose [11], along with electricity data from NVE [12]. Information regarding energy use and emissions from industrial companies were obtained from the Norwegian Climate and pollution agency (Klif) [13]. This is described in more detail in chapters 5 - 9.

3 Energy Resources and Production Processes

The following chapter gives an overview over renewable and fossil energy resources in Norway that is included in the model. Associated costs and potentials for the different energy carriers are also described. However the technologies for generating power or heat can be found in Chapter 4, and end use-technologies in Chapter 6.3, 5.3 and 7.3.

3.1 Renewable energy resources

This chapter describes the potential for renewable energy resources in Norway. Hydro and wind resources are described through their appurtenant power production capacity, whereas bioenergy resources are given in GWh heat content. (eller noe liknende).

3.1.1 Hydro power

The potential[3] for new hydro power is based on information from NVE and is given in Table 2 below. It is assumed that the potential for run-of-river hydro is divided equally between the two cost classes.

Table 2: Potential for new hydro power (GWh/year)

	Model name	Total
Reservoir	EEHYD02	2051
Reservoir (upgrade)	EEHYD07	7400
Run-of-river (medium cost)	EEHYD04	6040
Run-of-river (high cost)	EEHYD05	6040

Hydro power with reservoir is modeled by weekly inflow series. The water can either be stored to the next period or be used directly to generate electricity within the period. The hydro power plants can produce electricity during daytime (3 time slices), night and weekend in order to meet the demand. Thus, this modeling approach allows the model to store water both on a day-night level and on a seasonal level.

Electricity generation in reservoir hydro power plants is divided between existing plants and new large scale. Run-of-river hydropower production is modelled with a load curve (i.e. hydro inflow) included in the downstream ELC-HP commodity (Electricity high voltage: From hydro power). This approach reduces the amount of parameters for each production technology, and as a consequence, the model size is reduced considerably. A so-called unregulated hydro converter is then used to convert the ELC-HP into high voltage electricity (ELC-HV), see Figure 4.

[3] The hydro power potential will be updated based on new information from NVE. However, the TIMES-Norway version of February 2013 is based on the information in Table 2.

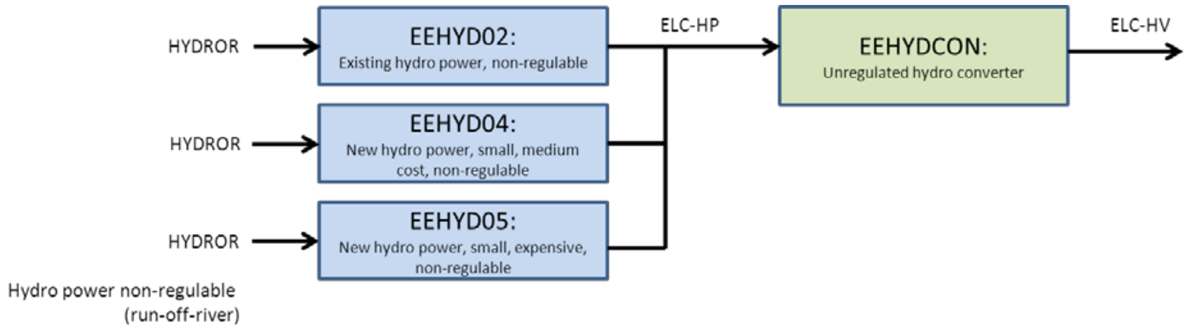

Figure 4: ELC-HP Commodity (Electricity high voltage from unregulated hydro power)

Run-of-river hydro is divided into existing and two groups of new small scale hydropower plants. The inflow series applied in the model is developed based on historically normal regional inflow series (1960-1990) for each region. The share of run-of-river is estimated by the use of the model Vansimtap [14].

Figure 5 and Figure 6 illustrate hydrologically normal inflow profiles for reservoir and run-of-river hydro for region West and East respectively. As illustrated in Figure 5, most of the production in region West comes from reservoir hydro due to large storage capacities. Run-of-river hydro contributes mainly in the summertime and early autumn. In region East, the hydro power capacity is more evenly distributed between reservoir and run-of-river hydro power (see Figure 6).

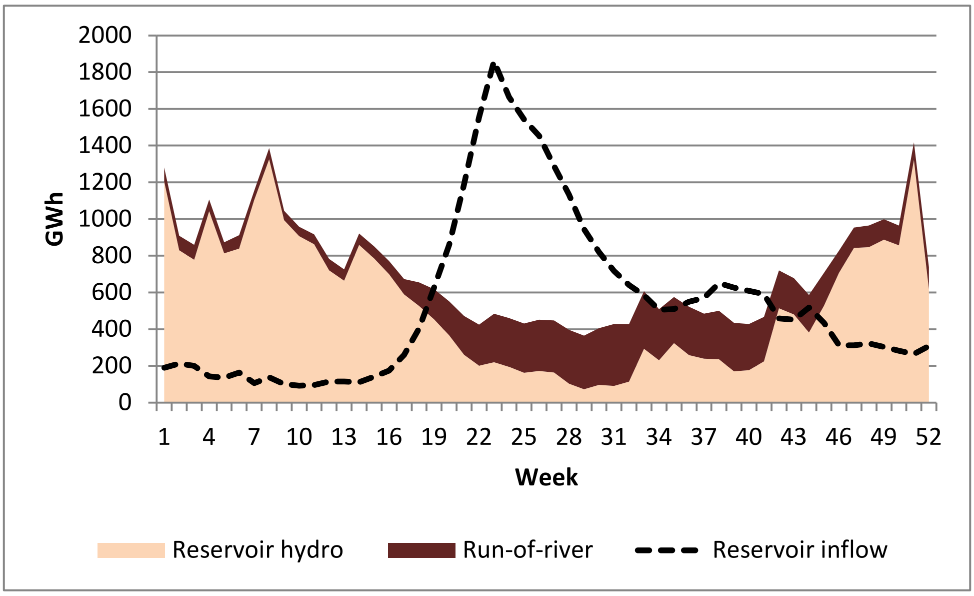

Figure 5: Inflow profiles and production from reservoir and run-of-river hydro in region 3 (West).

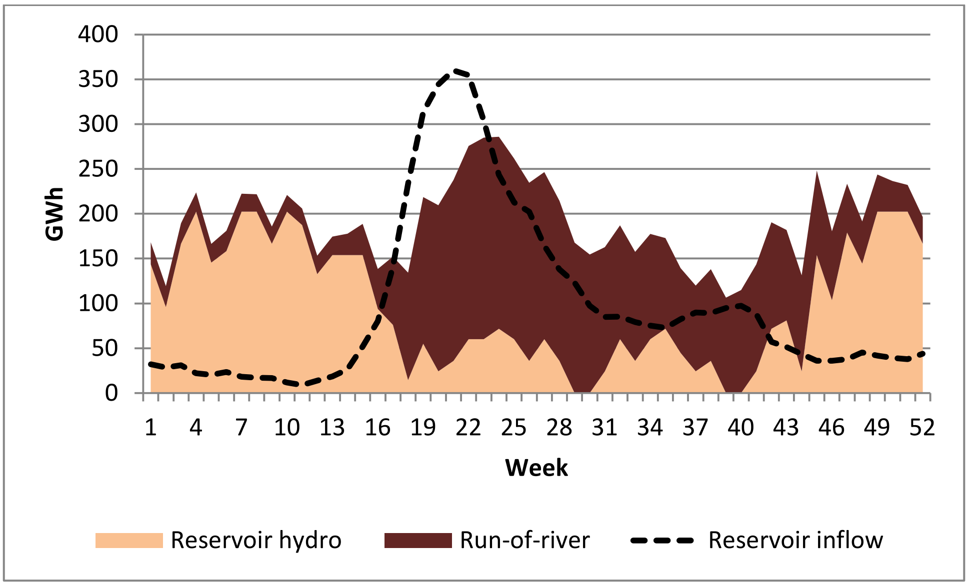

Figure 6: Inflow profiles and production from reservoir and run-of-river hydro in region 4 (East)

3.1.2 Wind power

The topology of the different wind power processes are illustrated in Figure 7. As shown in the figure, the wind profile is included in the downstream "Electricity high voltage: From wind power" commodity (ELC-WP) for all onshore wind power technologies, and not in the upstream wind commodity as one would expect. This approach reduces the amount of parameters for each production technology, and as a consequence, the model size is reduced considerably. A so-called wind converter is then used to convert the ELC-WP into high voltage electricity (ELC-HV) which is being fed into the national high voltage grid in the model. The offshore wind power technologies do not have the same wind profile as their onshore counterparts, and are only included in a few of the seven regions in the model. As a consequence, the wind profile is included directly in the technology since using the same approach as above would actually increase the model size.

Wind profiles, representing historical wind conditions, have been constructed for each of the seven regions in TIMES-Norway, both for onshore and offshore locations. A representative location was first identified for each region, and historical wind velocities with hourly time resolution were obtained for the last 10 years or more from The Norwegian Meteorological Institute in order to calculate wind profiles with 52 time steps (i.e. weekly). It was decided to use 52 time steps instead of 260 because of low daily variation in the wind velocity, making a weekly wind profile sufficient. As examples, onshore and offshore wind profiles for Region 1 and Region 7 are shown in Figure 8.

Wind velocities above the cut-off and below the cut-in speeds were removed in order to determine the maximum number of hours the wind turbines could operate at each location annually. This, combined with the different wind profiles, was used to determine the capacity factors for each region, both for onshore and offshore facilities. The capacity factors (ratio of the actual energy produced in a given period to the theoretical maximum possible) for different technologies and regions vary from 0.19 (region 6, onshore) to 0.6 (region 7, offshore).

