Nordic co-operation on electricity consumption modeling

Pre-study

Creating Common Nordic Bottom-up Model for Household Electricity

Final Report

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2 PREFACE

The initiative to extend the Danish ELMODEL bolig to cover other Nordic countries was suggested in the meeting of the NICHE group. The group is an unofficial forum for exchange of ideas and experiences in energy efficiency -related research of households. The acronym stands for Nordic Informal Co-operation (in Research of) Household Electricity.

The NICHE group found the extending of the Danish model an idea worth looking into. The group decided to apply funds for a pre-study to assess costs and benefits in detail. These funds were granted by the Nordic Council Task Force on Energy Efficiency.

A project group was established in Herlev, Denmark on March 10th, 2008. All participating countries had 2 to 3 members in the group at least one of them representing a governmental organization. Peter Bennich of Swedish Energy Agency (Energimyndigheten) was chosen to be the project leader. At the change of his duties Heini-Marja Suvilehto of STEM took over leading the project in July, 2008. The other members of the group were Even Björnstad (ENOVA, NO), Troels Fjordbak (IT-Energy, DK), Lea Gynther (Motiva Oy, FI), Ingrid Magnussen (NVE, NO), Michelle Peled (Klima- og Energiministeriet, DK), Virve Rouhiainen (Adato Energia Oy, FI) and Terje Wahl (NVE, NO).

The Nordic Council Task Force on Energy Efficiency acted as the Steering group. The NICHE group acted as a reference group. In addition to the Copenhagen meeting, the work group held three meetings: Stockholm (May 2008), Oslo (September 2008) and Helsinki (November 2008). In these meetings the project progress and results were discussed. Virve Rouhiainen had the overall responsibility of writing the project report. Troels Fjordbak was responsible for writing the parts were familiarity with the Danish model was a prerequisite.

The work group thanks the Nordic Council Task Force on Energy Efficiency for providing the funds necessary for carrying out this pre-study. The work has offered number of insights which the group hopes to convey in this report. We dedicate this report to the memory of Terje Wahl. His input and positive spirit was vital in getting the project started. We wish this spirit is reflected in the report and the report provides a solid basis for taking the decision to build a Nordic Bottom-Up Model for Household Electricity.

3 INTRODUCTION

3.1 MOTIVATION FOR A NORDIC MODEL

The ambitious climate and energy policy targets of the European Union create new needs for information. Especially, the implementation of EU's Energy Services Directive (ESD) necessitates the development of methods for monitoring energy efficiency improvement measures and forecasting and evaluating their effects. Presently, appropriate methods are being discussed and reaching consensus will in all likelihood take some time.

The concept end use refers to electricity or other energy used by an appliance category like refrigerators or washing machines. This concept is useful in assessing the potential for energy efficiency. When one knows the present consumption level of refrigerators, one can evaluate how much would be saved is if all the refrigerators were of the most energy efficient known technology. To an extent behavioral aspects, like the frequency of loads of laundry washed, are described, also the effect of behavioral changes can be evaluated.

Work to improve the available end use estimates for household electricity is ongoing in all four countries. The efforts are mostly non-coordinated and methodologically varied. Denmark and Norway are both participating in the REMODECE project financed by European Union. Swedish Energy Agency (STEM) is carrying out an extensive measurement project of end uses. End use measurements in a representative sample are certainly the best way to collect data for estimating the real size of the end use. However, doing that in practice is difficult and results of end use measurements are typically not representative. An alternative approach to measurements is using the conditional demand technique to decompose total electricity use to end use components. This approach has recently been tried by Statistic Norway but data quality and co-variation resulted in low precision of the estimates. The Finns have used both conditional demand analysis and end use measurements and the recently completed project generalizes end use measurement data via large sample using statistical methods related to conditional demand analysis.

The concept Bottom-up models refers to models that describe energy end uses in great detail. The Danish ELMODEL bolig is a bottom-up model describing the electricity consuming appliance stock of households via specific consumption data and estimates for frequency of use. Bottom-up models are well suited for evaluation of changes in technology and for long term scenario building. Thus far the Danish model has served Danish policy analysis (see 3.1. for details). Its extension could serve similar purposes in other Nordic countries.

