Balmorel - Data and Calibration

Version 2.05

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Units and abbreviations

CHP	combined heat and power
cif	Cost, insurance and freight
CO_2	carbon dioxide
DH	district heating
ECU	European Currency Unit (until 1998)
ECE	United Nations Economic Commission for Europe
EFOM	Energy Flow Optimisation Model
EU	European Union
GJ	Gigajoule
GW	gigawatt
GWh	gigawatt hours
HVAC	high voltage alternate current
HVDC	high voltage direct current
IEA	International Energy Agency
kW	kilowatt
kWh	kilowatt hours
Mtoe	million ton of oil equivalent
MARKAL	MARKet ALlocation (IEA energy model)
MW	megawatt
MWe	megawatt, electric
MWh	megawatt hours
NEA	Nuclear Energy Agency
NO_x	nitrogen oxides
OECD	Organistion for Economic Co-operation and Development
PJ	petajoule
RES	renewable energy sources
SO_2	sulphur dioxide
TJ	terajoule
toe	ton of oil equivalent
UN	United Nations
TWh	terawatt hours
Conversion factors	
1 GWh	3600 GJ
1 toe	41.86 GJ
Unit prefixes	
k	kilo, 10^3
M	Mega, 10^6
G	Giga, 10^9
T	Tera, 10^{12}
P	Peta, 10^{15}
E	Exa, 10^{18}

1 Introduction

This appendix contains details concerning the collection and construction of data for the Balmorel model Version 2.05 (March 2001) which is described in the main report and in this volume. The current dataset has been developed during the project period, and preliminary versions were published on the project website on the Internet.

The data for the implementation of the Balmorel model must necessarily come from different sources. Some data can be found in international statistics, other can be copied from similar models for the sector or the region, or analogies may be used, when appropriate. In some cases qualified guesswork may be used. Finally, some data are scenario assumptions used for a single or a series of model runs.

The data that are use to implement the Balmorel model (Version 2.05, March 2001) have been selected on the basis of experience from multinational modelling studies focusing on long-term forecasts of energy demand and energy conversion technologies. National specific data have been based on existing internationally comparable data that are regularly updated. Additional data have been provided by the partners from Poland, Russia and the Baltic countries.

1.1 Types of data for Balmorel

The types of data that are needed for running the Balmorel model to forecast the development of electricity and heat generation and electricity trade for a group of interconnected electricity regions are divided into the following groups:

- Technology data
- Structural data
- Macroeconomic data
- Global data

Structural data are used to describe the electricity and heat systems in the various countries, regions and urban areas. Most important are initial capacities of the various technologies and demands for electricity and heat in the start year. Also the assumptions on decommissioning of the existing generating capacities are site specific, because the ageing of these capacities depends on the vintages of the initial capacities.

Macroeconomic data such as growth rates and elasticities are assumptions necessary for determining the future demand for electricity and heat. Reference demand forecasts for electricity and heat are exogenous in the Balmorel model, but future demand is elastic. Thus price elasticities for the various consumer groups are input parameters in the model. The impact of consumer price elasticities on the wholesale demand for electricity and heat is highly dependent on taxes and the market structure. National fuel price forecasts are calculated adding transport costs and national taxes to cif prices (cost, insurance and freight) to a national harbour or border station. Fuel price forecasts for indigenous fuels are based on national forecasts.

Global data are mainly price forecasts for internationally traded fuels. The forecasts are the same for all countries.

1.2 Data sources

The data sources are different for the various groups of data. Technology data are selected from various technology catalogues and data used for other technology-based models (including the Baltic 21 Energy study) and data for specific technologies submitted by the participants. As a part of the Balmorel project a systematic set of technology data has been developed. A few reference technologies were chosen (conventional fossil fuelled steam turbines for electricity generation, combined cycle gas turbines, nuclear power stations, hydro power, wind turbines, electric heat pumps for district heating, and heat-only boilers). Based on these references the techno-economic data for a wide range of technologies has been determined by a systematic variation of parameters, such as fuel use, output (electricity and/or heat), scale, technology vintage, and end-of-pipe facilities for emission abatement.

The most important source for statistical data for initial capacities and electricity demand is the IEA (International Energy Agency) energy balances. These data are published annually for nearly all countries in the world. The sources for these data are national official statistics, ministerial annual reports, UN ECE Questionnaire and direct communications to the IEA Secretariat from national ministries. Most data are available with two years delay. The 2000 Edition cover the years 1997 and 1998. There is an ongoing activity to increase data quality. In some countries information may be limited due to confidentiality.

The Enerdata energy statistics (developed by Enerdata s.a., Grenoble, France) is an important additional source for national energy end economic time-series. The Enerdata statistics is based mainly on the OECD/IEA statistics. It may be purchased on a CD-ROM, which is updated twice a year. In addition to energy data, economic time-series from 1970 are included, e.g. value added in eight branches or aggregates.

Electricity and heat demand forecasts are based on official national forecasts if available, or the assumptions of the Baltic 21 Energy study are used. Demand elasticities are assumed for five consumer groups (heavy industries, light industries, transport, agriculture, ands residential and services) on the basis of international studies on energy price elasticities. The numerical values of these elasticities are highly uncertain. Initially the same direct price elasticities are assumed for each consumer group in all countries. However, given these assumed elasticities the wholesale price elasticity for electricity will be very different among the countries, because taxes and demand structures are very different.

The international fuel price forecasts are from the Shared Analysis Project. These are calculated by the POLES model for the global energy market (European Commission 1999a,b). The forecasts are supplemented by own calculations and submission from the participants for indigenous fuels.

1.3 User interface

The data input for the Balmorel model are organised in GAMS *.inc files, which are simple text files that may be modifies using a text editor. However, all these text files are written from a number of spreadsheets in which the input is presented and explained, and modifications of parameters and variables are possible. In Balmorel Version 2.05 (March 2001) the data are organised in the following spreadsheets:

- *Tech205:* Technology data for reference technologies with systematic parameter variations

- *Year205:* Annual data for electricity demand in regions and heat demand (urban/rural) areas, initial and residual capacities for generating technologies, and various constraints with annual variation.
- *Geog205:* Parameters for regions and areas without annual variation in the model (potentials for fuels and technologies, fuel taxes, distribution losses and costs, seasonal and diurnal variations of electricity and heat demand and hydro power supply, and miscellaneous constants. Price elasticities for electricity consumer groups and data for the structure of electricity demand for calculation of regional aggregate wholesale electricity demand)

The spreadsheets are written in Microsoft Excel 97. The opening sheets contains bottons that will save the GAMS *.inc text files. The following sheets present the calculation of data in a comprehensive form, emphasising the key parameters (e.g. a growth rate for demand forecasts). These assumptions and parameters are used to calculate the more detailed data that are required by the model. For some types of data, e.g. demand forecasts in Year205, it is possible to enter either a complete set of annual data, or use more aggregated assumptions. The last series of sheets in the workbook contains the actual GAMS formats, which are used by the model. These text files also contain some additional assumptions or constants that, normally, should not be modified by the user. All these text files are automatically documented with source and timestamp when saved using the bottons on the opening sheet.

These spreadsheets are not part of Balmorel Version 2.05. They may be skipped or replaced by other types of user interface. All the data used in Version 2.05 are in the text files that are written as GAMS *.inc files, which may be modified freely by the user, provided the modifications are consistent with the model specification in the main *.gms file that is used to invoke the model run.

1.4 Contents of the Appendix

Chapter 2 describes the technology data in details. The basic idea is that the techno-economic parameters shall vary systematically with various characteristics (fuels, generator type, scale, technology vintage, etc.). The sources of these data are available technology catalogues.

The structural data in *Chapter 3* are used to describe the electricity and heat systems in the various countries, regions and urban areas. Most important are initial capacities of the various technologies and demands for electricity and heat in the start year. The geographical structure of district heating systems is important for the modelling of the district heating with CHP, where a distinction between ‘urban’ and ‘rural’ areas is used. The structure for Denmark is well described for several bottom-up models, while rough assumptions are necessary for several of the countries in the region.

Chapter 4 shortly describes the macroeconomic and global data that are used either in the model or for preparation of the exogenous parameters to the model. These are macroeconomic data such as growth rates and income elasticities, which may be used outside the Balmorel model for forecasts of electricity and heat demands and energy prices. The chapter contains the global fuel price forecasts, a discussion on the choice of discount rate, and details concerning the conversion factors that are used for conversion of amounts in different from different sources into the currency used in the model, $€_{90}$. A detailed description of the selection of numerical demand elasticities is found in *Chapter 5*.

Finally, *Chapter 6* shortly describe the calibration of the model to reproduce the historical data in the late 1990s.

2 Technology data

A set of technology data for electricity generating units and other identifiable technologies has been developed within a series of studies. The basic idea is that the techno-economic parameters shall vary systematically with various characteristics (fuels, generator type, scale, technology vintage, etc.). The sources of these data are available technology catalogues. These data are used in the bottom-up elements of Balmorel with common data for all the countries in the region

2.1 Technology catalogues

2.1.1 Catalogue of technology data

Table 2.1 shows a selection of technology catalogues that were used as sources for technology data for Balmorel and other model studies. These technology catalogues, earlier versions of the same catalogues and selections from them used for other model studies were used to build up a database for electricity and heat generating technologies currently (March 2001) containing some 650 records describing 90 technologies or technology variants for electricity and heat generation technologies, combined heat and power (CHP), electricity and heat networks and abatement technologies for SO_2 and NO_x.

The preferred reference for Balmorel Version 2.05 is the *PRIMES Post-Kyoto Baseline Scenario* used for the Shared Analysis Project, which covers the period until 2020 for all EU Member States (European Commission 1999a,b). However, the PRIMES model covers only some of the countries in the Balmorel model, and the technology parameters are insufficient.

The most complete set of data to be used for the Balmorel model is found in the *Baltic 21 Energy study*. This is the most important source for technology data for the Baltic States, Russia and Poland. These data are considered and modified by the partners in these countries.

The *IKARUS database and model* (IKARUS: Instruments for the development of greenhouse gas reduction strategies), covers the power and heat sector, industry and tertiary sector. It was developed by numerous German research institutes during the first half of the 1990s for the German Federal Ministry of Research, and it reflects the commitment for a 25 % reduction of CO_2 emissions declared by the Federal Government in 1990. Both the optimisation model and the database are available on CD-ROM. Only the technology database was considered for the Balmorel project. Most of these data are updated to represent the technology status by 1995. The IKARUS database is a common reference for a wide range of energy-environment model studies in Germany. It is used for the German Forum for Energy Modelling and Energy Economics Systems Analysis. The main activity of the Forum during the recent years has been to organise two series of modelling experiments that involved a number of institutions and different models. The titles of these experiments were "Structural and Economic Effects of a Climate Protection Policy: The National Perspective" and "Phase-out of Nuclear Energy: Effects and Impacts of an immediate or gradual Renunciation of Electricity generated by Nuclear Power Stations in the Federal Republic of Germany".

Table 2.1. Selected technology catalogues

Catalogue	Name	Developer	Sponsor	Address	Country	Language	Contents	Update	Forecast	Availability	WWW
IKARUS	Instrumente für Klimagas-Reduktionsstrategien	Many German Institutes	Bundesministerium für Bildung und Forschung	Fachinformations-zentrum Karlsruhe	Germany	German	Electricity and heat, households, industry, transport. Structural data for Germany	1995	2020	CD-ROM	www.fiz-karlsruhe.de/peu/ikarus/index.html
Baltic 21	Baltic 21-Energy	An Agenda 21 for the Baltic Sea Region	Council of the Baltic Sea States	Danish Energy Agency, Amaliegade 44, DK-1256 Copenhagen K	Baltic region	English	Production of electricity and heat	1998	2020	Reports, CD-ROM, Internet	www.ee/baltic21
OECD-NEA	Projected Costs of Generating Electricity. Update 1998	OECD Nuclear Energy Agency/International Energy Agency	OECD/IEA,NEA		IEA	English	Projected cost of generating electricity. Country comparison	1998		Report	
Energi 21	Danmarks Energifremtider	Danish Energy Agency			Denmark	Danish	Energy Savings in buildings, industry and the public sector; electricity and district heating; renewables; biomass	1995	2020	Reports	www.ens.dk
PRIMES	PRIMES model	National Technical University of Athens	EU DG XII, XVII		EU	English	Simplified tecno-economic data for an equilibrium model	1999	2020	Reports	www.shared-analysis.fhg.de
Varmep-94	Varmepumpers teknologi, miljø og økonomi.	Rambøll, Hannemann & Højlund A/S	Danish Energy Agency		Denmark	Danish	Heat pumps	1994		Report	
VE2	Fluktuerende vedvarende energi i el- og varmeforsyningen - det mellemlange sigt	Risø National Laboratory	Danish Energy Agency		Denmark	Danish	Renewable energy.	1998		Report	www.risoe.dk/rispubl/SYS/ris-r-1055.htm
Prognos 2020	Deutscher Energiemarkt 2020	Prognos AG			Germany	German	5 fossil technologies and nuclear. Vintages 2005-2020.			Schlesinger and Schulz, 2000	

Table 2.2. Reference technologies

	Technology	Type	Output	Fuel	Scale	Vintage	SO2 clean.	NOx clean.	Elec. eff.	Total eff.	Elec.-heat ratio	Max. util.	NOx	SO2	Inv. cost	O&M cost	Comment
									p.u.	p.u.	p.u.	p.u.	kg/GJ	kg/GJ	€/kW	€/-MWh	
Conventional fossil fuelled	Coal Cond 3	Condens-ing	Elec	Coal	Large	1980	No	No	0.380			0.820	0.400	0.655	850	5.000	Old reference, coal (some values adjusted)
Combined cycle	Gas Cond CC	Condens-ing	Elec	Gas	500 MW	1990	No	Yes	0.500				0.070	0.000	400	1.700	Min. 100 MW, Max. 400 MW (some values adjusted)
Nuclear	Nuk Cond	Condens-ing	Elec	Nuclear	1000 MW	1990			0.350				0.000	0.000	1375	4.400	Min. 800 MW, Max. 1,300 MW (some values adjusted)
Wind	Wind Land	Land	Elec	Wind	500 kW	1995			1.000				0.000	0.000	794	9.000	Wind Turbines, land
Electric heat pump	Elec HP 2		Heat	Elec	20 MW	1980			1.000	2.700	0.370		0.000	0.000	245	1.729	Swedish source and guess.
Boiler	Gas DH 2		Heat	Gas	>1 MW	1980				0.850			0.150	0.000	40	0.400	Min. 1 MW, Max. 100 MW (Baltic21, some values adjusted)
Electric heat	Elec heat		Elec	Elec					1.000	0.950	-1.053	1.000	0.000	0.000	13	0.007	Min. 1 MW, Max. 100 MW (Baltic21)

Used in Sheet Tech205.xls Models

Technology catalogues containing a detailed description of energy technologies has been used for the *Danish energy planning* for many years. The first issue of the technology catalogue was in 1985. This catalogue was updated in 1988 and published in several large volumes. Further updates were part of the work for the national energy plans in 1990 and 1996, both focusing on CO_2 emission reduction (Ministry of Environment and Energy, 1996).

The *Nuclear Energy Agency of the OECD* published in the early 1980s a systematic set of comparisons between new nuclear and coal-fired base load units on a discounted levelised cost basis. This work has been updated and expanded several times, most recently in 1998 with cost figures submitted by member states for 1996 (OECD/NEA/IEA, 1998). Selected results from these studies are compared in Figure 2.1 using the generic assumptions of the studies (in particular discount rate 5 %) and €$_{90}$ as a common price basis.