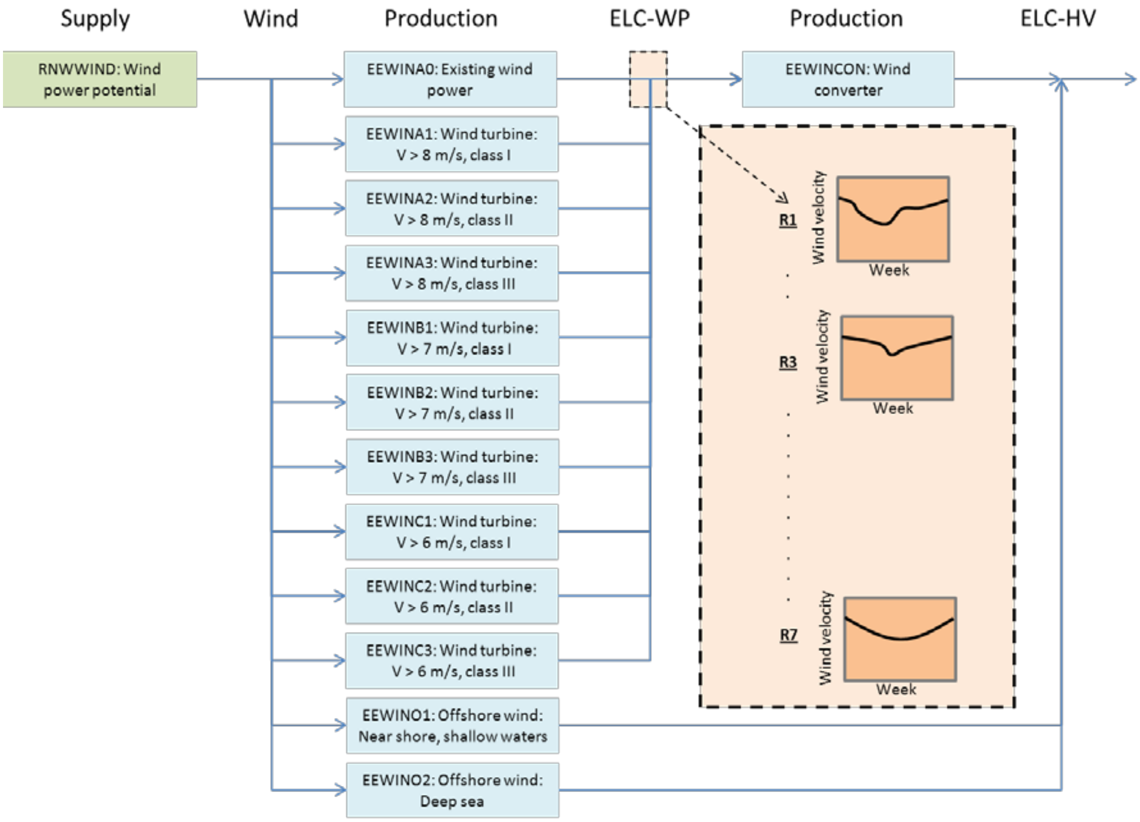

Figure 7: Modelling of wind power technologies in TIMES-Norway

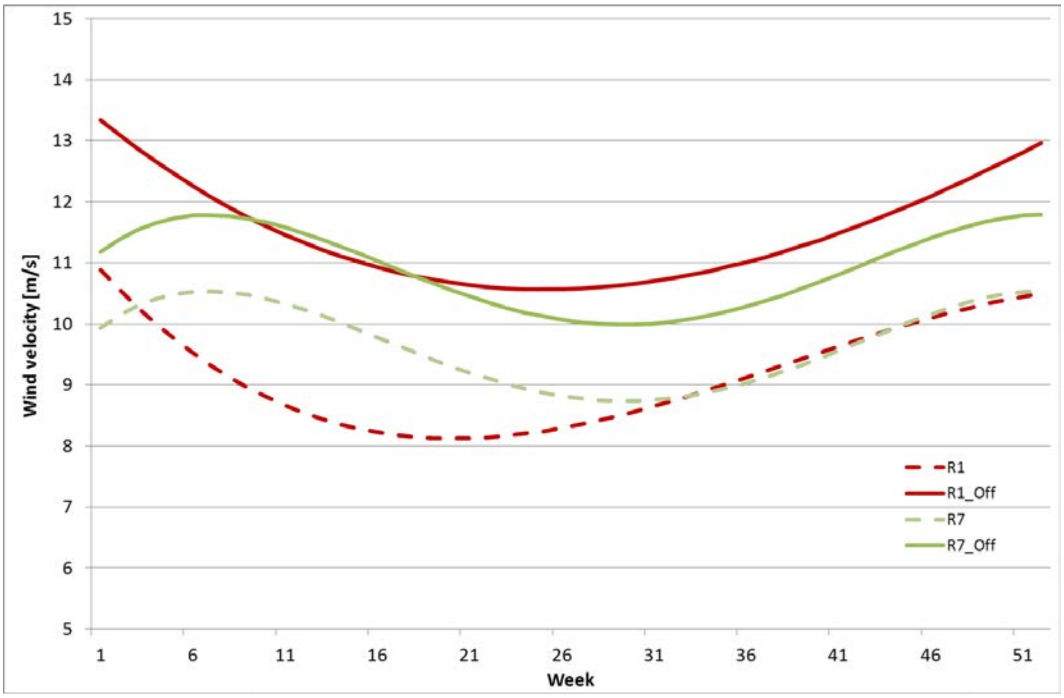

Figure 8: Wind profiles (offshore and onshore) for regions 1 and 7

The onshore wind power potential for the various model regions is given in Table 3 below. The offshore wind power potential [15] in TIMES-Norway is:

- 300 MW for region 7 (based on Sandskallen)
- 1500 MW for region 6 (based on Vannøya, Auvær, Nordmela, Gimsøy and Trænafjorden – Selvær)
- 300 MW for region 5 (based on Nordøyan – Ytre Vikna)
- 500 MW for region 3 (based on Frøyagrunnene and Olderveggen)
- 3500 MW for region 1 (based on Sørlige Nordsjø 1 and Sørlige Nordsjø 2)

It should be noted that in the model it is assumed that offshore wind facilities fixed to the bottom seabed are available from 2025, whereas floating offshore facilities are made available from 2030.

Table 3: Onshore wind power potential [MW] for the various model regions [16]

	2006	2010	2015	2020	2030	2040	2050
Region 1	4	4	704	700	700	700	700
Region 2	0	0	0	0	0	0	0
Region 3	5	24	624	724	800	800	800
Region 4	0	0	0	0	0	0	0
Region 5	223	331	2579	3176	3450	3450	3450
Region 6	8	8	682	782	875	875	875
Region 7	79	79	554	979	1325	1325	1325

Investment, operation and maintenance costs for the various onshore wind power technologies are given in Table 4, as well as the technical lifetime of the processes. The information is based on [17].

Table 4: Selected attributes for onshore wind technologies

	EEWINA0	EEWINA1	EEWINA2	EEWINA3	
NCAP_COST	13000	13000	14000	15000	[kNOK/MW]
NCAP_TLIFE	20	20	20	20	[years]
ACT_COST	100	100	150	180	[kNOK/GWh]

Investment, operation and maintenance costs for the various offshore wind power technologies are given in Table 5, as well as the technical lifetime of the processes. The information is based on input to Klimakur 2020 [18]

Table 5: Selected attributes for offshore wind technologies

		2006	2010	2015	2020	2030	2040	2050	
EEWIN01	NCAP_COST	20100	20100	20100	16500	14400	14400	14100	kNOK/MW
EEWIN01	NCAP_FOM	218	218	218	218	218	218	218	kNOK/MW
EEWIN01	NCAP_TLIFE	20	20	20	20	20	20	20	years
EEWIN02	NCAP_COST	30000	30000	30000	30000	26000	22000	18000	kNOK/MW
EEWIN02	NCAP_FOM	327	327	327	327	327	327	327	kNOK/MW

3.1.3 Bio energy

Bio energy is available in the model both as domestic resources, modeled as renewable processes (RNWBIOxxx), and as import of bioenergy carriers, modeled as import processes (IMPBIOxxx).

The domestic bio energy potential is presented in Table 6. The resources of bark are based on data from the municipality statistics of Statistics Norway. Increased by-product resources from the wood industry is estimated to 4.2 TWh by NVE [19]. The distribution per region is assumed to be the same as the statistics of use of bark in the base year, since the wood industry typically is located close to the resources.

Resources of wood chips are modeled as two cost classes. The total potential was estimated to 19-23 TWh including fire wood [19] and it is splitted into regions based on the use of fire wood in the base year from the municipality energy statistics [11]. The potential for municipal waste is set equal to the use of waste as energy in the base year 2006.

Table 6 Bio energy resources per region (GWh/year)

TIMES-Norway name	Region	1	2	3	4	5	6	7	Total
RNWBIOBARK	Bark	89	219	37	1 818	650	98	-	2 911
RNWBIOSAW	By-products wood industry	128	316	53	2 623	938	141	-	4 200
RNWBIOBLI	Black liqour	-	-	-	1 813	-	-	-	1 813
RNWBIOWDO	Fire wood	844	948	997	2 259	1 284	741	161	7 234
RNWBIOFOR1	Wood chips cl.1	934	1 048	1 102	2 898	1 420	820	178	8 000
RNWBIOFOR2	Wood chips cl.2	934	1 048	1 102	2 898	1 420	820	178	8 000
RNWBIOMWS	Municipal waste	184	280	231	1 092	343	77	15	2 221
	Total	**3 112**	**3 860**	**3 522**	**15 402**	**6 056**	**2 697**	**530**	**34 379**

In addition to the domestic resources of bio energy, it is possible to import several bio energy carriers. Based on the study of Klimakur 2020, it was made possible to import bioenergy products of oil, coal, coke, diesel and ethanol.

Fossil fuel oil can be fully substituted by bio oil. This is modeled as a “dummy” process using either fossil or bio oil, being the input to the end-use technology, see example in Figure 9. The same methodology is used for coal and coke, but the use of bio coke is limited in accordance to the Klimakur assumptions. Biooil is made available from 2015.

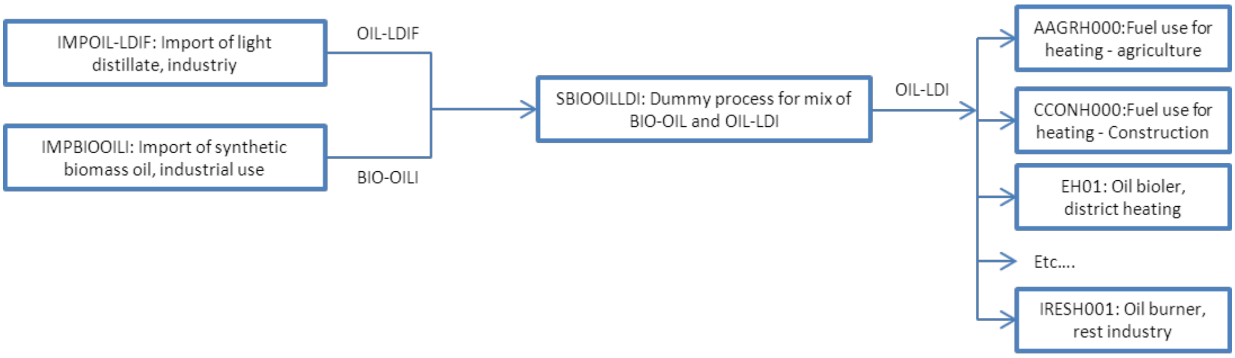

Figure 9 Illustration of substitution between synthetic and fossil fuel oil

Bio diesel is modeled as an input to cars, buses and trucks with a possible range from 5% to 20% (using standard diesel vehicles) or as input to special biodiesel cars or buses (using 100% biodiesel). Bioethanol is used by ethanol cars (85% bioethanol and 15% gasoline). Bioenergy products that are not listed in Table 6 are imported to TIMES-Norway without limitations.

The costs of bioenergy products are presented in Table 7. The costs are included in the model as ACT_COST or IRE_PRICE of the imported energy carrier or the domestic renewable resource. The development in costs is based on the price development of light distillate oil and therefore also by the development of crude oil (see Figure 10).