In addition to national needs, the model scenarios are likely to support the development of forecasts needed for the National Energy Efficiency Action Plans (NEEAPs) required by ESD (ex-ante evaluation). The present outline of rules for ex-post evaluation – like adjusting the data to reflect its reliability – could also be built in the model to be developed. As the ESD sets a minimum requirement for the use of bottom-up calculations and asks to increase the use of bottom-up calculations over time, need for bottom-up models is evident.

Maintaining models and collecting information is costly. As Nordic countries are in many respects similar, pooling resources to meet increased modeling and information needs on residential electricity demand is likely to reduce costs. In addition, co-operation and sharing experiences will help in creating better models as one is able to learn from earlier mistakes and successes. Synergies may also be found in other areas. The data to the model as well as some output data from it can be used for other purposes like filling the gaps in Nordic data in the Odyssee database.

The Danish model needs to be developed further when it is extended to cover other Nordic countries, as the countries, though similar, are not carbon copies of each other. For instance, in Finland sauna stoves are an important end use component. Further, electric heating needs more attention than at present model because of its higher prevalence in other Nordic countries than Denmark.

The advantage of the present Danish model is its systematic, yet flexible handling of several types of data. Thus the model can be extended relatively quickly on basis of existing data. As the name states ELMODEL bolig focuses solely on electricity consumption of appliances or end-uses in households. Thus it excludes other heating forms than electricity. The model will not solve all the needs for bottom up modeling in residential sector nor should one expect it to answer all data gaps with respect to electricity immediately. ELMODEL bolig has potential, but its realization will cost time, effort and money.

3.2 OBJECTIVE OF THE PRE-STUDY

The purpose of this pre-study is to assess the current availability of data with respect to household electricity in the Nordic countries, to determine the most important informational gaps and make a suggestion how to fill in these gaps. In addition, the study is to assess whether extending the Danish ELMODEL bolig into a Nordic model would make a positive contribution in solving these informational gaps. In case the extension of the model is deemed useful, the group is to draw a detailed project plan and make suggestion for the next steps.

3.3 REPORT STRUCTURE

The report is structured as follows. The present Danish model is described in Chapter 4. The gap analysis is presented in Chapter 5. Two types of gaps are identified: gap for tools and gap for data. Chapter 6 presents the design specification for the extended model. Chapter 7 discussed the data requirements of the model and Chapter 8 presents the steps needed to achieve extended model. In addition, resource and time table estimates are presented. These are divided into two: carrying out the model extension and maintaining the extended model.

To keep the text light model details and detailed data are presented in 4 appendices.

4 DANISH ELMODEL BOLIG

This chapter is an introduction to the Danish ELMODEL-bolig. It gives an overview how the model has been used in Denmark, describes the model structure and model usage. In addition, practical working methods and the maintenance scheme of the model is outlined and commented.

4.1 ELMODEL BOLIG IN RETROSPECTIVE

The model development started in the middle of 1980'ies as an initiative from the Danish Electricity utilities. Basically the idea was to establish a solid statistical basis on household electricity for supporting the ongoing political discussions with the regulators (Danish Energy Authority) in Denmark. The data collection was done together with the Authority, and some years later the Authority decided to buy a share of the model, thereby supporting both the common use of the results and the maintenance of the model in general.

At that time, the primary use of the model was to quantify the total consumption in different dwelling types, and to split the consumption into end-use groups, ensuring the ability to foresee developments for specific appliances or groups. The bottom-up approach was deliberately chosen, because the experience from then dominant top-down models was unsatisfactory even with respect to total use of electricity in households especially if disaggregated to dwelling types.

Since 1990 the model projections and reports have been updated every second year, the primary being a projection report for 19xx-2020 for the Danish household consumption in rich retail, containing both analysis of the past and estimates for the future. In recent years the usage of the model as a scenario tool has started. Below is a short list with descriptions of the purposes:

Year	Title	What was done
2003	Electricity Saving potentials in Households	1. Business as usual (BAU) sc.: standard projection 2. BAT technology and normal behaviour sc. standard projection + assuming only best technology are sold 3. Normal technology and optimal behaviour sc.: standard projection + assuming all kinds of wasteful behaviour (standby etc.) is stopped 4. BAT technology and optimal behaviour sc.: both sales of best technology and optimal behaviour 5. FUTURAMA sc.: based on statements from a researcher in the futures, an alternative projection was made. For all scenarios a comparison with BAU was done, and savings potentials were calculated.
2005	Labelling effects in Denmark	An alternative development of electricity consumption in white goods were calculated, based on old forecasts done before knowing anything about the labelling scheme. This scenario was compared with the actual development, and achieved savings were estimated.
2008	ICT in 2015	Two scenarios for how the ICT (Information and Communication

		Technology) consumption in 2015 may look like, assuming continued high increases in ownership levels and daily use of this type of equipment. The scenarios are not published yet.