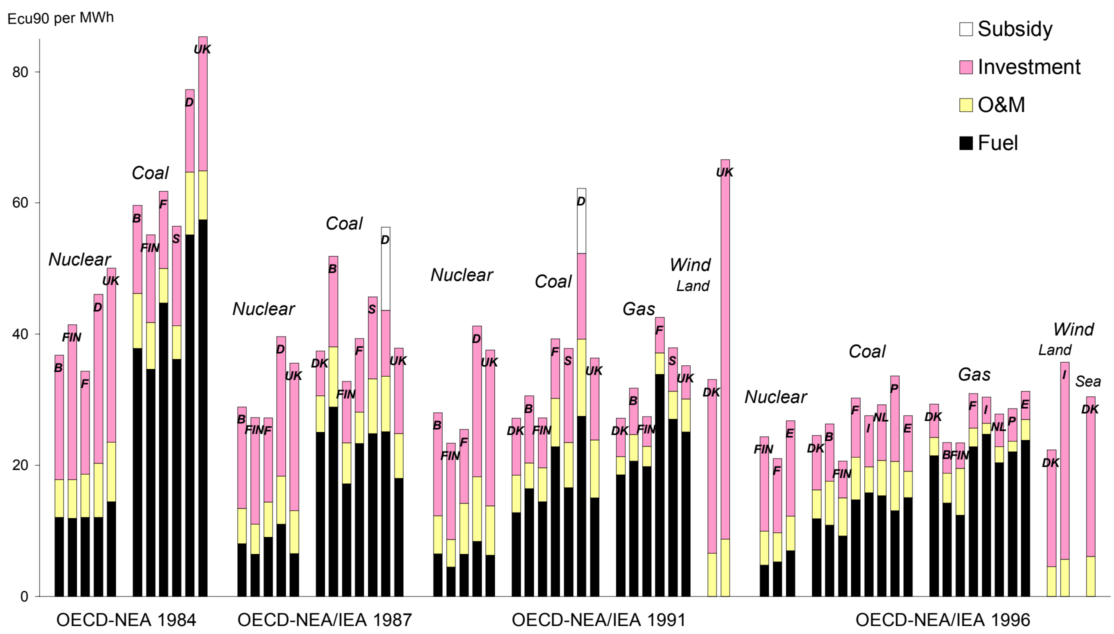


Figure 2.1. Projected costs of generating electricity. Comparison of OECD/-NEA studies 1984-1996.

The technology data for a recent study on the *German energy market until 2020* cover five fossil generating technologies and nuclear. The key assumption is that new vintages of each technology is cheaper and more efficient (Schlesinger and Schulz, 2000).

Finally a few studies on specific technologies are included in the technology database.

2.2 Systematic parameter variations

Table 2.2 shows techno-economic data for a selected set of reference technologies for electricity and heat production, which is used as a basis for systematic parameter variations. The following types of technologies are described in a spreadsheet:

- Conventional fossil fuelled
- Combined cycle gas turbines
- Nuclear

- Wind
- Electric heat pump
- Boiler

These reference technologies are used as basis for parameter variations for various types of electricity and heat generating technologies. The numerical variation of efficiency and cost variables are constructed to meet some logical requirement, e.g. new equipment is more efficient than old, or the construction cost for coal-fired units is larger than for gas

Table 2.3. Sensitivity factors for conventional fossil fuelled technologies for electricity generation

Parameters and values	Inv. cost €$_{90}$/kW	O&M pct %	O&M cost €$_{90}$/MWh	Elec. eff. p.u.	SO_2 kg/GJ	NO_x kg/GJ
Type : Condensing						
Type : Extraction	1.05		1.03			
Type : Back press	0.90		0.90			
Type : Peak	0.50		0.67	0.80	0.50	
Fuel : Coal						
Fuel : Lignite				0.90		
Fuel : Peat				0.90		
Fuel : Shale				0.90		
Fuel : Oil	0.90		0.90			
Fuel : Gas	0.80		0.80	1.05	0.00	
Fuel : Waste	1.80			0.90	0.33	0.50
Fuel : Biomass	1.80			0.90	0.00	0.50
Scale : Large						
Scale : 250 MW	1.10		1.10			
Scale : 50 MW	1.50		1.50			
Scale : 5 MW	2.00		2.00	0.95		
Vintage : 1980						
Vintage : 1990			0.75	1.10		
Vintage : 2000	0.85		0.50	1.20		
Vintage : 2010	0.80		0.50	1.30		
Vintage : Old	1.50		1.00	0.80		
SO2 clean. : No						
SO2 clean. : Yes	1.05		1.05	1.00	0.10	
NOx clean. : No						
NOx clean. : Yes	1.05		1.05			0.10

Used in Sheet Tech205.xls Conv . Default values (1.00) are not shown

In practice the parameter variations are shown as sensitivity factors compared to the reference technologies for investment and operation cost, fuel efficiency and emissions reduction,

2.2.1 Sensitivity factors for parameter variations

From this spreadsheet it is possible to write the GAMS include files for the Balmorel model or input files for other models.

The parameter variations for the different reference technologies concern

- Type of generating unit (condensing, back-pressure, extraction-condensing, peak load)
- Fuel input

- Scale
- Technology vintage
- SO_2 cleaning
- NO_x cleaning

Table 2.4. Sensitivity factors for new technologies for electricity generation

	Inv. Cost €90/kW	O&M cost €90/MWh	Elec. eff. p.u.	NOx kg/GJ
Combined Cycle Gas Turbines				
Type : Condensing				
Type : Extraction	1.20	1.20		
Type : Back pressure	0.90	0.90		
Fuel : Gas				
Fuel : Oil	1.10	1.10		
Fuel : Coal	1.70	2.00	0.95	
Scale : 500 MW				
Scale : 50 MW	1.60	1.25	1.00	
Scale : 5 MW	2.20	1.50	0.95	
Vintage : 1990				
Vintage : 2000			1.10	
Vintage : 2010			1.25	
IGCC : No				
IGCC : Yes	1.50		0.80	
NOx clean. : Yes				
NOx clean. : No	0.95	0.95		10.00
Nuclear units				
Type : Condensing				
Type : Extraction	1.03	1.03		
Vintage : 1990				
Vintage : 2010	0.95	0.95	1.03	
Wind Turbines				
Type : Land				
Type : Sea	2.00	1.33	1.50	
Scale : 500 kW				
Scale : 1000 kW	0.90	0.90		
Scale : 2000 kW	0.80	0.90		
Vintage : 1995				
Vintage : 2005	0.90	0.90		
Vintage : 2010	0.85	0.85		

Used in Sheets Tech205.xls CC, Nuk and Wind. Default values (1.00) are not shown

These parameter variations are shown as sensitivity factors compared to the reference technologies for investment and operation cost, fuel efficiency and emissions reduction, see Table 2.3. For the largest technology group, conventional fossil fuelled, some 60 technology variations are calculated. For the other reference technologies the number of variant vary from 4 to 18. These technology variants are used to represent all existing and potential technologies for electricity and heat generation in the countries of the Baltic Sea Region.

Although hydro power is very important in the region, it is not reasonable to assume detailed techno-economic data for this technology. The investment cost for large-scale hydro power is very site specific, and few investment data are available for small-scale hydro power facilities in technology catalogues. The investment cost for the reference hydro technology in Table 2.2 is 1000 $€_{90}$ per installed kW, which is the same order of magnitude as nuclear and wind.

Table 2.5. Sensitivity factors for technologies for heat generation

	Inv. Cost €90/kW	O&M cost €90/MWh	Elec. eff. p.u.
Electrical driven heat pumps			
Vintage : 1980			
Vintage : 1990	0.95	0.95	1.11
Vintage : 2000	0.90	0.90	1.20
Vintage : 2010	0.85	0.85	1.30
Boilers			
Fuel : Gas			
Fuel : Oil	1.50	1.50	
Fuel : Coal, lignite etc.	3.00	3.00	0.89
Fuel : Waste, Biomass	6.00	6.00	0.89
Vintage : 1980			
Vintage : 2000			1.12
Vintage : 2010	0.80	0.80	1.12
Vintage : Old			0.88

Used in Sheets Tech205.xls HP and Boil . Default values (1.00) are not shown

2.2.2 Parameter variations for conventional technologies

The sensitivity factors are used to calculate the parameters that are used in the model. All the sensitivity factors refer to the reference technology. If two or more parameters are different from the reference technology, the sensitivity factors are multiplied.

Table 2.6 shows the variations in electric efficiency for conventional fossil fuelled units as dependent of types of units, fuel input, sizes of units, and technology vintages. The table shows that newer units are significantly more efficient than old, and larger units are slightly more efficient than small units. It is also shown that gas-fired units are more efficient than coal or oil fired units as specified by the assumptions in Table 2.3.

Table 2.6. Conventional fossil fuelled units. Variations in electric efficiency for types of units, fuel input, scales and vintages.

Type/Fuel	Scale	Vintage				
		Old	1980	1990	2000	2010
Condensing/Extraction						
Coal	Large	0.304	0.380	0.418	0.456	0.494
Shale	Large	0.274				
Lignite				0.376	0.410	0.445
Peat	Large	0.274			0.410	0.445
Oil	Large	0.304	0.380	0.418	0.456	0.494
Gas	Large	0.319	0.399	0.439	0.479	0.519
Waste				0.376	0.410	
Biomass					0.410	
Back pressure						
Coal	50 MW		0.380	0.418		
Oil	50 MW			0.418		
Gas	50 MW			0.439	0.479	0.519
Gas	5 MW					0.493
Waste	50 MW				0.410	
Biomass	5 MW				0.390	
Peak						
Oil	Large		0.304			

Used in Sheet Tech205.xls Conv

The fuel prices and efficiencies are those parameters that are most significant for the economic dispatch among existing units in an interconnected electricity system. The units having the lowest variable costs will gain the highest utilisation time. With no further constraints the fuel use will be determined by these parameters.

For the long-term technology choice the investment costs will be another very significant parameter. This parameter is shown in Table 2.7. In particular, larger units are cheaper than smaller ones, and gas-fired units are cheaper than coal fired units (cf. Table 2.3). The extra investment costs for extraction-condensing units for CHP compared to condensing units for electricity-only are relatively small.

Obviously, the optimisation model will not select obsolete technologies for future investment. Thus, the investment cost for these technologies has little meaning for the model. They are used only under very special assumptions, e.g. for the optimisation of the past, or assuming that some newer vintages were not available.

2.2.3 Parameter variations for new electricity generating technologies

The technology data for combined cycle gas turbines (CCGT) are treated separately from conventional fossil fuelled units, because this technology has shown a significant progress over the last decade, and there is still a potential for efficiency gains. Table 2.8 shows that new vintages that may be available from 2010 will be much more efficient with no increase (or reduction) in investment cost (cf.. Table 2.4). It is also assumed that coal gasification will be available from 2010 at thermal efficiency similar to modern coal-fired units, but higher investment cost.

Table 2.7. Conventional fossil fuelled units. Variations in investment cost for types of units, fuel input, scales and vintages. €$_{90}$/kW.

Type/Fuel	Scale	Vintage				
		Old	1980	1990	2000	2010
Condensing						
Coal	Large	1275	850	937	797	750
Shale	Large	1275				
Lignite				937	797	750
Peat	Large	1275		937	797	750
Oil	Large	1148	765	843	717	675
Gas	Large	1020	680	714	607	571
Waste				1530	1301	
Biomass					1366	
Back pressure						
Coal	50 MW		1148	1148		
Oil	50 MW			1033		
Gas	50 MW			918	780	771
Gas	5 MW					1028
Waste	50 MW				1756	
Biomass	5 MW				2341	
Peak						
Oil	Large		383			

Investment cost for extraction units are 3 % higher than the cost of condensing units.
Used in Sheet Tech205.xls Conv.

Table 2.8. Combined Cycle Gas Turbines and coal gasification. Variations in electric efficiency and investment cost.

Technology	Scale	Electric efficiency			Investment cost, €/kW	
	MW	1990	2000	2010	<2000	2010
Combined Cycle Gas Turbines (CCGT)						
Condensing	500	0.50	0.55	0.63	400	400
Extraction	500	0.50	0.55	0.63	480	480
Back pressure	50	0.50	0.55	0.63	576	576
Back pressure	5		0.52	0.59	792	792
Coal gasification						
Condensing	500			0.48		1020
Extraction	500			0.48		1224

Used in Sheet Tech205.xls CC.

The variants of nuclear units are limited. Thus, no distinction is made between the different types of existing nuclear units in the region (PWR, BWR and RBMK). Extraction facilities for CHP are assumed to add 3 % to investment cost, and new vintages from 2010 may increase the thermal efficiency for electricity-only from 0.35 to 0.36, cf. Table 2.4. There is no example of large-scale heat supply from nuclear units in the region. This option was considered for some areas in the Baltic Sea Region in the late 1970s, and it is easily available in the model for possible new vintages of nuclear technology.

The parameter variations and potential technological progress for wind power is significant, but uncertain and complicated. There are significant regional differences in wind resources, and the constraints and requirement for a large-scale introduction of wind power cannot be addressed satisfactory with this type of model. Thus, the dataset contains only few parameter variations for wind power as shown in Table 2.9 using the few assumptions for wind power in Table 2.4.

Table 2.9. Wind turbines. Variations in load factor and investment cost.

Type	Scale	Load factor	Investment. Cost, €/kW		
	kW		1995	2005	2010
Land	500	0.22	750		
Land	1000	0.22	675		
Sea	500	0.33	1500		
Sea	1000	0.33		1215	
Sea	2000	0.33			1020

Used in Sheet Tech205.xls Wind

2.2.4 Parameter variations for heat generating technologies

Heat-only generating technologies are mainly boilers fired by various fuels. The potential for efficiency improvements and cost reductions are limited, except for biomass fuelled boilers. The technology data also contains data for electrically driven heat pumps, which traditionally has been used in regions with low electricity prices. There is some potential for efficiency improvements and cost reduction for heat pumps, see Table 2.10, which is based on the assumptions in Table 2.5.

Table 2.10. Heat generating technologies. Variations in load factor and investment cost.

	Total efficiency					Investment. Cost, €/kW			
	Old	1980	1990	2000	2010	<1980	1990	2000	2010
Heat pumps, 20 MW thermal output									
Electricity driven		2.70	3.00	3.25	3.50	250	237.5	225	212.5
Boilers, >1 MW thermal output									
Gas	0.75	0.85	0.85	0.95		40	40	40	
Oil	0.75	0.85				60			
Oil Shale	0.67	0.76				120			
Coal	0.67	0.76				120			
Lignite	0.67	0.76				120			
Peat	0.67	0.76				120			
Waste	0.67	0.76				240			
Biomass	0.67	0.76	0.76	0.76	0.85	240	240	240	192

Used in Sheets Tech205.xls HP and Boil.

2.2.5 Naming of technologies

The naming of technologies in Balmorel may be chosen freely by the user within the rules of the GAMS modelling system. The naming used in Version 2.05 is developed from Baltic 21 Energy, but adjusted to the system of technologies with systematic parameter variations.

Table 2.11. Naming of technologies

Main type	
ST	Steam
GT	Gas turbine
CC	Combined cycle gas turbine
IG	Integrated gasification gas turbine
Wind	Wind turbines (-L land, -S Sea)
HP	Heat pumps
DH	District heating boiler
Secondary type	
Con	Condensing
Ext	Extraction-condensing
BP	Back-pressure
Peak	Designed or used for peak load
Mini	Mini or micro CHP
Vintage	
-4	Obsolete technology
-3	Past technology
-2	Average technology
-1	Newest technology
00	Vintage 2000
10	Vintage 2010
Old	Obsolete technology (heat-only boilers)
New	Current technology (heat-only boilers)
Fuel	
-E	Electricity
-C	Coal
-L	Lignite
-P	Peat
-S	Oil shale
-O	Fuel Oil
-W	Waste
-B	Biomass

2.3 Environmental parameters

Table 2.12 shows emission factors for CO_2 and SO_2. These emission factors are fuel specific, and depends on the carbon or sulphur contents, while the NO_x emission factor depends on the combustion technology.

Biomass is defined as a renewable energy source. Although CO_2 will be emitted during the combustion, the same amount of CO_2 had been absorbed in the photosynthesis during a limited number of years in the past. This is in contrast to peat, which is burned using the same combustion technology. However, peat is a young fossil fuel that was created only few thousand years ago.

The CO_2 emission factor for urban waste must be based on convention, taking into account the composition of typical urban waste. The remaining emission factors are also based on conventions with much less uncertainty. The SO_2 emission factors represent conventional averages of low and high sulphur fuels. The use of abatement technologies for SO_2 or NO_x emissions will reduce the emission factors.