Table 7 Cost of bio energy carriers (NOK/MWh)

TIMES-Norway name		2006	2010	2015	2020	2030	2040	2050
IMPBIODSL	Import of biodiesel (2. generation)	900	1 052	1 152	1 194	1 252	1 282	1 303
IMPBIOETN	Import of ethanol (E85)	1 050	1 167	1 267	1 309	1 367	1 397	1 418
IMPBIOPEL	Import of pellets	274	339	412	443	485	507	522
IMPBIOCOAL	Import of bio-coal	243	243	248	251	256	264	274
IMPBIOCOKE	Import of bio-coke	317	317	321	324	330	337	347
IMPBIOOILI	Import of synthetic biomass oil, industrial use	670	708	809	851	909	939	959
IMPBIOOILS	Import of synthetic biomass oil, stationary use	760	870	970	1 012	1 071	1 101	1 121
RNWBIOBARK	Biomass bark	-	-	-	-	-	-	-
RNWBIOBLI	Black liquor	140	153	186	200	219	229	236
RNWBIOFOR1	Biomass from forestry cl 1	160	178	216	232	255	266	274
RNWBIOFOR2	Biomass from forestry cl 2	180	216	263	282	309	323	332
RNWBIOMWS	Municipal waste	-	-	-	-	-	-	-
RNWBIOSAW	Biomass saw	140	153	186	200	219	229	236
RNWBIOWDO	Fire wood	100	109	133	143	156	163	168

Delivery costs are added to some technologies as presented in Table 8. This is done do simulate the increased cost of use of pellets in a smaller scale as in the households compared to large commercial buildings. It is also used for bark used by others than the sawmill industry, to simulated the increased costs of transport. Municipal waste has a negative cost, and this is modeled as a delivery cost instead of as a cost of the energy carrier. All delivery costs are at present constant in the entire model horizon from 2006 to 2050.

Table 8 Delivery cost of some technologies (NOK/MWh)

Process	Commodity	2006-2050
Waste steam turbine, CHP	BIO-MWS	-206
Waste steam turbine, CHP (only heat production, electricity price from SKM)	BIO-MWS	-206
Biomass bark boiler, district heating	BIO-BAR	60
Waste boiler, district heating	BIO-MWS	-206
Waste heat, district heating	CSV-IWH	50
Pellets + ELC resistance, new multi-family	BIO-PEL	160
Pellets + ELC resistance, old multi-family	BIO-PEL	160
Pellets + ELC resistance, new single-family	BIO-PEL	160
Pellets + ELC resistance, old single-family	BIO-PEL	160
Fuel wood production from forestry	BIO-FOR	200

3.1.4 Other renewables

Future technologies like power production from tidal currents, waves and salt gradients are currently not included in TIMES-Norway, because data on a regional level is not available. However, these technologies will be added to the model at a later stage.

3.2 Fossil energy resources

Fossil fuel energy carriers are import processes in TIMES-Norway (IMPxxx). There are no limitations on the volumes and the prices are included as IRE_PRICE. Fossil fuel prices are calculated based on the IEA ETP 2012 report [20] and the development of different fossil energy carriers is presented in Figure 10.

Natural gas by pipeline can only be used in region 3 and 5, since these are the only regions with incoming gas pipelines from the North Sea. Possibilities for investments in natural gas infrastructures are not included. In addition, 4600 GWh/year is made available in Finnmark from 2010 from the production terminal in Hammerfest. At present, the use of CNG is limited to 0 in all regions. The model's coding name and the belonging CO_2 emissions for each of the fossil fuel energy carriers are listed in Table 9.

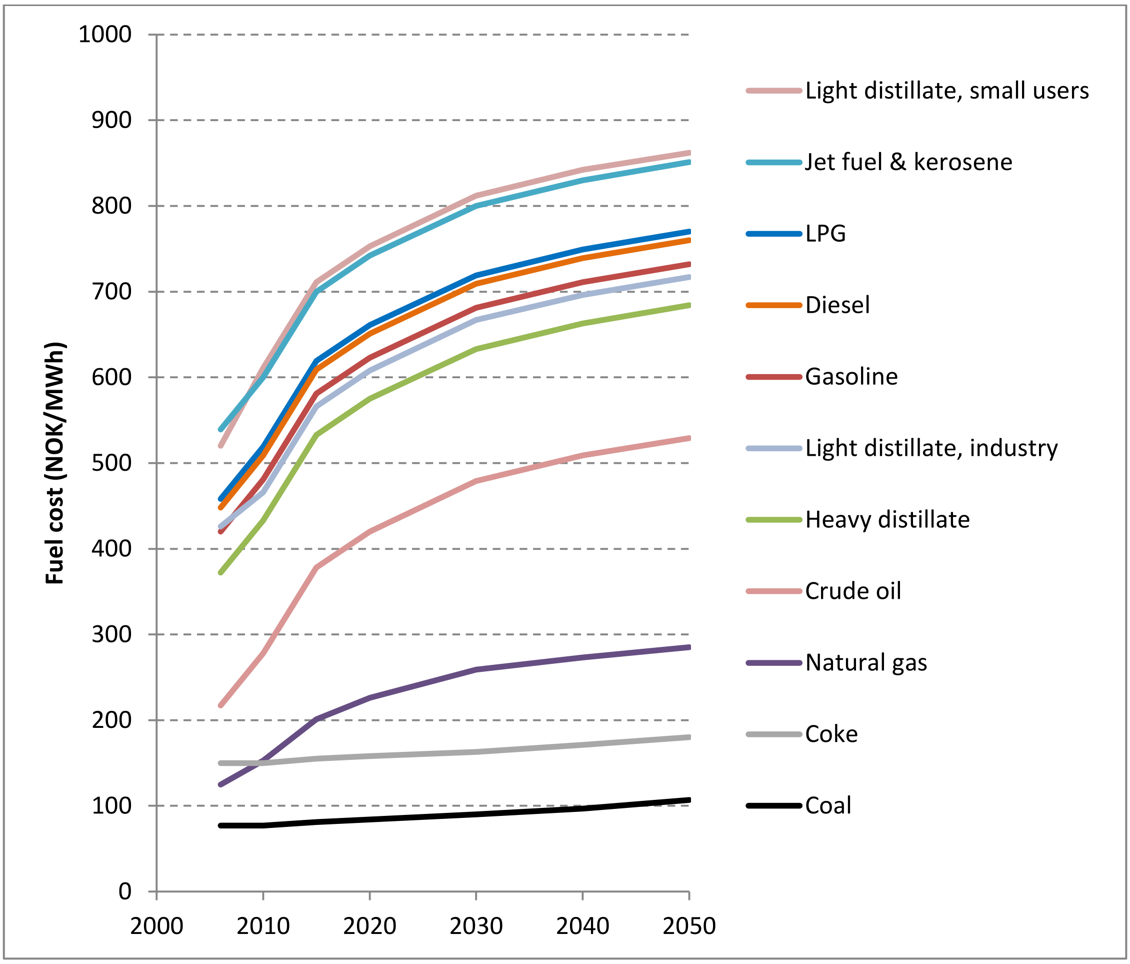

Figure 10 Import price of fossil fuels 2006-2050 (NOK/MWh)

Table 9 Fossil energy carriers, TIMES coding names, and CO_2 emissions (g/kWh)

TIMES-Norway name		CO_2 (g/kWh)
IMPCOAL-COKE	Import of coke	382
IMPCOAL-HC	Import of hard coal	340
IMPNG-CNG	Import of CNG	200
IMPNG-L	Import of natural gas	200
IMPNG-LPG	Import of LPG	240
IMPOIL-CRUDE	Import of crude oil	270
IMPOIL-DSL	Import of diesel (transport)	266
IMPOIL-GSL	Import of gasoline	260
IMPOIL-HDI	Import of heavy distillate industry	270
IMPOIL-HDT	Import of heavy distillate transport	270
IMPOIL-JET	Import of jet fuel	266
IMPOIL-KER	Import of kerosene	266
IMPOIL-LDIF	Import of light distillate industry	266
IMPOIL-LDSF	Import of light distillate stationary (small)	266
IMPOIL-LDT	Import of light distillate transport (marine diesel)	266

3.3 Trade

Import of fossil fuel, biodiesel, bioethanol, bio oil and biocoke are assumed to be carried out at international market prices with no limitations on capacity. As the model mainly describes the domestic energy system in Norway, the only energy consumption in the offshore oil and gas production is electricity consumption taken from the national electricity grid in order to make the national electricity balance meet.

Trade of energy carriers between regions and adjacent countries is only implemented for electricity at the moment. See section 4.1 for details.

3.4 Other Energy Processes and Infrastructures

Many energy processes are not yet included in the model. At present are e.g. bio oil products an import energy carrier to TIMES-Norway, and no production processes are included. Oil refineries are a part of the industry sector with a consumption of energy but without an output of energy carriers.

Three hydrogen production processes are included in TIMES-Norway, based on the research project «NorWays» [21]. The processes are local electrolysis and central SMR with distribution by pipeline or trailer, see Figure 11. The technology data for hydrogen production and distribution are presented in Table 10.

A grid of pipelines for distribution of natural gas or hydrogen is not included in the present version of TIMES-Norway.

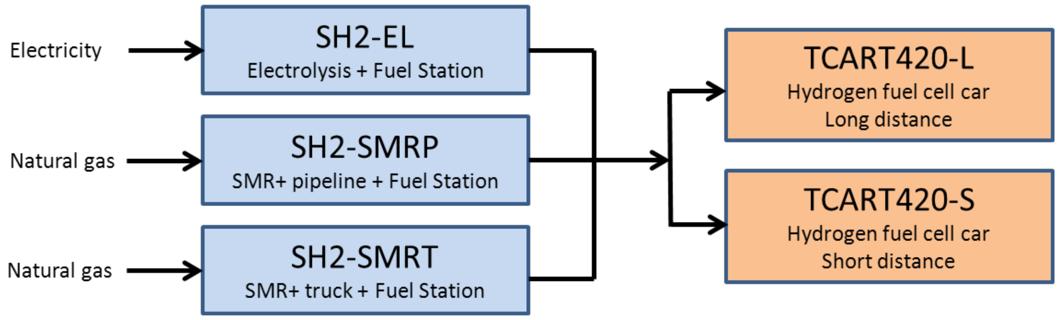

Figure 11 Modelling of hydrogen production with demand end-use technology

Table 10 Technology data of hydrogen production and distribution processes in TIMES-Norway in 2015-2050 (NOK/MWh)

Process	SH2-EL	SH2-SMRP	SH2-SMRT	Unit
	Electrolysis local incl. fuelling station	Central SMR incl. pipeline and fuelling station	Central SMR incl. truck and fuelling station	
Investment cost	5452	7163	4734	NOK/kW
Fixed operating and maintenance cost	233.6	372.45	359.45	NOK/kW
Activity cost	8	0	31	NOK/MWh
Efficiency	0.68	0.83	0.83	

4 Electricity Transmission and Heat Distribution Technologies

The following chapter gives an overview of electricity transmission, electricity export/import capacities and heat distribution technologies.

4.1 Electricity transmission

Figure 12 gives an overview of the electricity transmission system in TIMES-Norway. As illustrated in the figure, high voltage electricity (ELC-HV) can be produced in various power production plants in each of the model's seven regions. This electricity is then fed into the high voltage electricity grid within each region. High voltage electricity can either be used directly (typically in different industry processes), exported, transferred to another region or transformed into low voltage electricity (ELC-LV). Similarly, a low voltage electricity grid exists within each region.