Table 1. Special scenarios done with ELMODEL-bolig.

For all three titles reports in Danish are available.

4.2 GENERAL STRUCTURE OF ELMODEL BOLIG

The model is based on time series and can be used to describe and analyse the annual consumption since the beginning of the 1970's and to project the future consumption, making assumptions about future levels of frequency of use, specific consumption and stocks. As described above, Denmark is split into some 240 strata in the model all contributing to calculated electricity consumption. The equation used in the calculations is the following:

Electricity consumption	=	Stock of appliances	X	Specific consumption	X	Frequency of use

All factors are functions of time. Thus the stock of appliances is updated every year by new sales and the number of "dead" appliances meaning scrapped appliances. The latter is estimated through an assumption of a normal distributed longevity for each type of appliance. "Specific consumption" and "frequency of use" are tied together for some appliances, e.g. cooling, where the appliance is switched on all the time. How the input series are applied in detail depends on the specific appliance, see more in Appendix I.

In addition to sales figures, the factors are estimated from survey data about average sizes, daily usage, specific washing program choices etc. The survey data is collected every second year, where more than 2000 households are asked about their appliance stock, sizes, ages, frequency of use etc. The data are processed to be representative for Denmark through weight factors and are filled into the model. This results in a large up-to-date database with invaluable information about electricity use in Danish households.

The Danish model is organised in hierarchic layers:

Layer	Description	Segments
1	Geography (2)	East of Denmark West of Denmark
2	Dwellings (4)	Single family houses Flats Farm houses Weekend cottages
3	Appliances (30)	Appliance list including division into ON / Standby consumption

Table 2. Layer structure for ELMODEL bolig

As a result of the structure, the model currently consists of 240 strata (2 x 4 x 30).

In the database all tables reflecting the structure are also provided with a “view” layer, which is an actual extra key field (of integer type). In the database all tables reflecting the structure are also provided with a “view” layer. This enables the user to create multiple copies of the whole database as a start of a new scenario. Thereby no data are accidentally deleted or overwritten. A lock ensures that the original “view” No 1 can never be deleted.

Grouping appliances by end-use (Cooling, Cooking, Lighting, etc.) is normally done when presenting results. This allocation of appliances into certain groups does hot have an impact on electricity consumption and is therefore not an individual database layer. The grouping is maintained in reporting module. This solution helps to accommodate the changes in grouping practices.

The current appliance list consists of some 30 “major” appliances. The detailed list is in appendix 1.

4.3 CREATING AND REPORTING SCENARIOS

The projections are all carried out on the most disaggregated level. This means that a forecast for each single appliance in each dwelling category and geographic sector is made. The *driver* for the forecast is the time. Then for each of the projections, the model parameters in the above equation are calculated, choosing a curve along which the progress for the parameter is expected to go. The curve types to choose among are few and simple: constants, linear and Gompertz.