Table 2.12. Fuel specific emission factors

	CO_2 kg/GJ	SO_2 kg/GJ
Biomass	0	0.21
Waste	55	0.50
Natural gas	57	0.00
Fuel oil	78	0.49
Peat	85	2.00
Coal	95	1.00
Lignite	101	2.67
Oil Shale	109	2.67

Source: Baltic 21 Energy.
Used in Sheet Geog205.xls Param.

3 Structural data

The structural data are used to describe the electricity and heat systems in the various countries, regions and urban areas. Most important are initial capacities of the various technologies and demands for electricity and heat in the start year. Also the assumptions on decommissioning of the existing generating capacities, because the ageing of these capacities depends on the vintages of the initial capacities.

The geographical structure of district heating systems is important for the modelling of the district heating with CHP, where a distinction between ‘urban’ and ‘rural’ areas is used. In the ‘urban’ areas the heat supply is dispatch among different heat generating technologies supplying an interconnected network, while district heating in ‘rural’ areas are small district heating grids supplied by a single technology. The structure for Denmark is well described for several bottom-up models, while rough assumptions are necessary for several of the countries in the region.

3.1 Sources for structural data

The most important source for statistical data for initial capacities and electricity demand is the IEA (International Energy Agency) energy balances. These data are published annually for nearly all countries in the world. The IEA energy balances and further national data are published electronically by Enerdata s.a., Grenoble, France on a CD-ROM, which is updated twice a year.

The data for electricity demand are well described in official statistics and available in details that are sufficient for the model. Data for heat demand are much more uncertain. The definitions are unclear, there are significant differences between different statistical publications, and the data are available in sufficient details only for few countries.

Official data for the electricity generating capacities are too aggregate for the model. Other sources, such as national energy planning data or qualified guesses will be necessary to obtain initial capacities in reasonable details. The data for heat generating capacities are even more weak.

The starting point for the structural data for Balmorel version 2.05 has been the Baltic 21 Energy study. Further data and disaggregation of those assumptions were supplied by the participants in the project with data based on national sources.

The structure of district heating in Denmark is particular well described from numerous planning and modelling studies during nearly 25 years. A simplified structure describing a few stylised types of CHP regions has been developed for the EFOM-CHP model (Grohnheit 1993, Grohnheit 1999, Varming et al. 2000). A similar structure has been described for Latvia (Klavs and Grohnheit 1998).

The description of the heat markets in the different countries shall be further developed in later versions of Balmorel on the basis of analyses by the model and other studies. Recently, a situation analysis of district heating and CHP in the Baltic Sea Region was financed by the Danish Energy Agency for the BASREC Ad Hoc Group on Energy Efficiency and carried out by Euroheat & Power (Petersen 2000). A second phase of The Nordleden Project on grid distributed energy trade among the Nordic countries – using the techno-economic model MARKAL – was started in 2000 (Unger et al. 2000).

3.1.1 The structure of district heating in Denmark

About one-third of the total electricity demand in Denmark is supplied by CHP, and district heating from all sources covers about half of the market for space heating and hot water. In 1997 nearly 80 % of the district heating was supplied by CHP.

Table 3.1. Heat demand 1995 in electricity regions and district heating areas in Denmark

	Electricity regions		Total
	East	West	
Denmark	**42.4**	**69.9**	**112.3**
Urban areas	**29.9**	**37.1**	**67.0**
Copenhagen	*29.9*		*29.9*
Copenhagen Region, water	22.3		
Copenhagen Steam	7.6		
Large Cities		*37.1*	*37.1*
Esbjerg		4.5	
Odense		11.4	
TVIS		5.0	
Aalborg		5.4	
Aarhus		10.8	
Rural areas	**12.5**	**32.8**	**45.3**
Mid Towns	*10.4*	*29.5*	*40.0*
Brønderslev		0.4	
Frederikshavn		0.8	
Grenaa		0.3	
Helsingør	1.0		
Herning		2.6	
Hillerød	1.3		
Hjørring		0.8	
Holstebro		1.5	
Horsens		0.8	
Nykøbing F.	0.6		
Næstved	0.7		
Randers		1.8	
Silkeborg		1.2	
Slagelse	0.4		
Sønderborg		0.7	
Viborg		0.8	
Vordingborg	0.5		
Small towns	5.9	17.8	23.8
Rest of Denmark	*2.1*	*3.3*	*5.4*
Kalundborg	0.8		
Rønne	0.5		
Aabenraa		1.0	
Local power plants	0.8	2.3	3.1

Source: Energistyrelsen 1996

The interconnected district heating grid in the Copenhagen Region is one of the largest in Western Europe. The Copenhagen grid covers also the suburban 'fingers' and satellite towns to the west and south within a distance of about 35 kilometres from the city centre. There are similar grids in the city regions of Odense, Aarhus, Aalborg, Esbjerg, and the TVIS network in an industrial region with four towns around the Little Belt bridges. These transmission grids are supplied from different heat generating sources. Totally, there are about 300 distributors of district heating, either with independent supply systems covering a town or village, or connected to the large transmission grids.

Table 3.1 describes the structure of district heating and CHP in Denmark on the data of modelling data for the national energy plan, “Energy 21” published in 1996 (Energistyrelsen 1995, 1996). The 27 largest district heating networks are identified and aggregated for various modelling purposes.

In the published Balmorel Version 2.05 (March 2001) the Danish market is divided into the two electricity regions, east and west of the Great Belt, and ‘urban’ and ‘rural’ district heating areas in each electricity region. This is consistent with a model structure with a simplified representation of the heat markets and many electricity regions, focusing on the study of electricity trade and future electricity prices.

The two parts of Denmark are not directly connected. However, the two electricity regions are very similar in supply and demand structure, so they may be modeled as a single region for many modeling purposes, in particular when focusing on the structure and behaviour of the heat market. Thus, in the EFOM-CHP model (described in Varming et al. 2000) the whole country is treated as a single electricity region, and the district heating networks are divided into four types of district heating areas, Copenhagen, ‘Large Cities’, ‘Mid Towns’, and Rest of Denmark.

Copenhagen and ‘Large Cities’ are similar in structure. The differences are that Copenhagen is one single interconnected grid, while in ‘Large Cities’ the total demand, which is similar to that of Copenhagen, is divided into five grids. The heat to all these grids are supplied mainly from large-scale power plants and large waste incineration plants. In the Copenhagen region these technologies cover only base-load heat, and a significant share of peak load is supplied from boilers, while in the five large city regions the heat supply capacity from large-scale extraction-condensing power plants is abundant, and peak load boilers are needed only few hours during the year. These boilers are also needed as reserve capacity. In the Copenhagen Region a significant share of the regional heat market is outside the interconnected grid, while the interconnected district heating grids in the large city regions dominate the regional heat markets with little potential for further expansion.

The type of district heating areas ‘Mid Towns’ consist of 17 identified towns with a population between 10,000 and 60,000 inhabitants. In these towns the district heating market is dominated by one single CHP unit designed for the local market and commissioned during the 1990s. This type of district heating area also includes many towns below 20,000 inhabitants that have similar heat markets. The potential for expansion of this market is very limited.

The district heating area ‘Rest of Denmark’ is a residual. Part of this market consists of small towns near the sites of a few sites for condensing power plants whit extraction facilities for the local heat market. The rest of this market is supplied by local power plants, including industrial CHP. This market is small, but there is a significant potential for expansion.

3.1.2 ‘Urban’ and ‘rural’ heat areas

The basis for this distinction is that economic dispatch among heat generating units in merit order is possible in urban areas, but not in rural. Thus, in the rural area all heat generating units are synchronised and will have the same utilisation time. The combination of waste incineration and CHP for base and intermediate load and boilers for peak load, which is usual in Denmark not only in the large urban interconnected district hearing grids, but also in many medium-sized towns, will not be represented in ‘rural’ areas.

For Balmorel Version 2.05 it was chosen to define ‘urban areas’ as the large interconnected grids in Copenhagen and the five large city areas, which are connected to large extraction-condensing power stations, while the rest of the country is ‘rural’. In most medium-sized and small towns and villages the fast development of small-scale CHP (i.e. up to 100 MW units designed to be the only base load unit for a particular district heating grid) has left an abundant capacity of heat-only boilers. The share of this capacity that is used in the model may be determined by a calibration of the model to represent an appropriate technology mix for the ‘rural’ area.

In a more detailed version of Balmorel, several different types of urban areas may be specified.

For most of the countries the distinction between urban and rural areas is made by assuming a percentage of the market as urban. This assumption may be a matter of calibration.

3.2 Reference demand forecasts

Reference demand forecasts for electricity and heat are exogenous in the Balmorel model, but future demand is elastic. Thus price elasticities for the various consumer groups are input parameters in the model.

The reference demand forecasts in Balmorel Version 2.05 are taken from Baltic 21 Energy or submitted by the participants on the basis of more detailed or recent national studies.

Table 3.2. Demand forecasts in electricity regions

	DK_E	**DK_W**	**EE_R**	**FI_R**	**DE_R**	**LV_R**	**LT_R**	**NO_R**	**PL_R**	**RU_W**	**RU_K**	**SE_R**
Electricity available for distribution, GWh												
1995	16054	19939	7933	70870	541869	6235	11220	116346	136205	52569	5841	146669
1996	17016	21136	8243	73033	550059	6351	11630	113688	140049	51774	5753	146772
1997	16528	20529	8244	76828	549187	6324	11336	115474	140605	50941	5660	146700
1998	16397	20366	8131	79475	555762	6500	11550	120617	139315	50416	5602	147579
2005	17664	21940	9913	79144	606237	8649	14592	119722	153301	63992	7110	160001
2030	21624	26860	15499	102822	779689	16128	25506	128932	196907	91063	10118	198065
Electricity distribution losses												
1997	0.1406	0.1406	0.3871	0.0842	0.1593	0.3196	0.4058	0.1037	0.3272	0.3027	0.3027	0.1529
Electricity demand, GWh												
1995	13824	17170	4484	65304	451209	4474	6355	103766	89584	37545	4172	124566
1996	14204	17643	4828	66515	458358	4407	6516	103144	93306	36410	4046	126004
1997	14219	17661	5053	70361	461727	4479	6736	103897	94634	35522	3947	122766
1998	14264	17716	5095	72805	466127	4468	6809	109057	94848	35028	3892	123526
2005	15180	18855	6076	72482	509692	5885	8671	107301	103147	44623	4958	135534
2030	18583	23083	9500	94167	655520	10974	15156	115556	132488	63500	7056	167778
Growth rates, %												
1998-2030	30%	30%	88%	29%	41%	145%	125%	6%	40%	81%	81%	36%
1998-2005	6%	6%	19%	0%	9%	32%	27%	-2%	9%	27%	27%	10%
2005-2030	22%	22%	56%	30%	29%	86%	75%	8%	28%	42%	42%	24%
Demand index, 1995=100												
1998	103	103	114	111	103	100	107	105	106	93	93	99
2005	110	110	135	111	113	132	136	103	115	119	119	109
2030	134	134	212	144	145	245	238	111	148	169	169	135

Used in Sheet Year205.xls Estimate.

3.2.1 Electricity demand

Table 3.2 shows the data used for the electricity demand forecasts for the various electricity regions and the variables used for check of consistency. The different colours or shadings are used to identify different data sources and highlight exogenous assumptions.

The historical data are from the IEA statistics with a regional distribution between the two Danish electricity regions. The part of Russia that is included in the Balmorel model is 6.95 % corresponding to the share of the total population in the western region and Kaliningrad (10.3 million of 148.2 million) with 10 % of this share in the Kaliningrad region. Forecasts are given either as a fixed number for 2005 and 2030, or the growth from 1998 to 2030. The intervening years are calculated by linear interpolation. The year 2005 is used to make a distinction between the development in the medium-term and in the long-term.

Figure 3.1 shows an index for the electricity demand forecasts using the assumptions in Table 3.2. The assumptions for the development between 1998 and 2030 must take into account the very different development during the 1990s, when the electricity demand were reduced dramatically in the transistion economies.

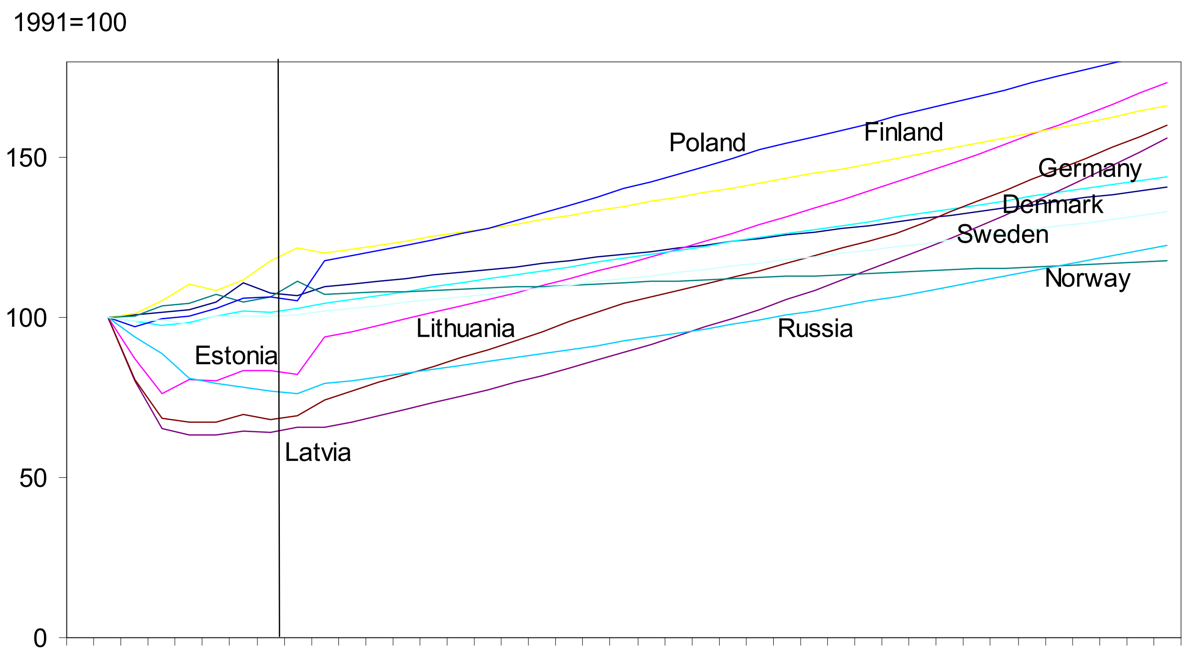
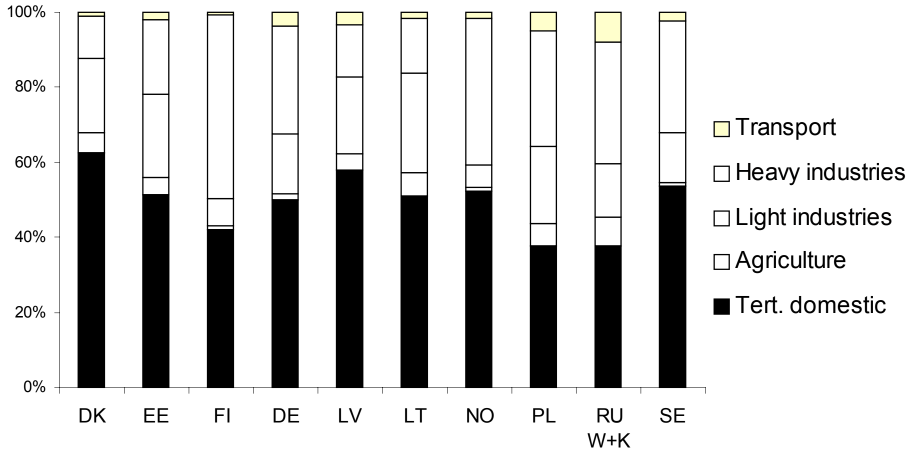


Figure 3.1. Electricity demand 1991-2030

The electricity demands for the various consumer groups are aggregated for each region outside the Balmorel model. Distribution losses and costs are added as weighted averages that are calculated for each region, using the percentage of each consumer group, see Figure 3.2. Thus, the model will represent the electricity demand and electricity cost as final energy delivered to the final consumers.

The index in Figure 3.1 shows the assumptions for the development of a reference demand for electricity in the electricity regions in the model. The electricity demand is, however, elastic and the endogenous electricity prices in the various regions will determine the demand. The assumptions on price elasticities are discussed in Chapter 5.