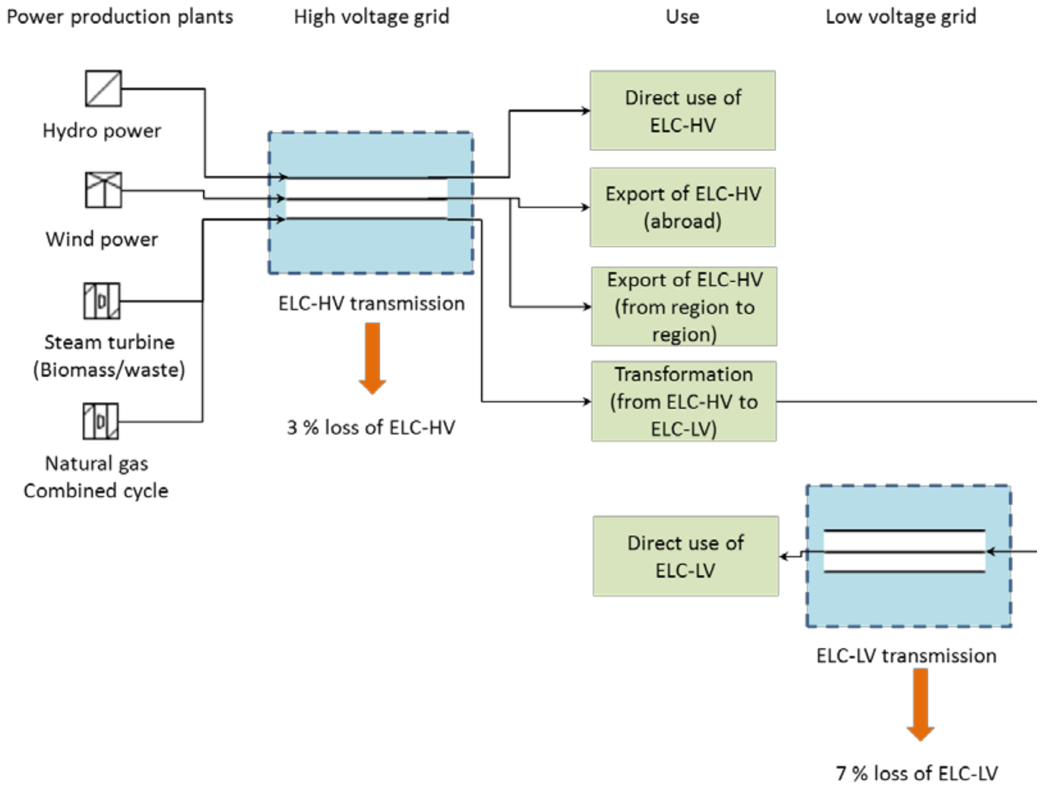

Figure 12: Electricity transmission system

The capacity of the power exchange in the existing high voltage grid between adjacent regions is shown in Figure 2. From 2012 it is possible to invest in new transmission capacity between regions. The model can also invest in transmission capacity domestically, internally within the regions, with associated costs shown in Table 11. Generally, investment costs for a given high voltage grid connection is dependent on the capacity, which is dependent on the size of the cross-section of the cable, and is given per length unit and not per power unit which is the required input to the model. Assumptions on the length of relevant cables for each region were made in order to find the necessary investments costs for the high voltage grid, which consequently varies from region to region. See Table 11 for details.

Table 11: Selected parameters for the DISTR-ELC technology[4] in TIMES-Norway

Region	NCAP_Cost [kNOK/MW]	NCAP_FOM [kNOK/MW]	NCAP_TLIFE [years]	LV length [km]	HV length [km]
Region 1	8 464	179	50	42090	3950
Region 2	8 009	179	50	42660	3700
Region 3	7 082	178	50	35610	3190
Region 4	9 500	180	50	67450	4520
Region 5	11 173	181	50	62940	5440
Region 6	9 027	180	50	36130	4260
Region 7	5 136	176	50	8580	2120

4.2 Electricity export/import capacities

Current electricity export and import capacities are given in Table 12. Notice that Region 6 has two connections with Sweden, and that export to Russia from Region 7 is not possible.

Table 12: Current exchange capacities between countries (MW)

	Netherlands	Denmark	Sweden	Finland	Russia
Region 1	700	1040	-	-	-
Region 2	-	-	-	-	-
Region 3	-	-	-	-	-
Region 4	-	-	2050	-	-
Region 5	-	-	600	-	-
Region 6	-	-	950 (two connections)	-	-
Region 7	-	-	-	100	50 (only import)

It is made possible in the model to invest in new transmission capacity to neighbouring countries. The potential and associated costs are given in Table 13. The new connection between region 1 and Denmark ("Skagerrak 4") is included in the TIMES-Norway model from 2015 as it is already under construction. The other alternatives are available from their possible start-up year. At the moment, it is not possible to invest in new transmission capacity neither to Finland nor Russia.

[4] The parameters in Table 11 were not included in previous TIMES-Norway versions (before February 2013). Instead, an additional tax was included in order to capture the electricity transmission costs.

Table 13: Capacity and costs for new international transmission lines (based on [10])

Connection	Max capacity (MW)	Investment cost (kNOK/MW)	Operating and maintenance cost (kNOK/MW)	Available from (year)
Reg 1 - Denmark	700	8 000	18	2015
Reg1 - Germany	1 000	14 400	33	2021
Reg 1 - Netherlands	700	13 800	32	2030
Reg 3 – UK	1 000	17 000	39	2021
Reg 4 – Sweden	1 400	900	9	2020
Reg 5 – Sweden	1 400	900	9	2020
Reg 6 – Sweden	1 400	900	9	2020
Reg 7 - Finland	-	900	9	-
Reg 7 - Russia	-	900	9	-

4.3 District heating grid

District heat may be generated from several different technologies, see Table 14. The three first mentioned technologies can produce both district heat and electricity (EC01-EC03). Investment costs and distribution losses shown in Table 15 are based on MARKAL-Norway. A bound on the district heating grid is added to ensure that all district heat produced is used (COM_BNDNET fixed 0 of commodity LTH).

Table 14: District heat generating technologies

TIMES name	Description	Commodity name	Commodity description
EC01	Natural Gas CHP gas turbine and boiler	ELC-HV and LTH1	high voltage electricity + district heat
EC02	Biomass steam turbine, CHP	ELC-HV and LTH1	high voltage electricity + district heat
EC03	Waste steam turbine, CHP	ELC-HV and LTH1	high voltage electricity + district heat
EH01	Oil boiler, district heating	LTH1	district heat
EH02	Natural gas boiler, district heating	LTH1	district heat
EH03	LPG boiler, district heating	LTH1	district heat
EH04	Biomass boiler, district heating	LTH1	district heat
EH05	Electric boiler, district heating	LTH1	district heat
EH06	Heat pump sea water, district heating	LTH1	district heat
EH08	Biomass bark boiler, district heating	LTH1	district heat
EH09	Waste boiler, district heating	LTH1	district heat
EH10	Waste heat, district heating	LTH1	district heat

Table 15: Data of district heat in TIMES-Norway

Parameter		Time slice	Data	Unit
NCAP_COST	Investment cost	-	3000	NOK/kW
NCAP_FOM	Operating and maintenance cost	-	140	NOK/kW
COM_IE	Efficiency	W01-W10	0.91	
COM_IE	Efficiency	W11-W18	0.88	
COM_IE	Efficiency	W19-W35	0.85	
COM_IE	Efficiency	W36-W43	0.88	
COM_IE	Efficiency	W44-W52	0.91	
COM_CSTPRD	Cost on production of commodity	Annual	12	kNOK

The end-use technology “district heat exchanger” xxxH007 is modeled with an investment cost based on information from Norwegian district heating companies and from the Swedish Energy Agency of 65 000 NOK/dwelling and 50 000 SEK/dwelling respectively.

Use of district heating in the model is restricted since only one grid per region is modelled. In principle, this restriction could be avoided, if a sufficient number of grids were modeled. At present, the restriction is based on assumptions of Klimakur 2020 where district heat is assumed to be able to cover maximum 38 % of heat demand in service buildings and 23 % of heat demand in residential buildings. Klimakur 2020 does not have separate potentials for apartments and single-family houses, and thus, an estimation based on Swedish data was done. In TIMES-Norway it is assumed that 80% of heat demand in multi-family houses may be connected to district heating and 15% of the heat demand of single-family houses (in total approximately 23%).

An overview of the district heating system in TIMES-Norway is given in Figure 13 below.

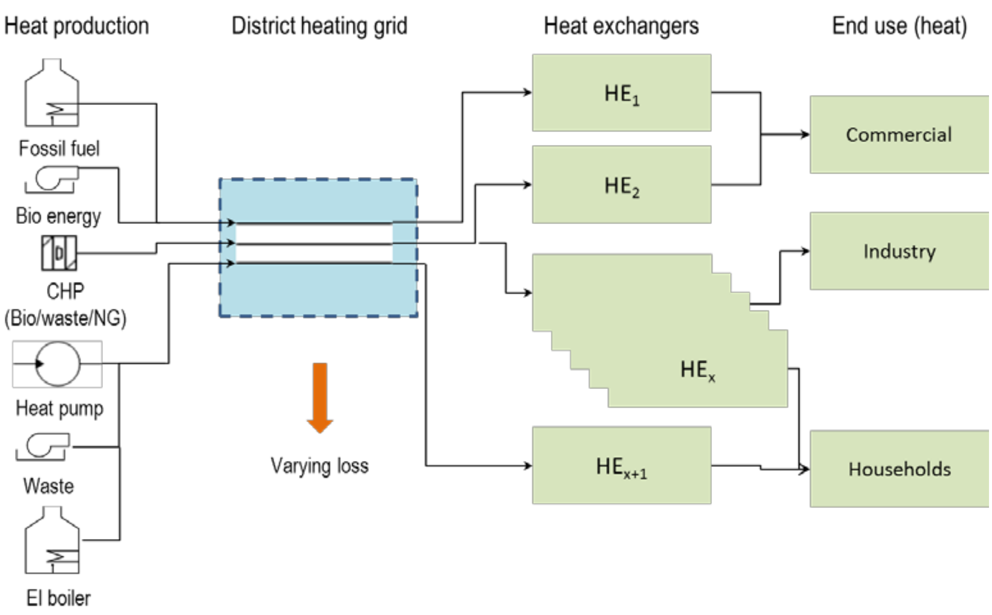

Figure 13: District heating system

5 Residential sector

5.1 Structure

The residential sector has five sub-groups with the model abbreviation in brackets:

- Existing (old) single-family houses (RSIO)
- New single-family houses (RSIN)
- Existing (old) multi-family houses (RMUO)
- New multi-family houses (RMUN)
- Cottages (RCOT)

New houses are houses built after the base year of the model (2006). The energy service demand is divided into heating and electricity. “Heating” includes both space heating and hot water, while “electricity” is all demand of electricity that can not be replaced by another energy carrier, i.e. lighting and electrical appliances.Energy service demand

5.1.1 Base year

The energy service demand in the base year 2006 is based on the municipality energy(?) statistics (“kommunestatistikken”), the reporting of electricity use to NVE (“eRapp”), and the dwelling statistics of 1 January 2006 (“boligstatistikken”). NVE and IFE agreed on an energy end-use share of 70% of energy use for “heating” and 30% for “electricity.” The demand of cooling was considered to be too small and uncertain to be included. It was further agreed to separate “heating” into 58 % for space heating and 12 % for hot water heating. The division of energy end use in “electricity” and “heating” demand was decided to be equal for single- and multi-family houses.