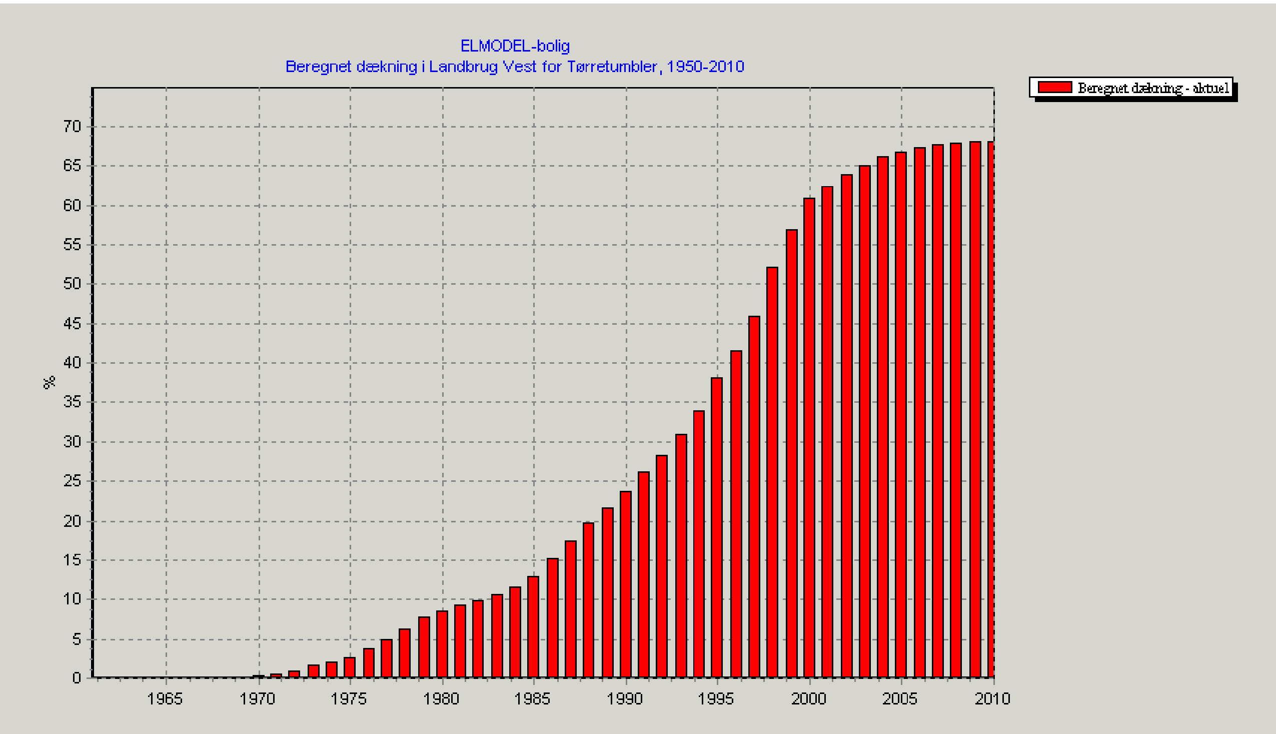

Figure 1. Calculated ownership level for tumble dryers in farmhouses, Western Denmark.

The Gompertz type simulates a typical saturation curve, and a saturation value (valid for far future) must be specified. For the stock parameter this will be 100% for appliances that are popular and are expected to populate all households (for TV sets the model operates with both TV1 and TV2, with TV1 near 100%), whereas appliances on their way out of the marked will have saturation level 0. A rapidly growing miscellaneous group accounts for new, unknown appliance types.

Also for the specific consumption a saturation curve is normally used. This simulates the fact that new technology is continuously introduced to the marked bringing the average consumption for an appliance type down. However, a theoretical minimum for the energy consumption must be expected, making a saturation curve a probable fit for a historical period.

The assessment of the saturation levels is usually done looking at the best available technology (BAT) at present, e.g. a new campaign technology, assuming all competing technologies will approach this level, thereby making the marked average reach this level. The development in the historical period is also used in this quite difficult assessment. The variations in the saturation level do not affect especially the short-term levels much since a statistical fit with the historical period is done. Hence, smooth transition from historical to forecasting period, combined with information about the best available technology, are key factors in the saturation level assessment.

Constants are often used for appliances fully introduced on the marked and expected to stay there, and for projections of usage frequencies for appliances running all the time. Linear curves are mostly used for projections of the household stock. For all curve types, the best fit is found using simple Least Squares methods on the historical data.

For penetration levels both sales figures and information from surveys are used. This means the levels are quite accurate, and that the number of appliances in each vintage is obtained. Combined with assumptions about normal distributed longevity for each appliance type (again based on survey data about how old the appliances are), estimates for the present stock of appliances each year are obtained. From this an average consumption can be calculated using the historical data. Multiplied by the frequency of use and the dwelling stock the total electricity consumption can be found.