Source: Enerdata. Used in Sheet Geog205.xls Elastic.

Figure 3.2. Composition of national electricity demand in 1997

Table 3.3. Demand forecasts in heat areas

	DK_E	DK_W	EE_R	FI_R	DE_R	LV_R	LT_R	NO_R	PL_R	RU_W	RU_K	SE_R
Heat generation TJ												
1995	48184	71917	30625	97704	416600	42616	81476	6499	420809	503708	55968	163084
1996	52394	78199	33132	126856	418943	54925	82736	6819	447646	419671	46630	177150
1997	50162	74868	32593	125702	381577	46540	76681	6870	422969	377706	41967	162435
1998	50505	75380	32593	117816	386518	46540	76681	7086	391568	377706	41967	167303
2005	58483	87289	34396	141554	425937	51256	93005	8084	429252	460370	51152	167516
2030	65064	97110	61263	160160	532239	84014	110720	9551	475986	569429	63270	146538
Heat distribution losses												
1997	0.2399	0.2399	0.1715	0.1009	0.0984	0.1787	0.2759	0.3073	0.1344	0.1070	0.1070	0.0719
Heat demand,TJ												
1995	37403	55825	24825	89011	366130	36733	65036	4405	369085	450166	50018	148183
1996	40559	60535	26177	115123	378000	46080	58509	4816	390463	373568	41508	163456
1997	38121	56897	26999	112997	343948	38216	55513	4758	366040	337226	37470	150725
1998	38499	57462	23748	106060	349097	35080	54206	5091	337771	342592	38066	155470
2005	44454	66349	28498	127272	384007	42096	67344	5600	371548	411111	45679	155470
2030	49455	73814	50758	144000	479845	69000	80171	6616	412000	508500	56500	136000
Growth rates, %												
1998-2030	28%	28%	88%	36%	37%	97%	48%	30%	22%	48%	48%	-13%
1998-2005	15%	15%	20%	20%	10%	20%	24%	10%	10%	20%	20%	0%
2005-2030	11%	11%	78%	13%	25%	64%	19%	18%	11%	24%	24%	-13%
Demand index, 1995=100												
1998	103	103	96	119	95	95	83	116	92	76	76	105
2005	119	119	115	143	105	115	104	127	101	91	91	105
2030	132	132	204	162	131	188	123	150	112	113	113	92
Urban areas, %												
1995	66.1%	55.3%	40.0%	67.0%	67.0%	50.0%	59.7%	0.0%	80.0%	67.0%	100.0%	67.0%
1996	65.9%	54.7%	40.0%	67.0%	67.0%	60.0%	59.7%	0.0%	80.0%	67.0%	100.0%	67.0%
1997	65.6%	54.1%	40.0%	67.0%	67.0%	60.0%	59.7%	0.0%	80.0%	67.0%	100.0%	67.0%
1998	65.3%	53.5%	40.0%	67.0%	67.0%	60.0%	59.7%	0.0%	80.0%	67.0%	100.0%	67.0%
2005	65.3%	53.5%	40.0%	67.0%	67.0%	60.0%	59.7%	0.0%	80.0%	67.0%	100.0%	67.0%
2030	58.9%	40.8%	40.0%	67.0%	67.0%	60.0%	48.3%	0.0%	80.0%	67.0%	100.0%	67.0%

Used in Sheet Year205.xls Estimate.

3.2.2 Heat demand

The quality of data for heat demand in urban and rural areas is widely different among the countries. The reference demand forecasts are taken from Baltic 21 Energy or submitted by the participants. The subdivisions in urban and rural areas are either based on aggregation of more detailed data (Denmark) or set by distribution parameters. The heat demand forecasts in Table 3.3 are similar to the electricity demand forecasts in Table 3.2. The main difference is that the heat demand forecast must be divided between 'urban' and 'rural' areas. These assumptions may be based either on a detailed geographical description of the heat market, or by a simple assumption on the 'urban' share of the heat market, which may be used for model calibration.

The heat demand is aggregated for all types of heat uses in each 'urban' or 'rural' area outside the model itself. Distribution losses and costs are added as weighted averages for each area. Thus, the model will represent the heat demand and cost of heat as final energy delivered to the final consumers.

The demand for district heating was reduced even more dramatic than the electricity demand in the transition economies in the first half of the 1990s.

In Balmorel Version 2.05 (March 2001) the heat demand is assumed inelastic. There is, however, little evidence for assumptions of heat demand elasticities.

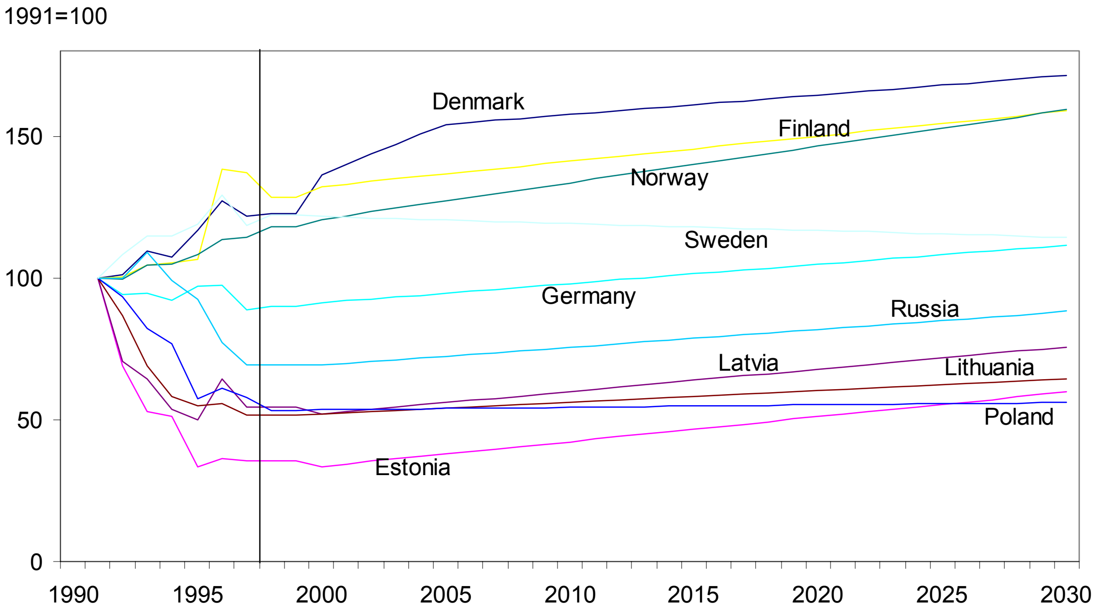


Figure 3.3. Heat demand 1995-2030

3.2.3 Model delimitation

The choice of technologies and data sources are significant for the delimitation of the model. The initial version of the model describes the electricity and heat markets in the Baltic Sea Region. The model covers practically all electricity that is generated and consumed, but only part of the markets for space heating and industrial steam.

The electricity market is very well described by national and international statistics, and the various statistical sources are using the same definitions and figures.

However, the definition of "district heating" is unclear. The term normally refers to public networks that are combining many property sites, while a similar heat distribution network for several buildings within the same site may not be considered as district heating. Thus, water-based heat distribution systems for blocks of flats or large institutions may be transferred to district heating systems without much additional investment in piping.

Outside the district heating systems there are large markets for CHP for industrial processes.

The focus of the Balmorel model is the part of the heat market that is suitable for CHP. This includes parts of the markets for both space heating and industrial processes. The delimitation chosen for the current version of the Balmorel model is “Heat production in the transformation sector” according to the IEA Statistics. This includes both district heating and industrial autoproducers.

When this definition is used the heat market does not include potential market for micro-scale CHP in the form of very small gas motors or – in the future – fuel cells. In some countries, there is a very developed natural gas grid that supply gas boilers for space heating. If micro-scale CHP becomes available the heat market suitable for CHP become much larger. These technologies are not included in the first versions of the model, including Balmorel Version 2.05 (March 2001).

3.2.4 Electricity and heat distribution

The distribution losses for electricity and heat and the consumer structure are fixed by 1997. The parameters for distribution losses shown in Table 3.4 are calculated from the demand and the generation adjusted for foreign trade in Table 3.2 and Table 3.3. The distribution losses in the year 1997 can be taken as representative for the second half of the 1990s. In the previous years the calculated distribution losses were very unstable.

Table 3.4. Distribution losses and costs

	Distribution losses		Distribution cost		
	Electricity	Heat	Electricity	Heat	
				Urban	Rural
	p.u.	p.u.	$€_{90}$/MWh	$€_{90}$/MWh	$€_{90}$/MWh
Denmark	0.1406	0.2399	5.00	1.00	2.00
Estonia	0.3871	0.1715	5.00	1.00	2.00
Finland	0.0842	0.1009	5.00	1.00	2.00
Germany	0.1593	0.0984	5.00	1.00	2.00
Latvia	0.3196	0.1787	5.00	1.00	2.00
Lithuania	0.4058	0.2759	8.86	1.00	2.00
Norway	0.1037	0.3073	5.00	1.00	2.00
Poland	0.3272	0.1344	5.00	2.31	2.31
Russia W+K	0.3027	0.1070	5.00	1.00	2.00
Sweden	0.3027	0.1070	5.00	1.00	2.00

Source: Enerdata. Used in Sheet Geog205.xls Param.

The demand forecast to the model is specified as the total demand for all final consumers in each electricity region and heat area. The electricity required for the national market to be fed into the transmission network or the required heat generation is the final demand plus the distribution losses.

Obviously, distribution losses are much smaller for large consumers than for small, and the losses may vary through time with the changes in demand structure and technology changes in transmission and distribution technology, but these variations are not addressed in the current version of the model, which focus on interregional and international electricity trade. Thus, the demand structure and distribution technology is fixed, and the losses is represented by parameters for electricity and heat in each electricity region and heat area. These parameters are calculated from data for 1997 as shown in Table 3.4. As shown in the table these ‘distribution losses’ are very different among the countries. These differences only partly reflect differences in demand structure, distribution technology and efficiency. They may also reflect differences in statistical definition and practice. The parameters for the year 1997 are used for the whole period. The 1997-data for the demand structure is representative for the years 1995-1998 for all countries. However, there are significant variations in the period 1991-1994, in particular for the transition economies.

3.2.5 Electricity and heat prices

Consumer prices and taxes for industrial and residential consumers are well described in international comparable statistics. Table 3.5 shows consumer prices for the main consumer groups. The differences between the various consumer groups are due to differences in electricity system cost and excise taxes.

The electricity and heat prices for an aggregate group of consumers in each electricity region and heat area are endogenous results from the model. However, a reference price forecast will be necessary to calculate price elasticities. The aggregated consumer prices are composed of the following elements:

- Wholesale price
- System cost (i.e. transmission and distribution cost)
- Consumer taxes

Some elements of system costs can be derived from distribution losses and distribution costs as shown in Table 3.4, but there may be a residual, which is unexplained and may be calculated using an assumption of a single wholesale market price for the whole region.

Table 3.5. Electricity consumer prices 1997, €$_{90}$/MWh

	Heavy industries	Light industries	Transport	Agri-culture	Tert. domestic	Weighted consumer price,
Denmark	34.23	46.21	34.23	64.37	140.54	104.79
Estonia	19.99	30.38	19.99	30.38	30.38	28.10
Finland	22.44	29.97	22.44	48.43	63.38	40.48
Germany	19.99	55.23	34.94	96.70	96.70	65.79
Latvia	19.99	30.38	19.99	30.38	30.38	28.58
Lithuania	19.99	30.38	19.99	30.38	30.38	28.69
Norway	19.99	47.66	36.14	47.66	47.66	36.70
Poland	19.99	29.64	26.14	29.64	29.64	26.49
Russia W+K	19.99	30.38	19.99	30.38	30.38	26.17
Sweden	19.99	27.46	28.66	38.50	38.50	31.32

Used in Sheet Geog205.xls Elastic

The prices for wholesale trade of electricity was assumed for the EFOM-CHP model as an annual contract price 2001 on the basis of price quotations in 1998 from the Norwegian-Swedish electricity exchange Nord Pool and the power broker Skandinavisk Kraftmegling for forward prices for annual contracts at 161 NOK per MWh (15.19 €$_{90}$). This price is divided into two components: the variable cost of a coal or gas fired power plant and a residual that represent the contribution margin for the marginal generator. However, this margin is too small to meet existing financial obligations or to finance new investments. In previous model analysis using the EFOM-CHP model the variable component was assumed to follow the price forecast for coal and gas respectively. The conclusion of this analysis was that the price of an annual contract for electricity should follow the lowest of a coal or gas reference price with fuel taxes or CO_2 payments (Varming et al. 2000).

Table 3.6. Electricity wholesale price and weighted consumer prices and taxes

	Electricity				District heat	
	Wholesale	System costs	Consumer tax	Consumer	Urban heat	Rural heat
Denmark	15.19	35.44	54.15	104.79	12.43	13.43
Estonia	15.19	12.91	0.00	28.10	6.50	7.50
Finland	15.19	16.55	8.74	40.48	8.67	9.67
Germany	15.19	39.95	10.65	65.79	14.60	15.60
Latvia	15.19	13.39	0.00	28.58	6.55	7.55
Lithuania	15.19	13.50	0.00	28.69	7.29	8.29
Norway	15.19	11.64	9.88	36.70	7.82	8.82
Poland	15.19	7.05	4.25	26.49	6.38	6.38
Russia W+K	15.19	10.98	0.00	26.17	6.10	7.10
Sweden	15.19	10.03	6.10	31.32	5.82	6.82

Used in Sheet Geog205.xls Elastic/Param.

The heat prices are calculated on the basis of the value of electricity loss from an extraction unit using the heat loss ratio 0.15, and taking into account the heat distribution losses and distribution cost.

3.3 Initial generation capacities

The initial generating capacities for electricity and heat for the various countries are divided into electricity regions and district heating areas on the basis of available statistics or estimates.

Urban areas consist of large-scale interconnected district heating networks and electricity generating technologies that supply these networks with heat or steam.

Rural areas contain all electricity-only technologies and small-scale CHP technologies that are designed for a local heat market.

Table 3.7 shows the initial capacities for electricity and heat generating technologies in Denmark 1995, following the structure of the electricity and heat market as described in Section 3.1.1.

Extraction-condensing plants are normally excluded in rural areas. However, some of condensing plants have extraction facilities for the local market. The capacity of these plants – or part of it – must be treated as extraction-condensing plants. The technical data for condensing and extraction-condensing plants of the same vintage are identical apart from the extraction facilities. Thus, the split between these two types of plants may be a matter of model calibration. (Initially, the full capacities of the large coal-fired plants Asnæs 3-5 and Ensted 3, which have extraction facilities to supply the heat markets in the neighbouring towns, were categorised as condensing plants located in rural areas).

A key figure to be used for the split between urban and rural area is the share of the heat market in urban areas. For the two Danish electricity regions this share was calculated to 66 % in DK_E and 55 % in DK_W.

District heating boilers are most often older boilers that are maintained for peak load supply. In most district heating areas their capacities are abundant, and their capacity limits will not be binding. The utilisation time will most often be very low. The data for their capacities in Table 3.7 are taken from Baltic 21 Energy. The splits between east and west Denmark and urban and rural areas are arbitrary 50 % east and west, 50 % urban and rural in east, 20 % urban and 80 % rural in west.