The demand for space heating was first temperature corrected by use of the heating degree method. Heating degrees for one representative place in each of the seven regions were used for the base year and for a normal year, see Table 16. The temperature corrected electricity consumption was adjusted to the temperature correction method used by NVE (for use in the EMPS model). The temperature corrected energy consumption in the regions number 1, 2, 4, 5 and 6 was therefore adjusted. The final temperature correction resulted in 2977 GWh increased electricity consumption in the base year compared to the statistics.

Table 16: Heating degree days of selected places in 2006 and of a normal year

Region	Place	2006	Normal	Ratio (2006/Normal)
1	Kristiansand	3245	3615	0.90
2	Skien	3605	3926	0.92
3	Bergen	3045	3530	0.86
4	Oslo	3550	4041	0.88
5	Trondheim	3740	4339	0.86
6	Tromsø	4556	5027	0.93
7	Sør-Varanger	6035	6296	0.96

5.1.2 Load profiles

NVE developed load profiles for all end use sectors in the TIMES-Norway model. The load profiles developed for households and tertiary sector are based on [22], combined with hourly electricity loads for selected tertiary sectors [23]. In [22], regression analysis on hourly measured energy consumption for various building types were performed and used to estimate the relationship between outdoor temperature and heat demand for each hour of the day. Various heat load profiles for households, hospitals, office buildings and other service buildings were obtained by using a representative outdoor temperature for each region.

The following load profiles were established with a time resolution of 8736 hours:

- Electricity and heat demand for each sub-sector within households, service sectors and the rest-industry sector
- Short distance personal cars
- Constant loads for industry and the rest of the transportation sector

Load profiles for heat demand include space heating and hot water for households and non-residential buildings. Load profiles for the electricity demand, including lighting and appliances, were found to be independent on outdoor temperatures, but have seasonal variations instead due to varying hours of daylight during the year [22].

To show how the generalised load profiles for TIMES-Norway fits the estimated load profiles from [22], the households are taken as an example. Figure 14 shows a load profile for a household in week 7 (middle of February), with an assumed consumption of 400 kWh/week. The electricity load is shown in blue, whereas the heat load is given in red. The solid lines are profiles applied in TIMES-Norway whereas the dotted lines are the hourly load profiles based on [22]. Figure 14 show that the profiles follow the daily variations quite well, with the evening load higher than the night load. However the peak hours are not totally captured, and the load profile during weekends are kept at constant level although this is not the case. Nevertheless, it was decided not to divide the weekend into more time slices to prevent the model size to increase further. In addition, the total electricity load in the power system is not critical during weekends, and thus it is likely that the benefit will be small with higher time resolution in this period.

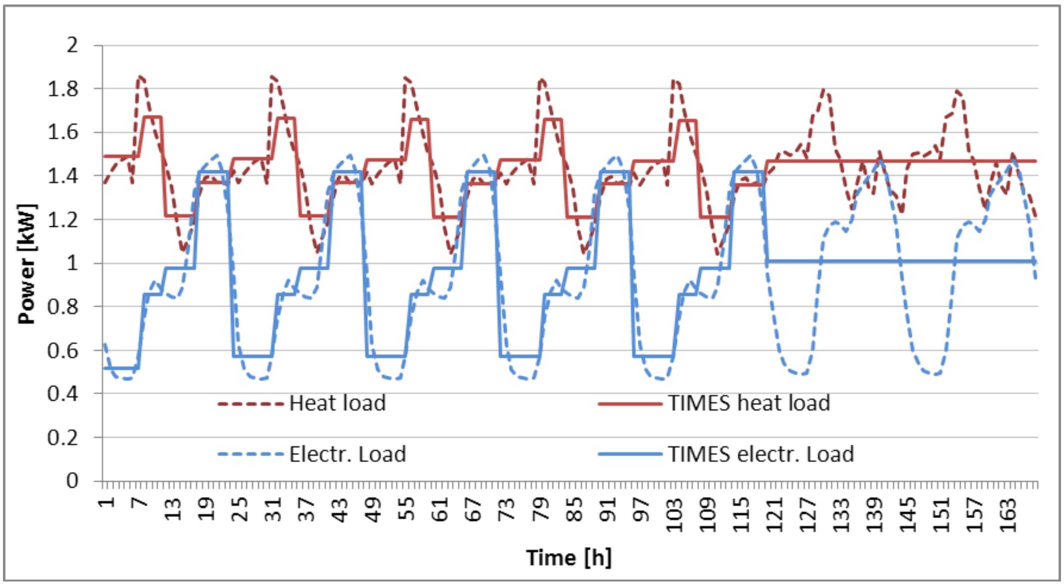

Figure 14: Electricity load and heat load over a week in February for a household in southern Norway based on [22]

In order to ensure that the total load profile in TIMES-Norway complies with the actual load profile for the electricity consumption, the load profiles using temperatures from 2006 were calibrated with the total electricity consumption in 2006 from Nord Pool Spot. Figure 15 shows how the estimated 2006 total electricity load profile (red) fits the actual total load profile (blue) for Norway in 2006 [24]. The estimated load profile fits quite well in winter and during summer. However, it seems like the estimated profile is not able to catch the lower demand in November and December in 2006.

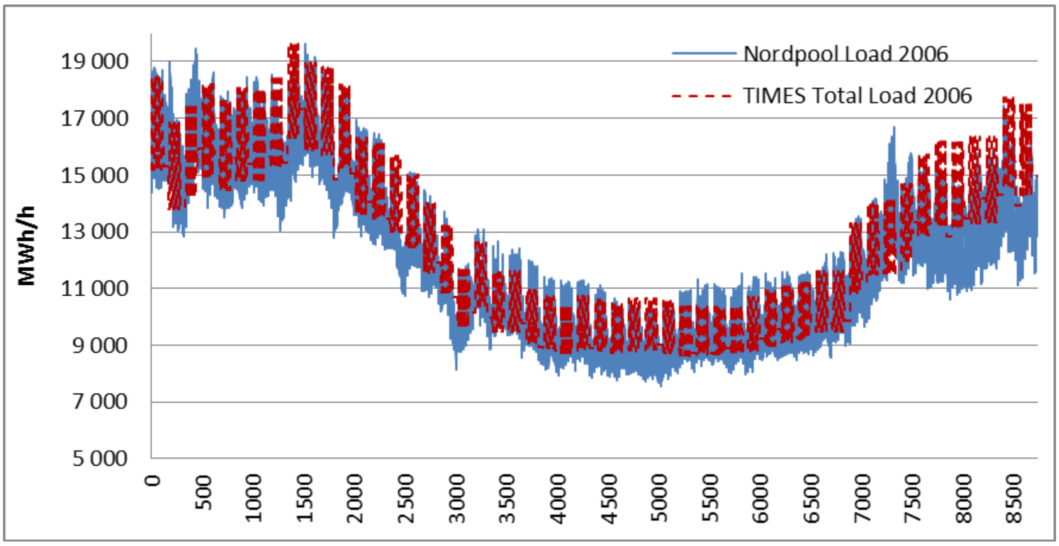

Figure 15: Calibration results for the electricity load profiles. Total load profile (blue) for Norway in 2006 (Nord Pool Spot) and estimated total load profile used in TIMES-Norway (red)

5.1.3 Energy demand forecast

Energy services demand of each period, sub-group and demand type are exogenous input to TIMES-Norway. The useful energy demand forecast of the base case of the 2012-version of the model is described in [25]. Important sources of this forecast are "Perspektivmeldingen 2009" [26] and the population projections of Statistics Norway in 2009 [27]. The population projection is divided in regions up to 2030 and the further projection up to 2050 is based on the same development as in 2020-2030 summing up to the population growth of Norway as a total, see Figure 16. The resulting forecast of the sub-groups and types of the residential sector is presented in Figure 17 and the development per region is presented in Figure 18.

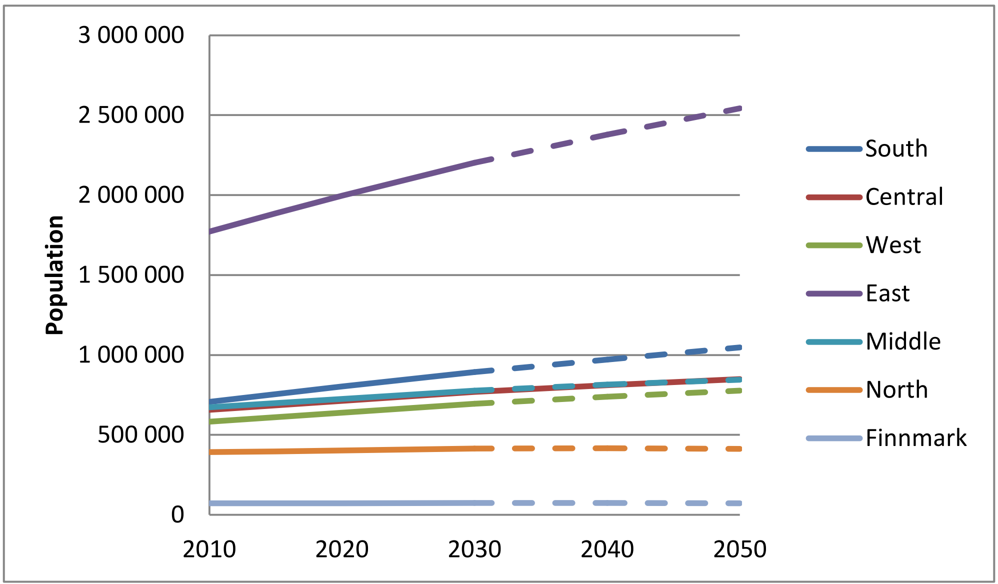

Figure 16: Population projection based on the middle scenario of Statistics Norway (MMMM) in 2009 [27]

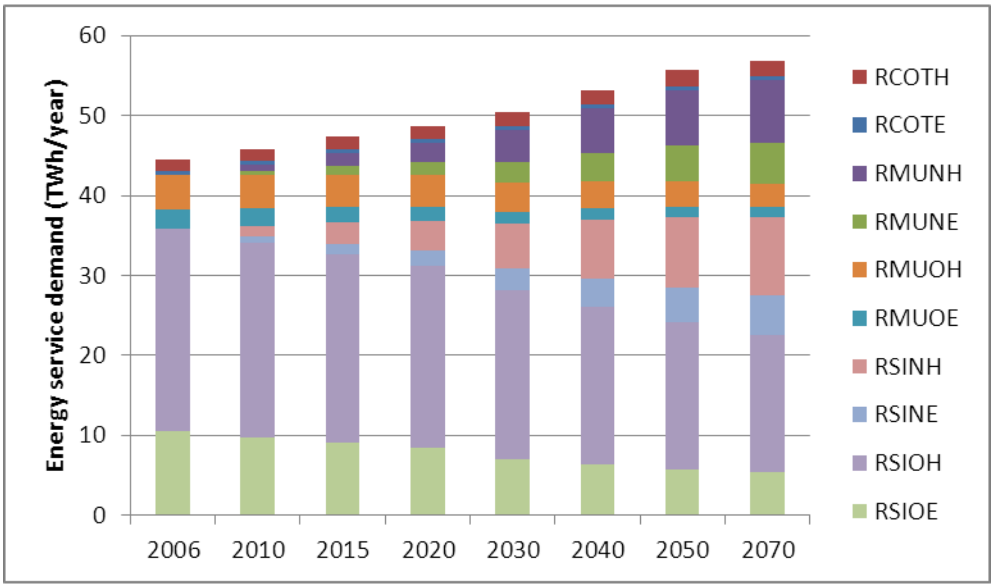

Figure 17: Forecast of energy service demand for households divided on sub-group and type, 2006-2050. (TWh/year)