Projections of dwelling stocks follow the same scheme as the appliances. For each dwelling type in each geographic sector a curve and – if relevant – a saturation level is specified. For single-family houses, flats, and weekend cottages the Gompertz is used in both geographic zones, indicating that the overall building stock (i.e. the Danish population) will saturate or grow only very slowly. For farmhouses a linear decline is normally used with a good fit, due to the constant development in Denmark towards fewer, larger farms.

After selecting curve types and saturation levels for all appliance parameters in all building categories, forecasts for all time series are carried out. This is normally done on a long-term basis, i.e. at least 20 years ahead. In the model software some reporting tools are available to aggregate the results to totals by dwelling type and ultimately for the whole Danish household sector. All single parameters can be examined together with the consumption for each year in the forecast period.

E.g. for PCs the model can give an estimate of the sales and stock of PCs in 2025, how frequent it is expected to be used and what yearly consumption it is expected to have. This is possible in each of the dwelling types and geographic zones. Hence, based on the considerable work to establish saturation levels for all parameter, a corresponding very detailed output can be obtained. This makes the model very suitable for estimating effects of marked campaigns aimed at very specific appliances, e.g. labelling of washing machines and cold appliances.

4.4 MODEL MAINTENANCE SCHEME

Below is a short description of a two-year cycle of the Danish model maintenance:

Approximate time	Typical tasks
1st quarter even years	Preparation of questionnaire, new questions etc. Updating data regarding specific consumption for various appliance types Updating software and web pages
2nd quarter even years	Preparation of questionnaire, new questions etc. – tender material Updating data regarding specific consumption for various other appliance types Updating software and web pages
3rd quarter even years	Questionnaire finalized. Tender published Contracting with tender winner. Updating data regarding specific consumption for various other appliance types Updating software and web pages
4th quarter even years	Preliminary results from questionnaire acquired. Data quality analysis. Fiscal tasks. Updating data regarding specific consumption for various other appliance types Updating software and web pages
1st quarter odd years	Analysis and application/inputting of new data Updating data regarding specific consumption for various other appliance types Updating software and web pages
2nd quarter odd years	Finalizing input of new data -> data basis report Start of forecasting tasks Updating data regarding specific consumption for various other appliance types Updating software and web pages
3rd quarter odd years	Finalizing forecasting tasks -> forecast report Updating data regarding specific consumption for various other appliance types Updating software and web pages
4th quarter odd years	Fiscal tasks Contracting Updating software and web pages

Table 3. Model maintenance tasks in two-year cycle.

5 GAP ANALYSIS

5.1 AVAILABILITY OF MODELS

The Danish ELMODEL bolig is a bottom-up model describing in great detail the appliance stock of households. It offers a systematic yet flexible way of combining data collected in number of sources. Systematic approach to modeling offers definite advantages. One can easily vary assumptions and compare the effect on assumptions on results. This facilitates discussion. In addition, systematic model development helps in identifying needs for further model development and data collection needs.

Today, only Danes have a bottom-up model for household electricity that is used by several parties. Some in-house applications exist in other Nordic countries, but those are not as systematically maintained and updated as the Danish model. Extending the Danish model to cover other Nordic countries would thus provide the countries with common tool to combine data on household electricity and to perform scenario analysis.

The ambitious energy policy targets of the European Union increase the need for policy analysis tools as updates of the scenarios become more frequent and in all likelihood also the detail required in analysis will be increasing. Thus need for a scenario tool exists.

It is worth noting that Bottom-up models seldom assess socioeconomic issues and this is the case with the Danish model. Though behavioral aspects could be studied by adding a socioeconomic grouping as a layer instead of geography, it is unlikely that the resulting additional data requirements could be met in near future.

5.2 AVAILABILITY OF DATA ON PRESENT ELECTRICITY USE OF APPLIANCES IN HOUSEHOLDS

The present availability of data on electricity end uses in households varies in Nordic countries. Denmark has most detailed data. For the ELMODEL bolig Danes have systematically collected time series on aggregate appliance sales by appliance category and electricity consumption by housing type and on results of cross-section studies (appliance ownership and usage).