Table 3.7. Initial capacities for electricity and heat. Denmark 1995

	Electricity	Coal	Lignite	Peat	Shale	Oil	Gas	Waste	Biomass	Total electricity	Total heat
	-E	-C	-L	-P	-S	-O	-G	-W	-B	MW	MW
DK_E										4230	1000
Urban											
ST-Ext-2		258				14	0			272	
ST-Ext-1		474				25				499	
ST-BP-2		79					164			243	
ST-BP-1								18	0	18	
DH-New		50				100	150	200	0		500
Rural											
ST-Con-3		716				38				754	
ST-Con-2		703				37				740	
ST-Ext-3		513				27				540	
ST-Ext-2		608				32				640	
Hydro	3									3	
WIND-L	195									195	
WIND-S	0									0	
ST-BP-2		30					236			267	
ST-BP-1								14	44	59	
DH-New		50				100	150	0	200		500
DK_W										5594	1000
Urban											
ST-Ext-2		2071				109	269			2449	
ST-Ext-1		749				39				788	
ST-BP-2		0					0			0	
ST-BP-1								24	2	26	
DH-New		50				100	150	200	0		500
Rural											
ST-Con-3		396				21				417	
ST-Con-2		157				8				165	
ST-Ext-3		0				0				0	
ST-Ext-2		570				30				600	
Hydro	5									5	
WIND-L	397									397	
WIND-S	0									0	
ST-BP-2		243					379			622	
ST-BP-1								85	40	125	
DH-New		50				100	150	0	200		500

Source: Energistyrelsen 1996. Used in Sheet Year205.xls Capa.

The data for initial capacities in Finland, Norway and Sweden in Table 3.8 are based on Baltic 21 Energy. The splits between urban and rural areas are based on rough assumptions. There are no 'urban' areas in Norway, i.e. there are no district heating areas with heat dispatch. In Sweden and Finland the share of urban areas is set at two-thirds for all years.

Table 3.8. Initial capacities for electricity and heat. Finland, Norway and Sweden 1995

	Electricity -E	Coal -C	Lignite -L	Peat -P	Shale -S	Oil -O	Gas -G	Waste -W	Biomass -B	Total electricity MW	Total heat MW
FI										14825	0
Urban											
ST-Ext-2		1015				300	710			2025	
ST-Ext-1		1265		300		0	400		1090	3055	
DH-New		0				0	0				0
Rural											
ST-Con-3						880				880	
ST-Con-2		620		2100		255	700			3675	
NU-Con-1	2340									2340	
HYDRO	2840									2840	
WIND-L	10									10	
DH-New		0				0	0				0
NO										27545	
Urban											
ST-Ext-2						157				157	
DH	0										
HP-DH-2	0										
Rural											
ST-Con-3						108				108	
HYDRO	27276									27276	
WIND-L	4									4	
DH	0										
HP-DH-2	0										
SE										34417	13350
Urban											
ST-Ext-2		220				175	40			435	
ST-Ext-1		1270				125	0		1590	2985	
ST-BP-1									97	97	
DH	1229										1229
DH-New		784				1119	392		2740		5035
HP-DH-2	2680										2680
Rural											
ST-Con-3						1818				1818	
ST-Con-2		680				1360	730			2770	
NU-Con-1	10045									10045	
HYDRO	16152									16152	
WIND-L	67									67	
ST-BP-1									48	48	
DH	606										605
DH-New		386				551	193		1350		2479
HP-DH-2	1320										1320

Used in Sheet Year205.xls Capa.

The initial capacities for the Baltic countries, western Russia in Table 3.9 and Poland in Table 3.10 are based on submission from the project participants in each of these countries and Baltic 21 Energy. The 'urban' share of the heat market is set at 40 % in Estonia and 60 % in Latvia. In Lithuania the urban share is calculated to 60 %. In Russia all the Kaliningrad region (RU_K) belongs to the urban area, and in RU_W the urban share is set at two-thirds.

Table 3.9. Initial capacities for electricity and heat. Estonia, Latvia, Lithuania, and parts of Russia, 1995

	Electricity -E	Coal -C	Lignite -L	Peat -P	Shale -S	Oil -O	Gas -G	Waste -W	Biomass -B	Total electricity MW	Total heat MW
EE										3265	6421
Urban											
ST-Ext-4				8	975	75	141			1199	
DH-Old				0	3057	462	1040		0		4559
Rural											
ST-Con-4					2066					2066	
DH-Old				0	0	308	694		860		1862
LV										1985	4700
Urban											
ST-Ext-2		64				8	8			80	
ST-Ext-1		21				0	193			214	
ST-BP-1									8	8	
DH-Old				78		620	776		78		1551
Rural											
ST-Con-2		3		3		24	0			30	
ST-Con-1		14				0	122			136	
HYDRO	1500									1500	
ST-BP-1									17	17	
DH-Old				157		1260	1575		157		3149
LT										5490	4000
Urban											
ST-Ext-2		72				290	362			724	
DH	240										240
DH-Old						1272	888				2160
Rural											
ST-Con-3						900	900			1800	
ST-Con-2		27		133		106	0			266	
NU-Con-1	2600									2600	
HYDRO	100									100	
DH	160										160
DH-Old						848	592				1440
RU_W										10506	38260
Urban											
ST-Ext-2		660				1100	440			2200	
DH-Old		5127				12305	7690	0	513		25634
Rural											
ST-Con-4					600					600	
ST-Con-3		2100				300	0			2400	
ST-Con-2		242				403	161			806	
NU-Con-1	3000									3000	
HYDRO	1500									1500	
DH-Old		2525				6060	3788	0	252		12625.8
RU-K										190	1000
Urban											
ST-Ext-2		30				160	0			190	
DH-Old		150				850	0	0	0		1000

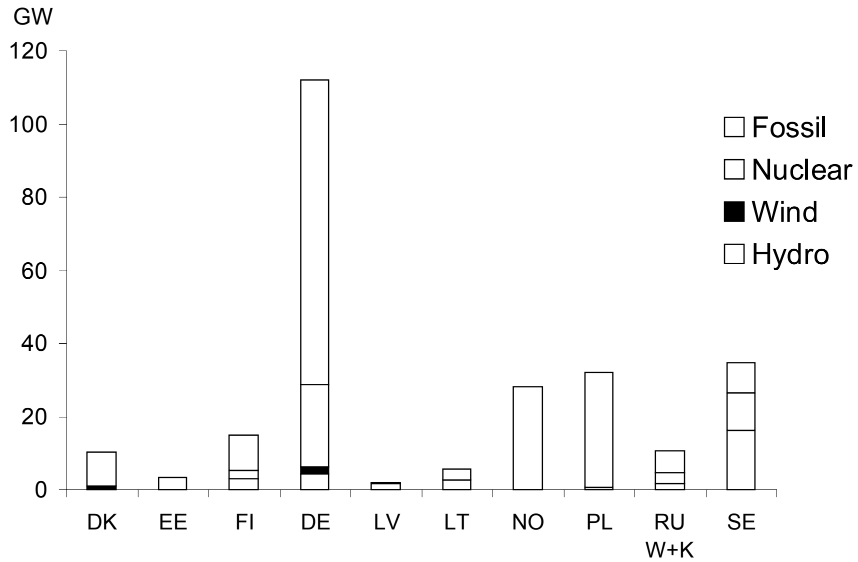
Used in Sheet Year205.xls Capa.

The data for initial capacities for Germany in Table 3.10 are based on Munksgaard et al 2000 and Baltic 21 Energy. The urban share of the heat market is set at two-thirds for Germany and four-fifths for Poland.

Table 3.10. Initial capacities for electricity and heat. Germany and Poland, 1995

	Electricity	Coal	Lignite	Peat	Shale	Oil	Gas	Waste	Biomass	Total electricity	Total heat
	-E	-C	-L	-P	-S	-O	-G	-W	-B	MW	MW
DE										111700	20000
Urban											
ST-Ext-2		13500	3000			1200	8000			25700	
ST-BP-2		0				0	0			0	
CC-Ext-1							3800			3800	
DH-New		5360				4020	4020				13400
Rural											
ST-Con-3							1200			1200	
ST-Con-2		20400	18100			4400	9000	800		52700	
NU-Con-1	22800									22800	
HYDRO	4400									4400	
WIND-L	1100									1100	
ST-BP-2		0				0	0			0	
DH-New		2640				1980	1980				6600
PL										31987	20000
Urban											
ST-Ext-3		1880								1880	
ST-Ext-2		4460								4460	
DH-Old		4355				2010	3015	2010	2010		13400
Rural											
ST-Con-3		9259								9259	
ST-Con-2		15938								15938	
HYDRO	450									450	
DH-Old		2145				990	1485	990	990		6600

Used in Sheet Year205.xls Capa.



Source: Enerdate and own estimates

Figure 3.4. Electricity generating capacities 1997.

The total generation capacity in the Baltic Sea Region – with the definition used for the current version of the model amounted to 253 GW in 1997. About 45 % of the capacity is situated in Germany. Figure 3.4 illustrates the composition of generation capacities for each country.

3.4 Interregional electricity transmission

The electricity trade among the electricity regions is calculated in the model. For historical years, the model may be calibrated to reproduce actual trade, or the differences between model results and actual trade may be explained in the calibration process.

3.4.1 Transmission capacities

Table 3.11 shows the initial electrical transmission capacities in 1995 between pairs of neighbouring electricity regions, and the cost of new capacities between these regions.

The capacities shown in Table 3.11 represent the nominal capacities in both directions. In Balmorel Version 2.05 the transmission loss is assumed at 2.5 % for all pairs of regions, and the cost of transmission between regions is set at 1000 €$_{90}$ per MWh.

Table 3.11. Initial transmission capacities between electricity regions and investment costs of new capacity.

	DK_E	DK_W	EE_R	FI_R	DE_R	LV_R	LT_R	NO_R	PL_R	RU_W	RU_K	SE_R
Initial transmission capacity between regions (MW)												
DK_E		0	0	0	600	0	0	0	0	0	0	1450
DK_W			0	0	1400	0	0	1040	0	0	0	550
EE_R				0	0	1300	0	0	0	1400	0	0
FI_R					0	0	0	100	0	1060	0	1435
DE_R						0	0	0	500	0	0	600
LV_R							2000	0	0	700	0	0
LT_R								0	0	0	1000	0
NO_R									0	50	0	3550
PL_R										0	0	0
RU_W											0	0
RU_K												0
SE_R												
Investment cost in new transmission cap. (€$_{90}$/MW)												
DK_E	0	0			300			300	300		500	300
DK_W	0	0			300			300	300		500	300
EE_R			0	300		300				300		600
FI_R			300	0				300		300		300
DE_R	300	300			0			600	300			400
LV_R			300			0	300		600	300	600	600
LT_R						300	0		300		300	700
NO_R	300	300		300	600			0		300		300
PL_R	300	300			300	600	300		0		300	300
RU_W			300	300		300		300		0		
RU_K	500	500				600	300		300		0	
SE_R	300	300	600	300	400	600	700	300	300			0

Nordel Annual Report 1995 and own estimates. Used in Sheet Geog205.xls trans.

There is no physical transfer capacity between the two Danish electricity regions east and west of the Great Belt. However, the two regions are very similar in their supply and demand structure, so they may be modeled as a single regions. The details of the data in Balmorel Version 2.05 do not allow an appropriate modeling of the trade between the two regions or an endogenous investment in transfer capacity.

3.4.2 Electricity import and export

The only data for trade that is needed for input is the trade with third countries. Only two countries are considered, Lithuania and Poland. In Lithuania the net exports reflects the operation of the Ignalina nuclear power plants. In 1995 1.1 TWh was imported. In the following years the net export were 1.8, 2..1, 5.4 and 1.4. In future years the export volumes are assumed at 2.0 TWh. From Poland 3.6 TWh were exported in 1998. This volume is assumed being reduced gradually and will be eliminated after 2010.

3.5 National or regional constraints

Some electricity generation technologies are constrained on a national, regional or area level either on resource limits or legal restrictions. These constraints are implemented on a maximum capacity for technologies using each fuel. Table 3.12 shows the constraints used in Version 2.05.

An important set of constraints are emission limits for SO_2, NO_x and CO_2. These constraints are mainly uses as policy parameters for analyses of different instruments. In a linear optimisation model such constraints are useful fore the calculation of the costs of different measures. The application illustrations in Sections 6.2 and 6.3 in the main report are based on the use of such constraints.

Table 3.12. Maximum potentials for electricity generation technologies, MW.

	Den-mark	Estonia	Finland	Ger-many	Latvia	Lithu-ania	Nor-way	Poland	Russia W+K	Swe-den
Nuclear	0	0			0		0	0		
Lignite	0						0			0
Oil Shale	0	6100	0	0	0	0	0	0	600	0
Peat	0	750	3200	0	370		0	0	4130	0
Wind	5500	120	3500	1600	600	500	38000	5000	2300	20500
Hydro	0	0	1480	40	2500	4000	30000	1370	810	18000
Solar	0	0	0	0	0	0	0	0	0	0
Biomass	5050	3440	27720	3790	4820	5040	8500	29830	19320	33680
Urban: Waste	540	40	540	490	70	100	460	2100	220	930
Rural: Waste	600									
Urban: Natural gas										
Rural: Natural gas										

Used in Sheet Geog205.xls Capa.

3.6 Seasonal and diurnal variations

The seasonal and diurnal variations of electricity and heat demands are described by load factors in per cent in each time period for each electricity region and heat area.

The basic optimisation period of the model is one year, which can be divided into a flexible number of sub periods (viz., seasons that are further subdivided into hours) making the model capable of handling seasonal and diurnal variations in the demand of electricity and heat. Table 3.13 shows different combinations of diurnal and seasonal subdivisions of year, which was used for an analysis of the Krounis Hydro Pumped Storage Power Plant in Lithuania (Galinis, Hindsberger and Ravn, 2000). In this study the time structures were made from the hourly load profile of Lithuania in 1999.

Table 3.13. Various subdivision of the year.

Name	Description
8760	All 8760 hours of the year
4-168	4 seasons each of 168 time periods
4-24	4 seasons each of 24 time periods
2-4	2 seasons each of 4 time periods
2-2	2 seasons each of 2 time periods
1-1	No subdivision of the year

In Balmorel Version 2.05, (March 2001) there are data for two diurnal and two seasonal time-periods.

- Diurnal: Day time: 7-21 (15 hours). Night time 1-6 and 22-24 (9 hours)
- Seasonal: Winter: October-March. Summer: April-September.

Table 3.14 shows the assumptions used in Version 2.05. The differences in the load variations among the electricity regions are due to the different structure of electricity demands. Regions with a large share of industrial electricity consumption tends to have less seasonal and diurnal variation and, thus, a higher overall load factor than regions with a small share of industrial demand. The demand variations for heat are set at the same values for all heat areas.

Table 3.14. Seasonal and diurnal variations of load factors for electricity and heat demands

	Winter	(October-March)		Summer	(April-September)		Sum
	Night	Day	Average	Night	Day	Average	Average
Electricity demand							
Denmark	61	89	71.5	33	47	38.3	54.9
Estonia	56	77	63.9	37	51	42.3	53.1
Finland	67	73	69.3	46	51	47.9	58.6
Germany	61	89	71.5	33	47	38.3	54.9
Latvia	56	77	63.9	41	56	46.6	55.3
Lithuania	69	77	72.0	37	51	42.3	57.1
Norway	69	80	73.1	41	46	42.9	58.0
Poland	71	85	76.3	39	41	39.8	58.0
Russia W+K	56	77	63.9	37	51	42.3	53.1
Sweden	69	83	74.3	38	45	40.6	57.4
Heat demand	33	36	34.1	7	7	7	20.6

Source. Own estimates. Used in Sheet Geog205.xls Season.

The diurnal and seasonal variations for wind and solar power are specified as load factors for the installed capacities. In the current version of Balmorel the same variations are used for all electricity regions. The same method is used for variations of electricity trade with countries outside the model area. These variations are used for Lithuania only, while no variations are assumed for Poland. See Table 3.15.

Table 3.15. Seasonal and diurnal variations of load factors for renewable electricity generation and electricity trade with third countries.

	Winter	(October-March)		Summer	(April-September)		Sum
	Night	Day	Average	Night	Day	Average	Average
Wind power	29	30	29.4	20	21	20.4	24.9
Solar power	1	5	2.5	4	20	10.0	6.3
Electricity trade							
Lithuania	60	73	64.9	42	53	46.1	55.5
Poland	100	100	100.0	100	100	100.0	100.0

Source. Own estimates. Used in Sheet Geog205.xls Season.

Table 3.16 contains the description of the seasonal variation of the amount of water inflow to the reservoirs for each installed MW capacity of hydropower with storage.

Table 3.16. Seasonal variation for hydropower with storage. MWh inflow per MW installed generation capacity

	Winter	Summer
Finland	1520	2830
Latvia	971	1040
Norway	1055	3140
Poland	1470	1470
Sweden	990	3135

Source. Own estimates. Used in Sheet Geog205.xls Season.