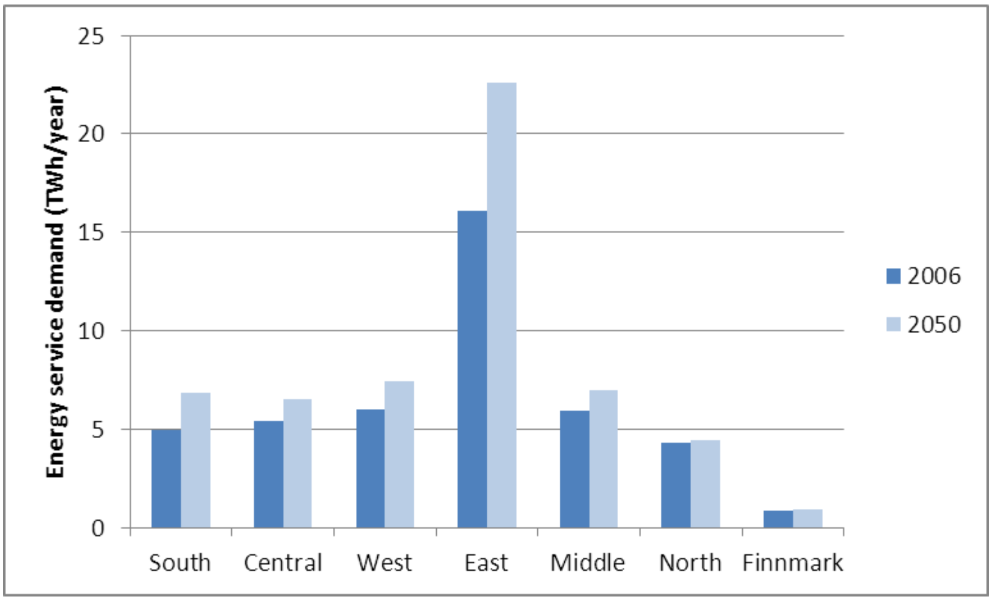

Figure 18: Forecast of energy service demand separated on regions (TWh/year in 2006 and 2050)

5.2 End-use technologies

Existing technologies of the Norwegian energy system is included as residuals in the model (RESID). The capacity in the base year (GWh/year) is included and in the household sector it is assumed that all existing technologies have a linear depreciation during the life time. The existing capacity is calculated based on the energy use in 2006. This has to be a minimum of the existing capacity and probably it is higher. In order not to overestimate the existing capacity, it is in most cases at the level of the 2006 consumption. Most of the end-use technologies have a capacity bound in 2006 in order to get about the same energy use as the energy statistics.

The following heating end-use technologies are available in TIMES-Norway (with the model number in brackets):

Technologies connected to a water-borne heating system within the building:

- Oil boiler (H001)
- Natural gas boiler (H002)
- LPG boiler (H003)
- Wood pellets boiler (H004)
- Electric boiler (H005)
- Heat pump – water-to-water (H006)
- District heat (H007)

Direct heating technologies (without water-borne heating system within the building):

- Direct electric heating (H010)
- Wood stove in combination with direct electric heating (H012)
- Wood pellets stove in combination with direct electric heating (H013)
- Kerosene stove in combination with direct electric heating (H014)

- Heat pump – air-to-air (H015)

Other technologies:

- Water-borne heating system (H020)
- Energy efficiency measures, heating, price class I
- Energy efficiency measures, heating, price class II
- Energy efficiency measures, heating, price class III
- Energy efficiency measures, heating, price class IV
- Energy efficiency measures, heating, price class V
- Solar thermal collectors, price class I (H025)
- Solar thermal collectors, price class II (H026)
- Solar thermal collectors, price class III (H027)

All boiler technologies, water-to-water heat pumps and district heating are connected to the technology for water-born heating system (H020). All direct heating technologies are modelled as combined technologies with partly direct electric heating (to cover all space heating) and with an electric water heater for hot water.

In cottages, the only heating technology made available is "Wood stove in combination with direct electric heating (H012)". Most of the end-use technologies are available for all single- and multifamily houses, however there are a few exemptions: solar thermal collectors are only available in new single-family houses, air-to-air heat pumps are not available for multi-family houses, and kerosene stoves are not available for new houses. This sums up to the following exemptions from the list above:

- New multi-family houses can not use:
    - Kerosene stove in combination with direct electric heating (H014)
    - Heat pump – air-to-air (H015)
    - Solar thermal collectors, all price classes I-III (H025 to H027)

- Existing multi-family houses can not use:
    - Heat pump – air-to-air (H015)
    - Solar thermal collectors, all price classes I-III (H025 to H027)

- New single-family houses can not use:
    - Kerosene stove in combination with direct electric heating (H014)

- Existing single-family houses can not use:
    - Solar thermal collectors, all price classes I-III (H025 to H027)

The investment costs of the end-use technologies are as far as possible based on data from Klimakur2020 [28]. The costs and calculations are described in [4].

With the costs used in the model, the potential for use of district heat and air-to-air heat pumps is restricted. There is an upper bound of the potential for district heat in multi-family houses of 80 % of the heat demand and in single-family houses of 15 % of the heat demand. In Klimakur2020 the potential of all dwellings were 23 %, but since no data for multi- and single-family houses separately were available, an assumption of the share was made, partly based on Swedish data.

Due to restrictions on use of air-to-air heat pumps in many multi-family houses, this potential is presently fixed to zero. The potential of air-to-air heat pumps in single-family houses is restricted to 55 % of the heating demand (it is assumed that this type of heat pump is not able to cover all space heating demand of the house. Solar thermal collectors are available for new single-family houses and the potential is calculated to 20 % of the heating demand. It is modeled with three classes of investment costs with equal potential. Both heat pumps and solar thermal collectors are modelled as technology choices in the modell and are not included in the energy efficiency potential described below.

The energy efficiency measures available in TIMES-Norway are gathered in four cost classes. The potentials and costs for each group are based on the work of Klimakur [28] and is shown in Table 14. Restrictions on use of some of the technologies are taken care of in scenarios, such as the TEK10 scenario were e.g. direct electric heating is made unavailable for new buildings.

Table 17: Energy efficiency measures in households in 2020 in TIMES-Norway based on the work of Klimakur2020 [28].

		Life time	Energy		Investment		
		year	GWh saved in 2020	%	kr/m2	kWh saved /m2	kr/kWh
	Existing dwellings						
1	Energy control	10	649	1.6%	6.37	5.80	1.875
2	Insulation and tighting	30	2 262	7.7%	175.31	20.20	16.25
3	Technical equipment (BAT)	15	1 120	2.8%	139.40	15.10	12.50
4	Energy management	10	894	2.2%	45.93	7.40	8.75
	New dwellings						
1	Energy control	10	91	1.8%	8.40	2.72	1.50
2	Insulation and tighting	30	319	10.0%	81.80	9.52	11.25
3	Technical equipment (BAT)	15	152	3.0%	60.72	6.80	15.00
4	Energy management	10	182	3.6%	68.22	5.44	20.00

6 Service sector

6.1 Structure

The tertiary sector has five sub-groups with the model abbreviation in brackets and 1 – 3 demand types:

- Construction (CCON) — heating, electricity (lighting & appliances)
- Education (CEDU) — heating, cooling, electricity (lighting & appliances)
- Health and social service (CHEA) — heating, cooling, electricity (lighting & appliances)
- Hotel and restaurant (CHOT) — heating, cooling, electricity (lighting & appliances)
- Office buildings (COFF) — heating, cooling, electricity (lighting & appliances)
- Other commercial (COTH) — heating, cooling, electricity (lighting & appliances)

- Road light (CROL) electricity
- Wholesale and retail (CWSR) heating, cooling, electricity (lighting & appliances)

6.2 Energy service demand

6.2.1 Base year

In 2006, 77 % of the energy consumption in this sector was electricity. The energy service demand in the base year (2006) is mainly based on the reporting of electricity use to NVE ("eRapp"), with additional information on national energy consumption per sector from the energy balance and regional energy consumption of the total service sector from the municipality statistics ("kommunestatistikken").

The division of energy service demand on electricity, heat and cooling demand for each of the eight tertiary sub-sectors are based on [29] and is presented in Table 18.

Table 18 Energy by end-use of tertiary sector

CCONE	CONstruction	Electricity	27 %
CEDUE	EDUcation	Electricity	31 %
CHEAE	HEAlthcare	Electricity	32 %
CHOTE	HOTel and restaurants	Electricity	40 %
COFFE	OFFices	Electricity	44 %
COTHE	OTHer commercial	Electricity	44 %
CROLE	ROad Light	Electricity	100 %
CWSRE	WholeSale and Retail	Electricity	50 %
CCONH	CONstruction	Heat	73 %
CEDUH	EDUcation	Heat	69 %
CHEAH	HEAlthcare	Heat	66 %
CHOTH	HOTel and restaurants	Heat	46 %
COFFH	OFFices	Heat	54 %
COTHH	OTHer commercial	Heat	54 %
CWSRH	WholeSale and Retail	Heat	30 %
CEDUC	EDUcation	Cooling	0 %
CHEAC	HEAlthcare	Cooling	2 %
CHOTC	HOTel and restaurants	Cooling	14 %
COFFC	OFFices	Cooling	2 %
COTHC	OTHer commercial	Cooling	2 %
CWSRC	WholeSale and Retail	Cooling	20 %

The heating demand is corrected for outdoor temperatures as described in chapter 5.1.1. The share to be temperature corrected is presented in Table 19.

Table 19: Temperature dependent share of heating demand in the sub-groups of the service sector

	Temperature dependent share of thermal energy use
EDUcation	90 %
HEAlthcare	79 %
HOTel and restaurants	72 %
OFFices	89 %
OTHer commercial	89 %
WholeSale and Retail	90 %

6.2.2 Load profiles

NVE developed load profiles for all end use sectors in the TIMES-Norway model as described in chapter 5.1.2.

6.2.3 Energy demand forecast

Energy services demand of each period, sub-group and demand type are exogenous input to TIMES-Norway. The useful energy demand projection of the base case of the 2012-version of the model is described in [25]. Important sources of this projection are “Perspektivmeldingen 2009” [26] and the population projections of Statistics Norway in 2009 [27]. The regional development is based on the regional population development. The demand in 2006 and 2050 of the base scenario is presented in Figure 19 and Figure 20.