Finland and Sweden have conducted detailed cross-section studies, but they have clearly less information on time series level and the data is dispersed. In both countries electricity use of the residential sector is disaggregated to an extent, but the disaggregation is based on calculation, not on collected data. Norway has one bottom up model covering all sectors and all energy carriers, which for obvious reasons is not as detailed as the Danish model. Statistics Norway has on a non-regular basis carried out a cross section survey on energy consumption in households. Data is available for the years 1993, 1994, 1995, 2001, 2004 and 2006. Norway is also participating in the European REMODECE Project.

Extending the Danish model would enhance the ability to provide disaggregated data. In addition, the data needed would be collected into one place instead of it being dispersed. The usefulness of this improved disaggregation ability depends on whether disaggregation of data is needed. In the face of future policy development this seems likely.

However, for the Danish model to be useful in describing electricity use in other Nordic countries it needs to be extended to accommodate the differences in relevant end uses. For instance, electric sauna stoves use approximately 8 % of household electricity in Finland.

It also important to note, that Nordic countries are very different in their electricity use profile. In the residential sector the most important difference is the prevalence of electric space heating. In Norway, 82 % of the households use electric space heating, though most often (62 %) it is combined with either wood or oil stoves. In Norway, electricity is the sole source of heating in 20 % of the households. In Finland, 23 % of households use electricity as the main source of heating. The share of electric heating in single family (or small houses) in Finland is about 44 %. The content of this figure is not similar to that used in Sweden and Norway as the Finnish definition is based on main heating system and thus does not take into account of use of more than on source of energy for heating. In Sweden, share of electric heating is described as share of energy used in small houses. 33 % of house use only electricity. Combination of electricity and biofuel is used by 24 % of the Swedish houses. In Denmark, the share of electric heating is considerably smaller than in other Nordic countries.

	Housing GWh	Share of housing of total	Population million	Housing per person kWh
Denmark	9 778	29 %	5,5	1 903
Finland	21 491	25 %	5,3	4 144
Iceland	941	9 %	0,3	3 280
Norway	37 425	34 %	4,7	7 903
Sweden	39 400	30 %	9,2	4 706
Nordel	119 125		25,0	4 770

Table 4: Overview of Housing Electrcity consumption in Nordic Countries, source Nordel.

Given that country-wise differences exist it is useful to look how different we are in light of the available cross-section studies. The following numbers are collected from the REMODECE draft report Analysis of Monitoring Campaign in Europe and the Finnish study Household Electricity Use 2006. The results of the Swedish measurement project were not available in this format at the time of writing.

Country kWh/appliance	**Sweden (families age 26-66 years)**		**Finland**	**REMODECE**		
	Houses	Appart.		**Denmark**	**Norway**	**Europe**
Refrigerator	196	259	223	287	307	384
Fridge freezer	525	495	402	379	374	451
Freezer	372	421	368	496	631	543
Washing	213	167	124		209	184
Clothes dryer	131	243	284		267	347

Dishwasher	236	214	186		206	234
Desktop PC	342	287	191	303	97	276
Laptop PC	36	43	33	61	87	56
Router for Internet	32	42		102	51	58
Wireless						72
Printer	51	70				33
TV CRT			118	109	172	124
TV LCD			240	174	223	186
	181	139				
TV Plasma				427	325	400
DVD	28	38	19	25	21	23
Hi-Fi	50	61		51	103	46
Set top box	97	79	72	83	84	75
Air conditioner					1 179	372
Oven/cooker	456	423	318		287	301
Microwave	38	29	33		30	33
Water kettle	51	45			24	70
Lamps	937	691	990	908	1 013	487

Table 5: Specific electricity consumptions in Nordic Countries according to recent measurement studies.

The numbers in table 5 are based on measurements, though the generalization method varies. The numbers are fairly similar. For instance, the cold appliance but for Norwegian freezers are below the European average. This suggests that borrowing Danish data to calibrate the model for other Nordic countries is likely to provide reasonable estimates.

In spite of this similarity of the unit consumptions, the structure of electricity consumption is different. This is illustrated in table x below, which shows the level of end use consumption by category in Denmark and Finland in 2006. It is worth emphasising that in population Denmark and Finland are similar and the differences stem from other factors like ownership of tumble driers and prevalence of electric heating.