4 Macroeconomic and global data

This chapter shortly describes the macroeconomic and global data that are used either in the model or for preparation of the exogenous parameters to the model.

Macroeconomic data such as growth rates and elasticities are assumptions necessary for determining the future demand for electricity and heat. A set of forecasts for electricity and heat demand and prices at the consumer level are exogenous to the Balmorel model (see Section 3.2).

However, the future demand for electricity and heat may be dependent of the endogenous consumer prices. Thus price elasticities for the various consumer groups are introduced as input parameters in the model.

This chapter describes the global fuel price forecasts, which are used for all the countries, the discount rate used for translating investment costs into annual cost for the optimisation, and the currency conversion factors that are used for conversion of amounts from different sources into the currency used in the model, $€_{90}$. A detailed description of the selection of numerical demand elasticities is found in Chapter 5.

4.1 Price forecasts

National fuel price forecasts are calculated adding transport costs and national taxes to cif prices (cost, insurance and freight) to a national harbour or border station. Fuel price forecasts for indigenous fuels are based on national forecasts. Price forecasts for internationally traded fuels are global data. The forecasts for these prices are the same for all countries.

Table 4.1 shows the fuel price forecasts used in Balmorel Version 2.05 for all countries.

Table 4.1. Fuel price forecast for all countries: cif plus domestic transport, $€_{90}$/GJ

	Nuclear	Natural gas	Coal	Lignite etc.	Fuel oil	Waste	Biomass
1995	0.981	1.842	1.367	1.027	1.936	0.000	1.386
1998	0.981	1.809	1.345	1.027	1.803	0.000	1.445
2000	0.981	1.786	1.331	1.116	1.714	0.000	1.485
2010	0.981	2.182	1.353	1.050	2.019	0.000	1.683
2020	0.981	2.581	1.385	1.160	2.324	0.000	1.881
2030	0.981	2.747	1.429	1.204	2.554	0.000	2.079

The international fuel price forecasts are from the Shared Analysis Project. These are calculated by the POLES model for the global energy market (European Commission 1999a,b). The forecasts are supplemented by own calculations and submission from the participants for indigenous fuels. In Version 2.05 of Balmorel the Polish forecast for lignite is used for lignite, peat and oil shale in all countries. The price of urban waste is set at zero.

4.2 Choice of discount rate

A key parameter is the discount rate, which may greatly influence the future technology choice. In practice the discount rate is implemented in Balmorel as an annuity factor for investment costs of new capacities. The annuity factor used in the main presentation in Chapter 6 of the main report is 0.16, which represent a 10 % discount rate and 10 years economic lifetime. Table 4 in the Appendix "Balmorel Model Structure" shows the annuity factor as a function of the discount rate and lifetime.

Variations in the discount rate are an important parameter for sensitivity analyses. The discount rate is also used to implement assumptions on the degree of competition and regulation. A high discount rate represents a high degree of competition and limited regulation.

In the PRIMES version for the Shared Analysis Project, steam and electricity generation are grouped together as if they were a single industrial sector. The analysis includes the whole production of industrial steam and the heat that can be distributed through small-scale or large-scale district heating network. The analysis deals with three standardised – or stylised – market suppliers, namely

- utilities
- industrial generators and
- other decentralised producers

The three stylised market suppliers have different technology choice menus reflecting their differences in size and associated economies of scale. The analysis treats stylised suppliers as if they were representatives of an unknown number of similar real-world companies. The discount rate applicable to all decisions on power generation capacity expansions has been assumed to be equal to 8 % per year in real terms. (see Varming et al. 2000 for further details).

The structure and boundaries of the optimisation model used in a liberalised market is very important. A societal discount rate of perhaps 5 % may be applied for the common optimisation of the economy including elements that are regulated monopolies, while the optimisation for a particular agent in a competitive market must apply a higher discount rate of 10 % real or more. In the latter case all elements that have a regulated monopoly character must be exogenous.

4.3 Currency conversion

Data for prices and costs of investment and operation and maintenance are from different sources and, thus, quoted in different currencies and different price-years. To use these different sources in a model requires conversion to the same currency and price year. All prices in the Balmorel model are shown in $€_{90}$ – or more correctly ECU 1990, because the Euro was not introduces until 1999.

The recommended sequences of calculation between national currencies of different years and ECU 1990 are:

- t1, t2>1990: National currency t1 <-> ECU t1 <-> ECU t2
- t1<1990, t2>1990: National currency t1 <-> National currency 1990 <-> ECU 1990 <-> ECU t2
- t1, t2<1990: differences in results from sequence of calculation should be tested.

This conversion is non-trivial. Adjustment for inflation may be based on differentt inflators, which may lead to very different results, and the sequence of the conversion of currencies and the inflation/deflation may have significant impact on the result. For both EUR and USD Amount (98) = 1.25* Amount(90). However, the exchange rates in 1990 and 1998 are different.

Table 4.2 shows the exchange rates between ECU/Euro and the currencies used in the Baltic Sea Region for the years 1989 to 1999, and the conversion factors to ECU 1990 are shown in Table 4.3 using the rules as described above.

Table 4.2. Exchange rates between ECU/EUR and selected national currencies.

Country	Currency	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Denmark	DKK	8.049	7.857	7.909	7.809	7.594	7.543	7.328	7.359	7.484	7.499	7.436
Estonia	EEK					15.491	15.396	14.990	15.276	15.715	15.753	15.647
Finland	FIM					6.696	6.191	5.709	5.828	5.881	5.983	5.946
Germany	DEM	2.070	2.052	2.051	2.020	1.936	1.925	1.874	1.910	1.964	1.969	1.956
Latvia	LVL					0.671	0.664	0.690	0.699	0.659	0.660	0.623
Lithuania	LTL					4.684	4.758	5.232	5.079	4.536	4.484	4.259
Norway	NOK	7.599	7.964	8.024	8.032	8.310	8.374	8.286	8.197	8.019	8.466	8.311
Poland	PLN									3.940	3.916	4.224
Russia	RUB									6.555	8.627	26.440
Sweden	SEK					9.122	9.163	9.332	8.515	8.651	8.916	8.804
USA	USD	1.100	1.273	1.236	1.295	1.171	1.190	1.308	1.270	1.134	1.121	1.065
Baltic 21	USD=6 DKK								1.227			
IMF	SDR					0.839	0.830	0.863	0.875	0.824	0.826	0.779

Notes: 8 EEK=1 DEM, 4 LTL = 1 USD, 0.7997 LVL = 1 SDR (Special Drawing Rights of the International Monetary Fund, a basket of EUR (till 1998 DEM, FRF), USD, JPY, GBP)
Sources: Official ECU exchange rates calculated and published by the European Commission. Annual averages 1993-98 / Danmarks Statistik. Tiårsoversigt / Danmarks Nationalbank. / Bank of Latvia, www.bank.lv.

Table 4.3. Conversion factors between ECU 1990 and selected national currencies .

	Currency	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
EU consumer prices		0.961	1.000	1.042	1.084	1.120	1.148	1.177	1.207	1.226	1.240	1.253
Denmark	DKK	7.738	7.857	8.239	8.466	8.503	8.662	8.627	8.881	9.175	9.296	9.318
Estonia	EEK					17.347	17.679	17.648	18.435	19.267	19.526	19.608
Finland	FIM					7.499	7.109	6.721	7.033	7.210	7.416	7.451
Germany	DEM	1.990	2.052	2.136	2.190	2.168	2.210	2.206	2.304	2.408	2.441	2.451
Latvia	LVL					0.751	0.762	0.812	0.844	0.808	0.819	0.780
Lithuania	LTL					5.245	5.464	6.160	6.129	5.562	5.559	5.337
Norway	NOK	7.306	7.964	8.359	8.707	9.305	9.616	9.755	9.891	9.831	10.494	10.415
Poland	PLN									4.831	4.855	5.293
Russia	RUR									8.036	10.693	33.134
Sweden	SEK					10.214	10.522	10.987	10.275	10.607	11.052	11.033
USA	USD	1.057	1.273	1.288	1.403	1.311	1.366	1.540	1.532	1.390	1.390	1.334
Baltic 21	USD=6 DKK								1.480			

Notes: Deflator EU consumer prices.
Sources: Eurostat: Harmonised Indices of Consumer Prices.

5 Demand elasticities

The impact of consumer price elasticities on the wholesale demand for electricity and heat is highly dependent on taxes and the market structure. National fuel price forecasts are calculated adding transport costs and national taxes to cif. prices. Fuel price forecasts for indigenous fuels are based on national forecasts.

The preliminary versions of the Balmorel model were techno-economic bottom-up models with exogenous demand for electricity and heat. The key parameters for the further development of the model to a partial equilibrium model has been partial price elasticities for electricity and heat at sectoral or aggregate levels.

5.1 Numerical values of elasticities

Elasticities for the energy demand have been widely published from numerous studies using different estimation techniques or calibration within a modelling framework. An important task in the model development will be the selection of appropriate numerical values and the implementation of these parameters into a partial equilibrium model, focusing on the calculation methods, validity, and interpretation of the parameters.

5.1.1 Elasticity concepts and standard functions

Elasticities are the most widely used concepts in economic modelling to describe the demand for goods as a function of income and prices. These parameters should be specified within a framework of functions that are useful for the development of an objective function and equilibrium condition for a partial equilibrium model.

Table 5.1 shows the elasticities concepts that are considered for the modelling of electricity and heat demand in the Balmorel model. A range of functions have been developed for optimisation or equilibrium condition. Table 5.1 also shows the two most elementary and widely used standard functions. The theory is further described in the Appendix “Elasticities – a Theoretical Introduction”. This current Appendix will focus on the numerical values of the various elasticities concepts and the availability of these values from empirical studies.

Table 5.1. Elasticities and standard functions

			Cobb-Douglas function	CES function
Mathematical form of Functions			$A\prod_{i=1}^{n} C_i^{\alpha_i} = A\left(C_1^{\alpha_1} C_2^{\alpha_2} \cdots C_n^{\alpha_n}\right)$ A>0 is constant $\alpha_i > 0$, $\sum_i \alpha_i = 1$	$\left(\sum_{i=1}^{n} \beta_i C_i^{\frac{E-1}{E}}\right)^{\frac{E}{(E-1)}}$ β is constant
Income elasticity	The percentage change in demand for good *i* per percent change in income.	$\varepsilon_I = \frac{\partial C_i / C_i}{\partial M / M} = \frac{\partial C_i}{\partial M} \frac{M}{C_i}$	1	1
Own price elasticity	The percentage change in demand for good *i* per percent change in the price for good *i*.	$\varepsilon_p = \frac{\partial C_i / C_i}{\partial p_i / p_i} = \frac{\partial C_i}{\partial p_i} \frac{p_i}{C_i}$	-1	$-E + (E-1)e_i$
Cross price elasticity	The percentage change in demand for good per percent change in the price for good *j*.	$\varepsilon_{i,j} = \frac{\partial C_i / C_i}{\partial p_j / p_j} = \frac{\partial C_i}{\partial p_j} \frac{p_j}{C_i}$	0	$(E-1)e_j$
Own price elasticity, compensated	Compensation for Income effect	ζ_p	$\alpha_i - 1$	$-E(1-e_i)$
Cross price elasticity, compensated	Compensation for Income effect	$\zeta_{i,j}$	α_j	Ee_j
Elasticity of Substitution	The percentage change in the relative consumption of goods *i* and *j* per percent change in their relative prices.	$\sigma_{i,j} = \frac{-\partial\left(\frac{C_i}{C_j}\right)}{\partial\left(MRS_{ij}\right)} \frac{\left(MRS_{ij}\right)}{\left(\frac{C_i}{C_j}\right)}$	1	E

C_i demand for good *i*, p_i price for good *i*, *M* income, *MRS* marginal substitution or marginal utility of goods *i* and *j*, α_i or e_i share of input or budget for good *i*.

The Cobb-Douglas functions are the most basic function type for this purpose. It may be used to describe a production function and a utility function. The only parameters are the shares of goods that are considered in the model. The values of the elasticities are restricted to their unit values. However, price elasticities with compensation for the income effect are dependent on the budget share of the goods.

The CES functions (constant elasticity of substitution) allow much more flexibility of parameters. The income elasticity must be unity, but price elasticities can be specified individually for each pair of goods. This restriction to pairs of goods may be overcome by a hierarchy of pairs of goods in *nested CES functions.* In an energy model the first level considers an aggregate energy demand and all other goods, the next level may consider electricity (or heat) versus other energy demand. If a level contains more than two elements (e.g. heat divided into district heating, natural gas, oil coal, peat, etc.) all these elements must have the same substitution elasticities.

The numerical values are estimated either by econometric methods from time-series or cross-section analyses, or they are calibrated within a model framework. Estimations by econometric methods require a large amount of good-quality statistical data, which can be found in national account statistics. This statistics has been developed over several decades in all developed market economies, and concepts and methods have been harmonised by the effort within international organisations such as the OECD and the European Union. In most transition economies this statistics is under development, but it is obviously not available for econometric estimations on long time-series. In these countries it is necessary to use parameter values from cross-section analyses or model calibrations.

5.1.2 Exogenous own price elasticities in CES functions

Two types of parameters are used in a CES function for the demand side: the share of total expenditure and a price or substitution elasticity. If one of these elasticities is known the others can be calculated using the formulas in Table 5.1. Own and cross price elasticities have a good intuition, while substitution elasticities are more difficult Table 5.1 describes the numerical values of the relations of the various concepts using budget shares and own price elasticities as entries.

Compensation of price elasticities for income effects of price changes will depend on the scenario specification. Changes in import prices for energy do not provide any compensation for import effect, while revenue-neutral taxes or 'grandfathered' emission permits will provide some compensation, but these measures may have an impact on the income distribution.

Table 5.2. Exogenous own price elasticities in CES functions

Budget share for electricity	$e_i=0.10$					
Own price elasticity	ε_p	*-0.10*	*-0.25*	*-0.50*	*-1.00*	*-2.00*
Cross price elasticity	$1-\varepsilon_p$	-0.90	-0.75	-0.50	0.00	1.00
Own price elasticity, compensated	ε_p+e_i	0.00	-0.15	-0.40	-0.90	-1.90
Cross price elasticity, compensated	$-(\varepsilon_p+e_i)$	0.00	0.15	0.40	0.90	1.90
Substitution elasticity	$-(\varepsilon_p+e_i)/(1-e_i)$	0.00	0.17	0.44	1.00	2.11
Budget share for electricity	$e_i=0.50$					
Own price elasticity	ε_p	*-0.10*	*-0.25*	*-0.50*	*-1.00*	*-2.00*
Cross price elasticity	$1-\varepsilon_p$	-0.90	-0.75	-0.50	0.00	1.00
Own price elasticity, compensated	ε_p+e_i	0.40	0.25	0.00	-0.50	-1.50
Cross price elasticity, compensated	$-(\varepsilon_p+e_i)$	-0.40	-0.25	0.00	0.50	1.50
Substitution elasticity	$-(\varepsilon_p+e_i)/(1-e_i)$	-0.80	-0.50	0.00	1.00	3.00
Budget share for electricity	$e_i=0.10$					
Own price elasticity, compensated	ζ_p	*-0.10*	*-0.25*	*-0.50*	*-1.00*	*-2.00*
Cross price elasticity, compensated	$-\zeta_p$	0.10	0.25	0.50	1.00	2.00
Own price elasticity	$-\zeta_p-e_i$	-0.20	-0.35	-0.60	-1.10	-2.10
Cross price elasticity	$1-(\zeta_p-e_i)$	-0.80	-0.65	-0.40	0.10	1.10
Substitution elasticity	$-\zeta_p/(1-e_i)$	0.11	0.28	0.56	1.11	2.22
Budget share for electricity	$e_i=0.50$					
Own price elasticity, compensated	ζ_p	*-0.10*	*-0.25*	*-0.50*	*-1.00*	*-2.00*
Cross price elasticity, compensated	$-\zeta_p$	0.10	0.25	0.50	1.00	2.00
Own price elasticity	$-\zeta_p-e_i$	-0.60	-0.75	-1.00	-1.50	-2.50
Cross price elasticity	$1-(\zeta_p-e_i)$	-0.40	-0.25	0.00	0.50	1.50
Substitution elasticity	$-\zeta_p/(1-e_i)$	0.20	0.50	1.00	2.00	4.00

Own price elasticities in either definition are used as entries for calculating of other elasticity concepts, i.e. cross price elasticities and substitution elasticities. The values of these elasticities are dependent on the budget share of de demand for the good that is considered (e.g. electricity or heat). In Table 5.2 two levels of budget shares will be considered.