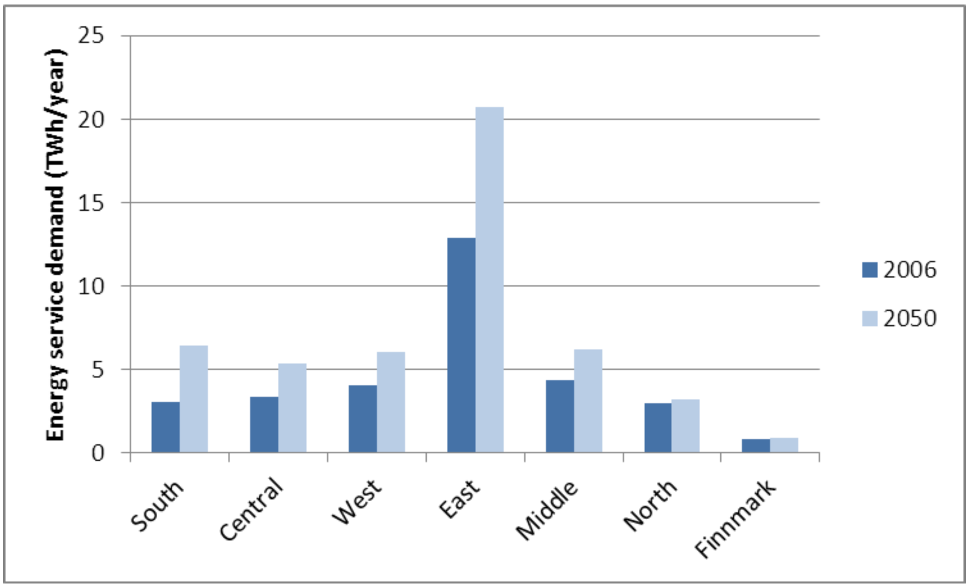

Figure 19 Energy service demand per region of the tertiary sector in 2006 and 2050 (TWh/year)

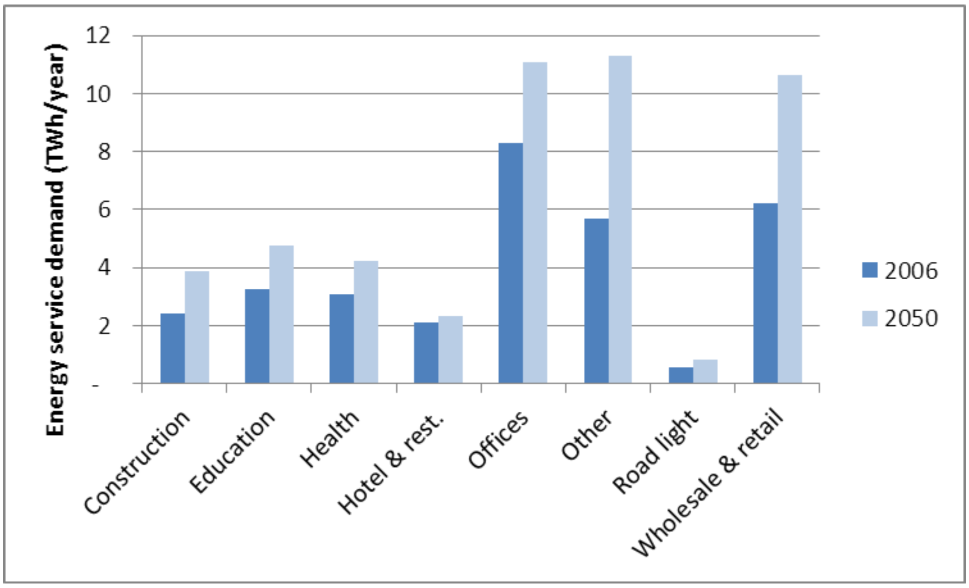

Figure 20: Energy service demand per tertiary sub-sector in 2006 and 2050 (TWh/year)

6.3 End-use technologies

Existing technologies of the Norwegian energy system is included as residuals in the model (RESID). The capacity in the base year (GWh/year) is included and in the service/tertiary sector it is assumed that all existing technologies have a linear depreciation with a zero residual when the life time of the technology is reached. The existing capacity is calculated based on the energy use in 2006. This has to be a minimum of the existing capacity and probably it is higher. In order not to overestimate the existing capacity, it is in most cases at the level of the 2006 consumption. An exception is the capacity of oil boilers that is assumed to have at least the same capacity as electric boilers. Most of the end-use technologies have a capacity bound in 2006 in order to get about the same energy use as the energy statistics.

The following heating end-use technologies are available for the tertiary sector in TIMES-Norway (with the model number in brackets):

- Oil boiler (H001)
- Natural gas boiler (H002)
- LPG boiler (H003)
- Wood pellets boiler (H004)
- Electric boiler (H005)
- Heat pump – water-to-water (H006)
- District heat (H007)
- Direct electric heating (H010)
- Water-borne heating system (H020)
- Energy efficiency measures, heating, price class I
- Energy efficiency measures, heating, price class II
- Energy efficiency measures, heating, price class III
- Energy efficiency measures, heating, price class IV
- Energy efficiency measures, heating, price class V

All boiler technologies, water-to-water heat pumps and district heating have to have a water-born heating system (H020).

The construction sector is modeled as a fixed share of energy carriers, equal to the statistics of 2006.

Cooling is modeled as a demand of electricity with no possibilities to choose end-use technologies. This is intended to be better modeled in the future.

The district heating potential is limited to a maximum of 38 % of the heating demand, in accordance with the Klimakur2020 study. As for the residential sector, energy efficiency measures is based on the work of Klimakur2020 [28]. The energy efficiency measures included in the TIMES-Norway model are presented in Table 20.

The investment costs of the end-use technologies are as far as possible based on data from Klimakur2020 [28]. The costs and calculations are described in [4]. Restrictions on use of some of the technologies are taken care of in scenarios, such as the TEK10 scenario were e.g. direct electric heating is made unavailable for new buildings.

Table 20: Energy efficiency measures in tertiary sector in 2020 in Klimakur2020 [28]

		Life time	**Energy**		**Investment**		
		year	**GWh saved in 2020**	**%**	**kr/m2**	**kWh saved /m2**	**kr/kWh**
1	Energy control	10	312	1.0%	6.10	5.92	2
2	Insulation and tighting	30	557	3.1%	62.23	4.72	19
3	Technical equipment (BAT)	15	382	1.3%	111.52	8.57	23
4	Energy management	10	499	1.7%	142.44	8.08	13

7 Agricultural Sector

The energy use in the agricultural sector is rather small and is only modeled as a demand of energy carriers with the same share as in the base year. The forecast of energy demand is based on the development of value added in this sector in "Perspektivmeldingen 2009" and increases from 2.6 TWh in 2006 to 5 TWh in 2050.

8 Industry Sector

8.1 Structure

The industry sector has the following 11-14 sub-groups with the model abbreviation in brackets (region 3 has 5 aluminium sub-sectors, the other regions have 2):

- ALuminium Company A(IALA)
- *ALuminium Company B (IALB) – only in region 3*
- *ALuminium Company C (IALC) – only in region 3*

- *ALuminium Company D (IALD) – only in region 3*
- ALuminium group Residual (IALR)
- CHemical industry group A (ICHA)
- CHemical industry group Rest (ICHR)
- MEtal industry group A (IMEA)
- MEtal industry group Rest (IMER)
- MINing (IMIN)
- Pulp and Paper group A (IPPA)
- Pulp and Paper group Rest (IPPR)
- REFineries (IREFr)
- RESidual industry (IRES)

Energy demand in all industrial sub-sectors is divided on heat, electricity (non-substitutable) and energy use as raw material. Energy demand in offshore activities are not included, however energy demand for petroleum activities onshore and electrification of oil platforms from the onshore grid are included in the "Mining" sub-group (IMIN). The name of the companies in all major groups are presented in [3].

8.2 Energy service demand

8.2.1 Base year

It was challenging to determine energy use divided on each of the industry sub-groups in each region. The energy balance is detailed on a national level of different industry subsectors, while the municipality statistics only includes industry as a total. Company data of energy carriers except electricity could be found for many companies in the database of Klif [13] , but it was difficult to harmonize these data with other data. Important data sources for electricity demand were the reporting of utilities to NVE (eRapp) and Nord Pool. Updating of the base year for industry will be time consuming.

8.2.2 Load profiles

Load profiles for the industry are assumed to be flat, i.e. constant load over the year. This fits well for the energy intensive industry in Norway which operates continuously, except from revisions and maintenance breaks.

8.2.3 Demand forecast

The forecast of energy service demand of the base case of the 2012-version of the model is described in [25]. In general, most of the energy intensive industry are assumed to have constant future energy demand in the base case scenario. Increased and decreased activities in these large plants are handled in different scenarios. The known closing of plants by 2011 is included in the forecast.

Forecast of other industry ("Residual industry (IREF)") is as described in [25], resulting in a small decrease of 1 % in 2020 and 4 % in 2050. Onshore petroleum activities as well as electrification of offshore activities is included in "mining" and in the base case scenario this will increase by 114 % due to planned expansion of these activities. Forecasted energy service demand of the industry sector in the Base case is shown in Figure 21.

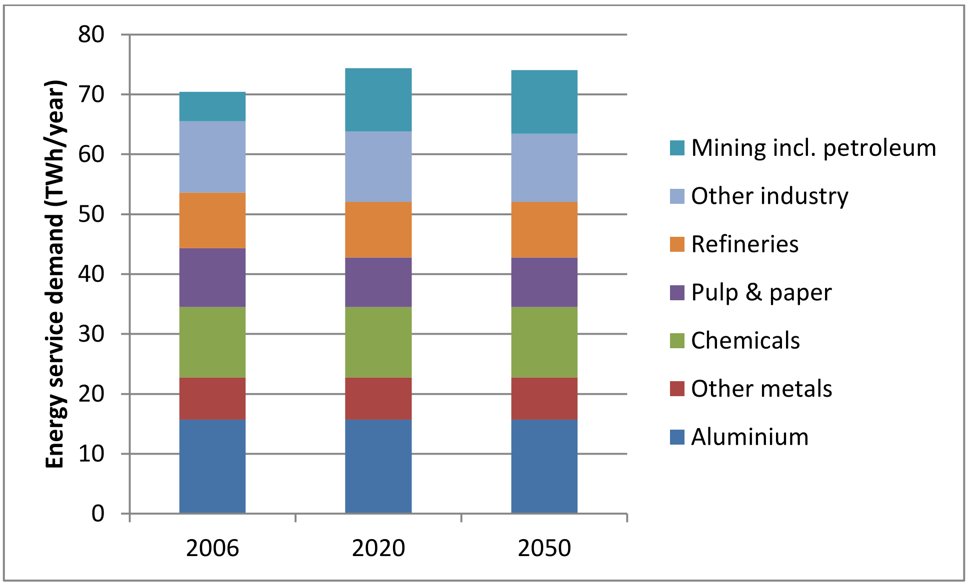

Figure 21: Energy service demand in 2006, 2020 and 2050 (TWh/year)

8.3 Energy end-use technologies

The energy end-use technologies available for the industry sector are in general:

- Oil boiler (H001)
- Natural gas boiler (H002)
- LPG boiler (H003)
- Electric boiler (H005)
- Heat pump – sea/ground (H006) – only in other industry (residual industry)
- District heat exchanger (H007)
- Biomass boiler – chips (H008) – in pulp & paper, rest metals, residual industry
- Black liquor boiler (H009) – only in pulp & paper industry
- Biomass boiler – bark (H018) – only in pulp & paper industry and other industry (wood ind.)
- Steam turbine – in metal industry and pulp & paper

Chemical industry, refineries and mining have only a demand of energy carriers since it was difficult to divide the energy use in direct use and process heat. The share of energy carriers is kept constant.