- Budget share 0.1 when considering share of total budget
- Budget share 0.5 when considering share of energy expenditure or fuel substitution

Figure 5.1 illustrates that – for a given budget share of the demand for a good (electricity or heat) – a series of elasticity concepts become linear functions of the own price elasticity.

For very inelastic demand, e.g. own price elasticity at –0.1 for electricity, the substitution and cross price elasticities become negative. Higher electricity or heat prices without compensation for the income effect will therefore lead to lower demand for other goods. This was a common experience for the consumers in many transition economies during the 1990s.

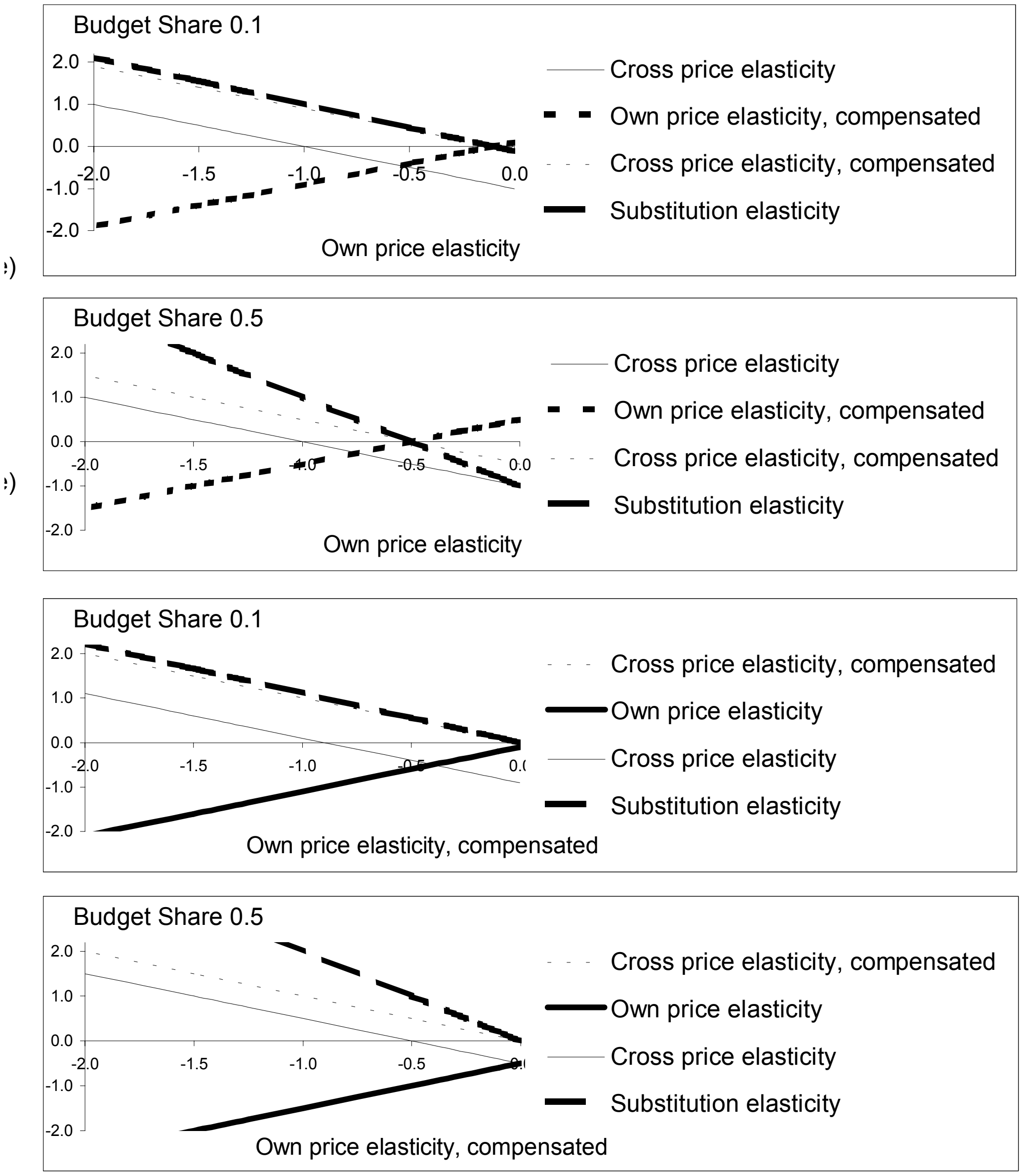


Figure 5.1. Efficiency concepts in a CES function

Table 5.3. Long-term own price elasticities for electricity demand. Sorted.

Country	Sector	Demand	Value	Method	Dataset	Comment
Norway	Heavy industry	Electricity	-0.10	Assumption	ESA-1	
Nordic power market	Residential	Winter Night	-0.10	Assumption	ESA-3	
Denmark	Manufacturing	Electricity	-0.15	Estimation	AKF	1966-1990, analysis on primary data
Norway	Residential	Electricity	-0.20	Assumption	ESA-1	
Northern Europe	Residential	Electricity	-0.20	Assumption	ESA-2	
Northern Europe	Manufacturing	Electricity	-0.20	Assumption	ESA-2	
Nordic power market	Residential	Summer Night	-0.20	Assumption	ESA-3	
Nordic power market	Residential	Winter Day	-0.20	Assumption	ESA-3	
Nordic power market	Manufacturing	Summer Night	-0.20	Assumption	ESA-3	
Nordic power market	Manufacturing	Winter Night	-0.20	Assumption	ESA-3	
Norway	Heavy industry	Electricity	-0.20	Estimation	B&J-1	
Denmark	Manufacturing	Electricity	-0.20	Estimation	B&J-1	
Finland	Manufacturing	Electricity	-0.20	Estimation	B&J-1	
Norway	Residential	Electricity	-0.20	Estimation	Nesbakken	Aasness and Holtsmark (1993) Household data
Norway	Residential	Electricity	-0.24	Estimation	Nesbakken	1995, micro data
Slovenia		Electricity	-0.25	Estimation	Slovenia	
USA	Residential	Electricity	-0.26	Estimation	SEO	Lowest in Table 2 for pooled time-series/cross section, macro
Norway	Services	Electricity	-0.30	Assumption	ESA-1	
Norway	Manufacturing	Electricity	-0.30	Assumption	ESA-1	
Nordic power market	Residential	Summer Day	-0.30	Assumption	ESA-3	
Denmark	Heavy industry	Electricity	-0.30	Estimation	B&J-1	
Sweden	Heavy industry	Electricity	-0.30	Estimation	B&J-1	
Denmark	Food	Electricity	-0.30	Estimation	B&J-1	
Sweden	Manufacturing	Electricity	-0.30	Estimation	B&J-1	
Denmark	Services	Electricity	-0.30	Estimation	B&J-1	
Norway	Services	Electricity	-0.30	Estimation	B&J-1	
Denmark	Manufacturing	Electricity	-0.30	Estimation	AKF	1966-1990, analysis on annual data, low
		Electricity	-0.32	Estimation	EMMA	
USA	Residential	Electricity	-0.33	Estimation	SEO	Highest in Table 2 for pooled time-series/cross section, macro
Germany	Residential	Electricity	-0.38	Estimation	Nesbakken	Micro data, Dennerlein (1987)
Norway	Wood	Electricity	-0.40	Assumption	ESA-1	
Nordic power market	Manufacturing	Summer Day	-0.40	Assumption	ESA-3	
Nordic power market	Manufacturing	Winter Day	-0.40	Assumption	ESA-3	
Norway	Manufacturing	Electricity	-0.40	Estimation	B&J-1	
Finland	Services	Electricity	-0.40	Estimation	B&J-1	
Denmark	Manufacturing	Electricity	-0.40	Estimation	AKF	1966-1990, analysis on annual data, high
Norway	Residential	Electricity	-0.42	Estimation	Nesbakken	Halvorsen og Larsen (1998)
Finland	Heavy industry	Electricity	-0.50	Estimation	B&J-1	
Sweden	Services	Electricity	-0.50	Estimation	B&J-1	
USA	Residential	Electricity	-0.50	Estimation	SEO	Lowest in Table 2 for time-series, macro
USA	Residential	Electricity	-0.60	Estimation	SEO	Highest in Table 2 for time-series, macro
Finland	Wood	Electricity	-0.70	Estimation	B&J-1	
Sweden	Wood	Electricity	-0.70	Estimation	B&J-1	
Norway		Electricity	-0.75	Calibration	ELEPHANT	
Norway		Heat	-0.75	Calibration	ELEPHANT	
Sweden		Electricity	-0.76	Calibration	ELEPHANT	
Sweden		Heat	-0.76	Calibration	ELEPHANT	
UK	Residential	Electricity	-0.76	Estimation	Nesbakken	Micro data. Barker et al. (1989)
Finland		Electricity	-0.78	Calibration	ELEPHANT	
Finland		Heat	-0.78	Calibration	ELEPHANT	
Nordic countries	Residential	Electricity	-0.80	Estimation	B&J-1	
Denmark		Electricity	-0.84	Calibration	ELEPHANT	
Denmark		Heat	-0.84	Calibration	ELEPHANT	
Norway	Wood	Electricity	-1.50	Estimation	B&J-1	
Norway	Occational power	Electricity	-2.00	Assumption	ESA-1	
Norway	Net power	Electricity	-3.00	Assumption	ESA-1	

Source. Elasticities database

5.1.3 Elasticities database

So far, a comprehensive survey of numerical values for elasticities that also covers the economies in transition has not yet been found. Thus, as a part of the Balmorel project an elasticities database has been developed containing numerical values for elasticities, which are useful for energy demand modelling. A recent survey covering OECD countries is found in OECD 2000.

Table 5.3 shows a sample of own price elasticities for electricity from various sources sorted by their absolute values. There are significant differences for estimations or assumptions for the same country and sector by different studies. Except for some particular Norwegian sectors the absolute values of sectoral or aggregated elasticities are below one, and most values based on estimations are below 0.5. Larger absolute values for elasticities have been calibrated for the ELEPHANT model (Hauch 1999). There are estimated values above 0.5 for residential electricity demand in Norway, Sweden, UK and USA, and for the Swedish and Finnish wood industry.

Table 5.4 shows a selection of cross price elasticities for electricity demand to other fuels. Only Nordic sources are reported. In general cross price elasticities are low. The most obvious exception is the wood industry, where the large own price elasticity is reflected by a high cross price elasticity for oil.

A study for electricity demand in Danish manufacturing industries (Kristensen and Oksbjerg 1992) concludes that cross price elasticities are small and insignificant.

If electricity prices are correlated with other fuels, e.g. gas, cross price elasticities will be small.

Table 5.4. Long-term cross price elasticities for electricity demand.

Country	Sector	Price	Value	Method	Dataset	Comment
Denmark	Manufacturing	Other fuels	~0	Estimation	AKF	1966-1990. Cross price elasticities are small and insignificant
Denmark	Food	Oil	0.00	Estimation	B&J-1	
Finland	Wood	Oil	0.00	Estimation	B&J-1	
Denmark	Manufacturing	Oil	0.00	Estimation	B&J-1	
Finland	Manufacturing	Oil	0.00	Estimation	B&J-1	
Sweden	Manufacturing	Oil	0.00	Estimation	B&J-1	
Denmark		Other fuels	0.04	Estimation	EMMA	
Norway	Manufacturing	Oil	0.10	Estimation	B&J-1	
Denmark	Services	Oil	0.10	Estimation	B&J-1	
Norway	Services	Oil	0.10	Estimation	B&J-1	
Finland	Services	Oil	0.20	Estimation	B&J-1	
Sweden	Services	Oil	0.20	Estimation	B&J-1	
Norway	Residential	Oil	0.30	Estimation	B&J-1	
Denmark	Residential	Oil	0.40	Estimation	B&J-1	
Finland	Residential	Oil	0.40	Estimation	B&J-1	
Sweden	Residential	Oil	0.40	Estimation	B&J-1	
Sweden	Wood	Oil	0.50	Estimation	B&J-1	
Norway	Wood	Oil	0.80	Estimation	B&J-1	

Source. Elasticities database

5.2 Elasticities in transition economies

Empirical studies of elasticities on a macro level normally require long time series and an established national account systems. These statistical tools are yet only limited available in transition economies. Empirical studies of consumer behaviour on a micro level, however, is independent of a national account system, and empirical data may be derived from cross-section analyses as well as time series.

5.2.1 Key assumptions for demand projection in Latvia

Income and price elasticities are key assumptions used in domestic electricity demand projection for transition countries. Table 5.5 and Table 5.6 show examples of values used for mid-term energy projections for Latvia from the World Bank mission to Riga 1996.

In Table 5.5 the elasticity for households is equal one in the mid-term after a few years with elasticities above one. The elasticities above one in agriculture indicate the assumption that mechanisation is lagging behind. The elasticities far below one in industry illustrate expected structural changes in the direction of less energy intensive industries similar to Western Europe.

Table 5.5. GDP/electricity elasticity

	Industry	Agriculture	Households	Other
1996	0.76	1.09	1.04	0.98
1998	0.72	1.07	1.02	0.94
2000	0.68	1.05	1.00	0.90
2002	0.64	1.03	1.00	0.86
2004	0.60	1.01	1.00	0.82
2005	0.58	1.00	1.00	0.80

Source: World Bank 1996

The price elasticities for electricity demand in Table 5.6 are very low, and the numerical values are common for all end uses. The short-term elasticity is very low, but the lagged values for the following years add to the impact of price changes. The long-term price elasticity shows that the electricity demand is assumed very inelastic and mainly dependent on economic growth.

Table 5.6. Price elasticity for electricity (numerical values)

t(0) short-term	0.08
t(1) lagged 1 year	0.06
t(2) lagged 2 years	0.04
Long term	0.18

Source: World Bank 1996

Residential consumers

Within the residential sector which annually consumes some 120-140 million cubic meters, naturals gas has two specific uses – cooking and heat production.

The estimated price elasticity on demand of energy for the residential consumers are summarised in Table 5.7. There is no distinction between short-term and long-term elasticities. The own price elasticity for residential consumers is a little higher than that in Table 5.6, but both assumptions are within the range for residential electricity demand found in many studies for well-established market economies.

Table 5.7. Estimated price elasticities on demand of energy – Residential consumers (1997)

Demand change in %	Price change													
	Natural gas		Coal		District heat		LFO		Electricity		Wood		Peat	
	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%
Natural gas	-2.00	1.00	-	-	0.50	-	5.00	-	-	-	-	-	-	-
Coal	-	-	-15.00	1.00	-	-	-	-	-	-	-	-	0.50	-5.00
LFO	-	-	-	-	-	-	4.00	-	-	-	-	-	-	-
Wood	-	-	12.00	-	2.00	1.00	-10.00	-	-	-	-0.50	-	2.50	-
Peat	-	-	3.00	-1.00	-	-	-	-	-	-	-	-	-3.00	5.00
District heat	1.00	-	-	-	-3.00	1.00	-	-	0.30	-0.50	0.40	-	-	-
Electricity	1.00	-1.00	-	-	0.50	-	1.00	-	-0.30	0.50	0.10	-	-	-

Source: PHARE 1998

Industry and district heating

Even that Latvijas Gaze has no competitors of its kind, it is in intense competition with other fuel suppliers. Industrial and district companies by nature of their consumption in Latvia are very similar.

Larger consumers with over of 10 MW installed capacity, playing the most important part in natural gas sales can easily switch to HFO (mazut). All natural gas fired facilities formerly were required to have a backup fuel option. Smaller companies, particularly within the growing woodworking industry and in woody areas, would use wood instead of gas.

Taking into account the present price relationships, HFO represents the main competition for this sector, while wood remains the cheapest option for woodworking industry and small facilities in other branches.

Table 5.8. Estimated price elasticities on demand of energy – Industry and District Heating (1997)

Demand change in %	Price change											
	Natural gas		LFO		Electricity		HFO		Wood		Peat	
	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%	+5%	-5%
Natural gas	-15.00	1.00	-	-	-	-	9.00	-10.00	-	1.00	-	-
HFO	10.00	1.00	-	-	-	-	-10.00	10.00	-	2.00	-	-
LFO	-	-	-15.00	-	-	-	-	-	0.50	3.00	-	-
Wood	3.00	-	12.00	-	-	-	1.00	-	-2.00	6.00	5.00	2.00
Peat	1.00	-	3.00	-	-	-	-	-	1.00	-	-5.00	2.00
Electricity	-	-	-	-	-2.00	1.00	-	-	0.50	-	-	-

Source: PHARE 1998

Power plants

Power plant sector in Latvia is actually composed of two CHPs in Riga that both have well-developed HFO infrastructure. Even that CHP-1 annually utilises some 200 thousand tons of peat this sector due to political pressure at present is regard as impenetrable by natural gas.

Power plants are the most important and flexible natural gas consumers. Their gas purchases are not based on long term agreements and fuels could be switched very quickly. Meanwhile both CHPs together technically annually could consume over 500-600 million cubic meters of natural gas or some 50 % of the total present gas demand. So far gas covers 25-50 % of their consumption and the difference has been covered by HFO.

Table 5.9. Estimated price elasticities on demand of energy – Power Plants (1996)

Demand change in %	Price change			
	Natural gas		HFO	
	+5%	-5%	5%	-5%
Natural gas	- 25.00	25.00	25.00	- 25.00
HFO	25.00	- 25.00	- 25.00	25.00

Source: PHARE 1998

5.2.2 Energy tariff calculation sheets

In an earlier collaborative project concerning natural gas and energy tariffs in Latvia, completed in 1996, a system of Customer Calculation Sheets for the analysis of consumer expenditure and utility revenue was developed (Klavs and Grohnheit 1998). The results of that study was discussed as an appropriate source for demand elasticities for the Balmorel model, see Grohnheit and Klavs 2000.

5.3 Elasticities in established market economies

In most established market economies there is a long tradition for national account statistics, which is an important source for econometric analyses bases on long time-series. In addition there has been an ongoing activity over several decades for standardisation and harmonisation of these statistical sources. These activities have been further supported by the development and use of macroeconomic models of different types.

5.3.1 Wholesale electricity prices, taxes and consumer prices in Denmark

Electricity demand elasticities are assumed for the national electricity market for different types of customers. Price elasticities refer to consumer prices, which are composed by the electricity wholesale price (e.g. on the Nord Pool spot or forward market for electricity in Oslo, Norway), a fixed cost per MWh for electricity transmission and distribution and excise taxes (electricity, CO_2, and SO_2 taxes. Table 5.10 shows some widely different assumptions for electricity price elasticities, which could be assumed on the basis of the database shown in Table 5.3. Prices are in ECU 1990, which is used for fixed prices in several economic models within the EU, e.g. PRIMES. (1.27 US$= 1 ECU in 1990).

Table 5.10. Price elasticities, fuel independent costs of electricity

	Moderately elastic prices	Very elastic prices	System costs, Ecu90/MWh	Excise taxes, Ecu90/MWh
Heavy industry	-0.5	-0.8	4.80	2.40
Light industry	-0.2	-0.4	15.19	11.19
Transport	0.0	0.0	4.80	2.40
Residential, Service	-0.3	-0.8	15.19	62.36

Source: EFOM-CHP, Elasticities database.

Table 5.11 shows the results of a scenario study using the EFOM-CHP model for Denmark. The model and scenario specifications are described in details in Varming et al. 2000, while the introduction of elastic demand is was made for this study.

Table 5.11. Impact of price elasticities, fixed cost elements and taxes on electricity demand. Denmark, 1995-2020

		Reference			CO_2 ¨payment 11 Ecu90		
	1995	2000	2010	2020	2000	2010	2020
Wholesale price, Ecu90/MWh	*15.48*	*15.19*	*15.37*	*15.62*	*19.56*	*22.41*	*23.73*
Consumer price, Ecu90/MWh							
Industry	41.86	41.57	41.75	42.00	45.94	48.79	50.11
Transport	22.67	22.39	22.56	22.82	26.75	29.60	30.92
Tertiary/domestic	93.02	92.74	92.91	93.17	97.10	99.95	101.27
Electricity demand, TWh							
Light industry	*11.7*	*12.3*	*12.7*	*12.1*	12.1	12.3	11.7
Transport	*0.2*	*0.3*	*0.4*	*0.4*	0.3	0.4	0.4
Tertiary/domestic	*19.5*	*18.9*	*18.0*	*17.7*	18.6	17.6	17.2
Total electricity demand	31.4	31.5	31.1	30.2	31.0	30.3	29.3
Impact of elastic demand							
Electricity generation requirement, TWh	34.7	34.8	34.4	33.4	34.2	33.4	32.4
Difference, TWh					-0.6	-0.9	-1.0
Consumer price. Changes in %							
Industry					10.5%	16.9%	19.3%
Transport					19.5%	31.2%	35.5%
Tertiary/domestic					4.7%	7.6%	8.7%
Wholesale price. Changes in %					28.7%	45.8%	51.9%
Electricity demand. Changes in %							
Industry					-2.1%	-3.4%	-3.9%
Transport					0.0%	0.0%	0.0%
Tertiary/domestic					-1.4%	-2.3%	-2.6%
Total electricity demand					-1.7%	-2.7%	-3.1%
Aggregate wholesale price elasticity					-0.058	-0.059	-0.059

Source: EFOM-CHP model, Varming et al. 2000.

Emission taxes or tradable permits at 11 Ecu90 per ton CO_2 may be transferred to the international wholesale price for electricity. However, the impact on consumer prices will be much lower, because both the payment for electricity system services (transmission and distribution, etc.) and excise taxes are cost elements that are independent of CO_2 emissions.

The impact of CO_2 taxes or tradable permits will be most significant for large energy consuming industries, not only because energy is a significant fort of the production values, but also because they have traditionally been exempted from national excise taxes. On the other hand, the electricity wholesale price is only a small fraction of the electricity price paid by residential end users in Denmark, because most of the electricity price is taxes.

Considering price elasticities on the electricity wholesale market, which could be useful for the implementation of the Balmorel model own price elasticities must be must lower. This is shown in the last row of Table 5.11.

5.4 Own price elasticities in Balmorel

The impact of consumer price elasticities on the wholesale demand for electricity and heat is highly dependent on taxes and the market structure. National fuel price forecasts are calculated adding transport costs and national taxes to cif prices (cost, insurance and freight) to a national harbour or border station. Fuel price forecasts for indigenous fuels are based on national forecasts.

Table 5.12 shows the own price elasticities for electricity in the demand segments used to calculate the aggregate wholesale demands. At the consumer level the same elasticities are assumed for all countries.

Table 5.12. Own price elasticities of electricity demand

Sector	Own price elasticity
Heavy industry	-0.5
Light industry	-0.2
Transport	0.0
Agriculture	-0.2
Residential and services	-0.3

The impact of consumer price elasticities on the wholesale demand for electricity and heat is highly dependent on taxes and the market structure. Table 5.13 shows the calculation of aggregate wholesale elasticities on the basis of the different structures of demand in the countries or regions in the Balmorel model. In some countries energy taxes are very different among the consumer groups. The most notable example is Denmark with very high taxes on residential consumers and low taxes on industrial energy consumption. This structure of electricity demand and taxes explains the very low aggregate wholesale price elasticirties for Denmark.

Table 5.13. Electricity structure demand 1997 and calculated aggregate demand elasticities.

	Heavy industries	Light industries	Transport	Agriculture	Residential and services	Aggregate wholesale price elasticity
Denmark	11	20	1	5	63	-0.06
Estonia	20	22	2	5	51	-0.18
Finland	49	7	1	1	42	-0.20
Germany	29	16	4	2	50	-0.14
Latvia	14	20	3	4	58	-0.17
Lithuania	15	26	1	6	51	-0.17
Norway	39	6	2	1	52	-0.20
Poland	31	21	5	6	38	-0.19
Russia W+K	33	14	8	8	38	-0.20
Sweden	30	13	2	1	54	-0.19

Source: IEA Energy Balances and calculations based on Table 5.12.

The price elasticities are implemented as factors that specify the variations from the reference forecasts for prices and quantities in each region.

6 Calibration of Balmorel

The Balmorel model contains the possibility to calibrate various parameters. The purpose of this is to adjust the model results in order to attain better correspondence with historically observed values; it is expected that this will also increase the credibility of the model result for future years.

The first possibility is to adjust basic parameters of the generation units. In particular, each unit is characterised by a fuel efficiency, which may be modified using a calibration parameter. The model estimate of the total fuel consumption for a particular year should be close to the historical figure. If not so, the fuel efficiency may be adjusted. This may be done for a unit individually or for a group of units, as the data material permits. 1998 has been used as base year for a calibration where all thermal units were taken as one group. The IEA statistics was used for fuel use and for heat and electricity generation.

The second basic possibility is to adjust the demand functions so that demand in a base year, as calculated in the model, coincides with the statistical data. The mechanism here is to shift the demand function upwards or downwards, so that the desired consumption results. A particular point is here that historically there has not been much variation of prices of the day or over the year. However, the model operates with prices for each time segment (time of the day and year), this has to be reflected in the calibration. Also here the 1998 IEA statistics have been used as a source for the calibration.

The two spreadsheets, Year205.xls and Geog205.xls. contain several parameters that can be used for calibration of the model. This includes correction factors for the fuel efficiencies that are specified for the various technologies as part of the systematic parameter variations in the technology spreadsheet, Tech205.xls. In most optimisation models the fuel requirement will be calculated too low, because the economic dispatch cannot be made as efficient in real life than assumed in the models by using the nominal efficiencies.

Another parameter is used to calibrate the price side of the electricity demand function in order to get demand consistent for a base year. This parameter is specified in $€_{90}$/MWh. The size of this parameter is likely to be considerable and difficult to explain for a new model with limited experience.

In Version 2.05 the heat prices are calculated on the basis of the value of electricity loss from an extraction unit The standard value of this parameter is 0.15 representing the normal electricity loss ratio for an extraction-condensing CHP unit.

The spreadsheet Year205.xls (sheet Capa) contains tables to calibrate the capacities for the base year 1995 in the format shown in Table 3.7 through Table 3.10. This calibration may be used to adjust the split among fuels for multifuel generating units or the split between condensing and extraction-condensing units in urban areas, where the heat generating capacity from local plants is abundant.

Chapter 9 in the Appendix “Balmorel Model Structure” contains a detailed technical description of the calibration parameters that are included in the model. The further development of the model and the accumulated model experience by users and developers will change the need for calibration.

References

Enerdata s.a. (2000) *CD-ROM, November 2000.*

Energistyrelsen (1995), *Danmarks Energifremtider*, København.

Energistyrelsen (1996), *Energi 21. Forudsætninger og resultater.* (unpubliceret maj 1996) København.

European Commission (1995). *JOULE II Programme, The PRIMES Project*. EUR 16713 EN.

European Commission (1999a), *The Shared Analysis Project: Economic Foundation for Energy Policy*. Energy in Europe. Special Issue, European Commission, Directorate General for Energy. December 1999, *www.shared-analysis.fhg.de./.*

European Commission (1999b), *The Shared Analysis Project: European Union Energy Outlook to 2020.* Energy in Europe. Special Issue, European Commission, Directorate General for Energy. November 1999, *www.shared-analysis.fhg.de./.*

Galinis, A.; Hindsberger, M. and Ravn, H. (2000), *Buttom Up Modelling of an Integrated Power Market with Hydro Reservoirs,* Proceeding, Second International Conference, "Simulation, Gaming, Training and Business Process Reengineering in Operations". Riga Technical University, Riga, Latvia, September 8-9, 2000.

Grohnheit, P. E. (1993), *Modelling CHP within a national power system.* Energy Policy, Vol. 21, No. 4, p. 418-429.

Grohnheit, P.E., (1999), *Energy policy responses to the climate change challenge: The Consistency of European CHP, Renewable and Energy Efficiency Policies.* The Shared Analysis Project, Volume 14. *www.shared-analysis.fhg.de./* (Printed as Risø.R-1147(EN). Risø National Laboratory, Roskilde, *www.risoe.dk/rispubl/-SYS/ris-r-1147.htm*)

Grohnheit, P.E., Klavs, G. (2000), *Elastic electricity and heat demand in the Balmorel model.* Second International Conference, "Simulation, Gaming, Training and Business Process Reengineering in Operations". Riga Technical University, Riga, Latvia, September 8-9, 2000.

Hauch, Jens (1999): *Environmental Regulation and Nordic Energy Markets. An Economic Simulation Approach.* Ph.D. Thesis. Institute of Economics, University of Copenhagen and Secretariat of the Danish Economic Council.

IEA (1998a), *Energy Statistics and Balances of Non-OECD Countries 1995-1996*, Paris.

IEA (1998b), *Energy Statistics of OECD Countries 1995-1996*, Paris.

IEA (1999), *Electricity Information, (1999 Edition)*, Paris.

IEA (2000a), *Energy Balances of Non-OECD Countries*, Paris

IEA (2000b), *Energy Balances of OECD Countries 1997-1998*, Paris

IKARUS Datenbank (1999), Version 3.1, *Instrumente für Klimagas-Reduktion-strategien*. Fachinformationszentrum Karlsruhe

IKARUS - Instrumente für Klimagas-Reduktionsstrategien, http://www.fiz-karlsruhe.de/peu/ikarus/index.html.

Klavs, G.; Grohnheit, P.E., (1996), *Model development for energy tariffs in Latvia*. International conference on simulation, gaming, training and business process reengineering in operations, Riga (LV), 19-21 Sep 1996.

Klavs, G.; Grohnheit, P.E., (1998), *Models for energy tariffs in Latvia.* Latv. J. Phys. Tech. Sci. (1998) (no.5) , 29-41

Kristensen, Klaus; Oksbjerg, Kjeld (1992), *Elforbrugets prisfølsomhed i industrien* AKF Forlaget, København.

Ministry of Environment and Energy (1996), *Energy 21,* Copenhagen, www-ens.dk/.

Munksgaard, J.; Alsted Pedersen, K.; Ramskov, J. (2000): The German Power Market – Data Collection for Model Analysis. AKF Forlaget Copenhagen

Nordel Annual Report 1995.

OECD Nuclear Energy Agency/International Energy Agency (1998), *Projected Costs of Generating Electricity. Update 1998*, Paris.

OECD (2000), *Behavioral Responses to Environmentally-Related Taxes*, COM/ENV/-EPOC/DAFFE/CFA(99)111/FINAL, Paris. www.olis.oecd.org/olis/1999doc.nsf/-LinkTo/com-env-epoc-daffe-cfa(99)111-final

Petersen , Henrik (2000), *Situation analysis in relation to district heating and CHP in the Baltic Sea Region.* Euroheat & Power, Brussels. www.euroheat.org.

PHARE (1998), *Multi-country Energy Programme "Natural Gas Pricing, Tariffs and Operational Twinning" Latvia - Country Report*.

Schlesinger, Martin; Schulz, Walter (2000), Deutscher Energiemarkt 2020, Energiewirtschaftliche Tagesfragen Nr. 3, 2000

Stein, G.; Wagner, H.-F. (Hrsg.) (1999), *Das IKARUS-Projekt: Klimaschutz in Deutschland. Strategien für 2000-2020,* Springer, Heidelberg.

Unger, T.; Andersson O.; Rydén, B.; Wene, C.-O. (2000), *The Nordleden Project: Grid distributed energy trade and common action among the Nordic countries to facilitate CO_2 reductions.* Final Report. Energy Systems Technology Division, Chalmers University of Technology, Gothenburg.

Varming, S.; Eriksen, P. B.; Grohnheit, P. E.; Nielsen, L.; Svendsen, G. T.; Vesterdal, M. (2000), *CO_2 permits in Danish and European energy policy.* Risø.R-1184(EN). Risø National Laboratory, Roskilde, *www.risoe.dk/rispubl/SYS/ris-r-1184.htm*).

World Bank mission, Riga 1996.

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