Electricity production by steam turbines is available in pulp & paper industry and in other metals industry, but the potential is restricted to the capacity of the base year. Heat pump is a possible technology in the other industry sectors and it has a potential of 25 % of the heating demand. Energy efficiency measures on the detailed level that TIMES-Norway requires are not available, and therefore no energy efficiency measures are included (except for the mentioned steam turbines and heat pumps).

9 Transport sector

Energy demand in the transport sector is divided into the following categories and units, with the model abbreviation in brackets:

• Car transport short distance (TCART-S)	Million Vehicle -km (MV-km)
• Car transport long distance (TCART-L)	Million Vehicle -km (MV-km)
• Freight transport (TFRET)	GWh
• Public transport by bus (TPUBT)	Million Vehicle -km (MV-km)
• Public transport by train (TPUTT)	GWh
• Air transport (TAIRT)	GWh
• Sea transport (TSEAT)	GWh
• Other (TOTHT)	GWh

Car transport can choose between the following technology options (types of cars):

- Gasoline car
- Diesel car (fossil fuel with 5-20 % biodiesel)
- Biodiesel car (100 % biodiesel)
- E85 cars (85 % ethanol and 15 % gasoline)
- Electric battery car
- Hybrid car (electricity and gasoline)
- Plug-in hybrid car (electricity and gasoline)
- Fuel cell car

Freight transport can vary the share of biodiesel from 5 % to 20 %, but have no other choices (see chapter 3.1.3). Bus transport has three alternatives: diesel bus, biodiesel bus and natural gas bus. Transport by train and sea has no alternative choices at present. “Other (TOTHT)” is a residual in order to capture all energy used for transportation purposes according to the national energy statistics. Basing the energy use on the municipality statistics gave a problem with inter-regional use such as air and sea transport and much of this consumption is included in “other” for simplicity.

The load profile for personal short distance electric cars is developed on the assumption that the cars will be charged during the night only. This was an initial assumption which needs to be improved.

The forecast of energy demand in the transport sector is mainly based on The National Transport Plan [30] and is described in [25]. A summary of the forecast of car transport per region is shown in Figure 22.

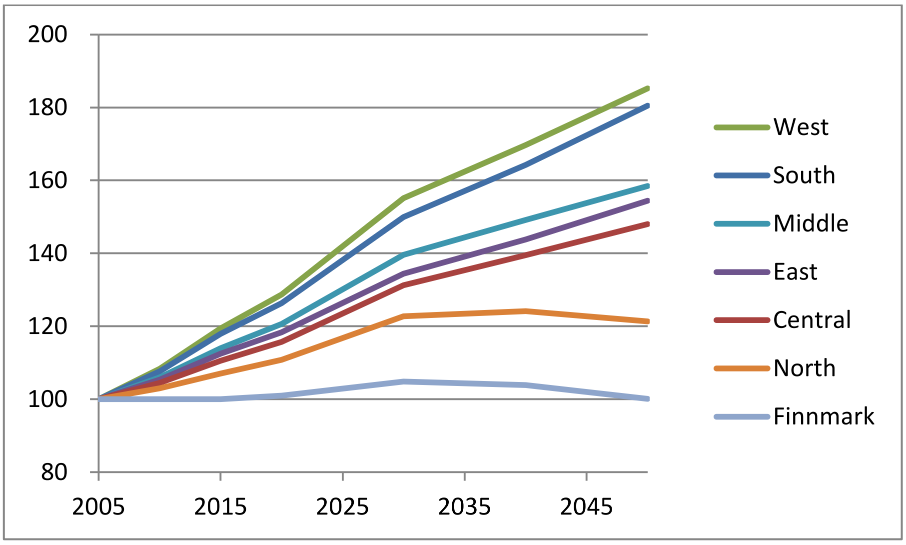

Figure 22 Relative development of car transport per region

10 Scenarios

10.1 Methodology

Technologies and/or data that not always are included in the analyses, can (by benefit) be modeled as a scenario. Examples are electricity production plants which are included in the scenario PP (Power Plants) and when TIMES-Norway is run in combination with EMPS, the scenario PP is not included, since the electricity price is an input to TIMES-Norway from EMPS (see paragraph 2.4 for more information of the interaction with EMPS).

The running order of scenarios is important, since data is “overwritten” by the last scenario (for more information, see the TIMES documentation [5-7]).

10.2 Scenario description

The scenarios are an important part of the analyses and will naturally be developed along with new analyses. As of January 2013, the following main scenarios are included in the model:

- PP Power Plants
- DH District Heating Plants
- EMPS Power Price from EMPS (Samkjøringsmodellen)
- TAX Taxes

All the power production processes in the model are included in the PP scenario, whereas all heat production technologies connected to a district heating grid are included in the DH scenario. The EMPS scenarios is described in paragraph 2.4 and the taxes are described in chapter 10.3. In addition several variations of these scenarios are developed, such as DH_ENOVA with the present subsidies from the Energy Fund and PP_CER with a simple modeling of the Green Certificate Market.

In different analyses, new scenarios are developed such as:

- FORNYBR	Fornybarbrøken (Target on the renewable fraction [31, 32])
- TRABROK	Transportbrøken (Target on renewable fraction of transportation [31])
- TEK10	Restrictions on the use of electricity for heating
- PP_CE_CL	Power plants with certificate market and climate change
- HIGH_POP	Scenario 1: High population (High demand scenario)
- LOW_IND	Scenario 2: Low demand in industry
- ELC_OFF	Scenario 3: Electrification offshore
- HIGH_REG	Scenario 4: Increased activity in region 5 (Industry cluster)

In the scenario TEK10, restrictions to the use of electricity for space heating is included in order to model this part of the buildings regulations of 2010. Technologies using direct electric heating such as xxxxH010 and electric boilers (xxxxH005) have an activity bound equal to the residual of the base year in this scenario.

Scenario PP_CE_CL and two others (PP_CE_C4 and PP_CE_C9) are from analyses including the effects of climate change on hydropower production. The climate change data is from an earlier MARKAL-project [33] and the new results from analyses with TIMES-Norway are described in [34].

The last 4 above (Scenario 1-4) are scenarios with different forecasts of future energy service demands.

10.3 Scenario: Taxes

Taxes in TIMES-Norway is gathered in the scenario TAX. The TIMES-parameter is FLO_TAX and the taxes are at present based on the taxes of 2012 [35], and kept constant from 2010 to 2070, see Table 21. A simple modeling of VAT of 25 % is included in private energy consumption, based on the level of energy prices in 2012 and with a constant value throughout the modeling horizon.

Table 21: Energy taxes in TIMES-Norway 2010-2070 (NOK/MWh)

Commodity	Name	2010-2070 (NOK/MWh)
BIO-DSL	Biodiesel	420
BIO-ETN	Ethanol	231
BIO-OILI	Bio-oil, industrial use	-
BIO-OILS	Bio-oil, small users	-
BIO-PEL	Wood pellets – Commercial consumption	-
BIO-PEL	Wood pellets – Private consumption	83
ELC-HV	Electricity, high voltage – industry	4.5
ELC-LV	Electricity, low voltage – industry	5
ELC-LV	Electricity, low voltage – commercial consumption	114
ELC-LV	Electricity, low voltage – private consumption	284
LTH	District heat – private consumption (VAT)	130
NG-L	Natural gas before pipeline distribution (for industry and power plants)	4.5
NG-LPG	Liquid Petroleum Gas	52
NG-LPG	Liquid Petroleum Gas – private consumption	182
NG-PL	Natural gas after pipeline distribution (local)	174
OIL-DSL	Diesel – commercial consumption	424
OIL-DSL	Diesel – private consumption	661
OIL-GSL	Gasoline – commercial consumption	613
OIL-GSL	Gasoline – private consumption	899
OIL-HDI	Heavy distillate for industry	75
OIL-HDT	Heavy distillate for transport	157
OIL-KER	Kerosene	366
OIL-LDIF	Light distillate, industrial use (fossil)	168
OIL-LDSF	Light distillate, stationary use (fossil)	168
OIL-LDS	Light distillate (bio + fossil) – private consumption (VAT)	162

Table 22: Taxes 2012 [35]

Stortingsvedtak:

Vedtatte avgiftssatser for 2012

Oppdatert: 14.12.2011

Følgende avgiftssatser er vedtatt for budsjettåret 2012

	Gjeldense sats 2011	Vedtatt sats 2012
7. Forbruksavgift på elektrisk kraft (øre/kWh)		
Generell sats	11,21	11,39
Redusert sats	0,45	0,45
til industri og bergverk	0,45	0,45
til produksjon av fjernvarme	0,45	0,45
til arbeidsmarkedsbedrifter	0,45	0,45
til Finnmark og div. kommuner i Nord-Troms	0,45	0,45
8. CO2-avgift på mineralske produkter (kr/liter)		
CO2-avgift på petroleumsvirksomhet, kr/liter eller Sm3	0,48	0,49
CO2-avgift på mineralolje	0,59	0,60
CO2-avgift på mineralolje til innenriks luftfart, ikke kvotepliktig	0,69	0,70
CO2-avgift mineralolje til innenriks luftfart, kvotepliktig	0,69	0,42
CO2-avgift på mineralolje til treforedl., sildemel - og fiskemelind.	0,31	0,31
CO2-avgift på mineralske produkter - bensin	0,88	0,89
Naturgass, kr/Sm3	0,44	0,45
LPG, kr/kg	0,66	0,67
Redusert sats for naturgass, kr/Sm3	0,05	0,05
9. Svovelavgift på mineralske produkter		
Svovelavgift, kr/liter	0,076	0,077
10. Grunnavgift på mineralolje mv. (kr/liter)		
Mineralolje	0,983	0,999
til treforedlingindustrien, produksjon av fargestoffer og pigmenter	0,126	0,126
11. Veibruksavgift på bensin (kr/liter)		
Bensin, svovelfri, (u.10 ppm)	4,62	4,69
Bensin, lavsvovlet, (u. 50 ppm)	4,66	4,73
Annen bensin	4,66	4,73
12. Veibruksavgift på mineralolje (autodiesel) (kr/liter)		
Svovelfri, (u.10 ppm svovel)	3,62	3,68
Lavsvovlet (u. 50 ppm svovel)	3,67	3,73
Annen minieralolje	3,67	3,73
Biodiesel	1,81	1,84
13. Båtmotoravgift (kr/hk)		
Båtmotorer/blokker	153,00	155,50
14. Avgift på sukker (kr/kg)		
Sukker	6,94	7,05
15. Avgift på sluttbehandling av avfall - deponi		
Deponering (kr/tonn)	280,00	284,00

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