	Finland 2006	**Denmark 2006**

Appliance	Level GWh	%	Level GWh	%
Heating	10230	36	2100	20
Lighting	2427	13	1110	11
Cold appliances	1461	5	1756	17
Entertainment	1241	4	2423	24
Cooking	733	3	805	9
Washing	636	2	1415	14
MISC	1562	8	485	5
Total	**18290**	**100**	**10094**	**100**

Table 6: Electricity Consumption by End Use Category in Finland and Denmark in 2006.

5.3 SUMMARY OF GAPS

Two major information gaps were identified regarding the capacity of Nordic countries to carry out household electricity analysis. The first gap is the lack of tools to perform scenario analysis on policies. The second gap relates to availability of data. Today, data is dispersed and time series disaggregated to end uses are typically not available.

Finland and Sweden have carried out cross-section studies to disaggregate the household electricity use. The cost of these studies prohibits carrying them out more often than, say, every five years. Thus a tool to disaggregate the statistical data would be useful.

It is worth noting that the need of collecting data does not disappear with the development of the tool. At minimum, one needs to conduct a survey at regular intervals. It is also worth noting that aggregate models like the Danish model may miss important trends. How likely this is, depends on the level of data available to calibrate the electricity use calculated with the model.

6 DESIGN SPECIFICATION FOR THE NORDIC MODEL

6.1 HOUSING SEGMENTS AND END USES

A similar structure as in presentation of the Danish model is suggested.

Layer	Description	Segments
1	Countries (4)	Finland, Sweden, Norway, Denmark
2	Geography (N)	<Segment 1>, <Segment 2>, ...
3	Dwellings (4)	Single family houses Flats Row houses Weekend cottages
4	Appliances, see Appendix 1	Appliance list including division into ON / Standby consumption

Table 7. Proposed resulting model structure.

Geographic segmentation is obviously nation specific. Dwelling segmentation consists of four groups. The idea is to have similar names, though data will not allow similar content in all countries. This obviously limits detailed comparisons between countries.

Dwelling category	NO	FI	SWE	DK
Single family houses	Detached houses	Detached houses	detached houses pair-houses row-houses farm houses weekend cottages	Detached houses <Today: row-houses> pair-houses <New: farm houses>
Row houses	rows house terrace house	row houses		<New: Row houses>
Flats	Flats	Flats	Flats	Flats
Weekend cottages	Cottages	Summer houses		Weekend cottages

Table 8. Possible contents in Dwelling segments.

The model segmentation can easily be adapted to new or improved information or to new informational needs. For instance, it is possible to create a new scenario where to segments are combined or an existing segment is split into two.

The appliance list is similar for all the countries and covers all know major appliance. The starting point is the present enumeration of appliances in ELMODEL-bolig. This is extended to cover new appliances. The detailed appliance list is in Appendix 1.

Maintaining the enumeration of appliances is clearly a task needing co-ordination if the common Nordic model is developed. The decision maker will be the owner board. It is suggested that rules be developed for inclusion of new appliances to the model and to the questionnaire separately, so that the database administrator can make suggestion for inclusion of new appliances. For instance, inclusion rule for the model could be such that an appliance is included if its annual consumption in one country is greater than 100 GWh or more 1 % of the total consumption or more than 5 % of the total consumption in the dwelling segment the appliance is relevant. Obviously, country specific differences can be accommodated by just setting the ownership to zero.

For the purpose of following the market development a list of miscellaneous appliances needs to be maintained. These should be divided into two groups: appliances with smallish consumption but large possible volume. Typical appliances of this group include consumer electronics like electric photo frames of which one family can have several. The second group consists of appliance that may become large end uses due to their considerable specific consumption. For instance, appliances in this category include water beds and electric cars.

The data collection for the miscellaneous appliance group is challenging. One should start collecting data when the appliances emerge, yet only for relevant appliances. Today the Danes collect data separately for the model and thus the decision making depends solely on the modelling needs. This need not be the case for the Nordic model and so other needs than that of the model may well require attention. For instance, the length of the questionnaire influences the data quality, so adding questions omnibus survey requires careful consideration.

6.2 REPORTING

Reporting functionality of the model will ultimately determine usefulness of the model itself. The Danish model has rather been used for systematically updating forecasts and creating alternative scenarios than for performing quick reference calculations. Though the need for such work will certainly continue, it is likely that need for quick reference calculations are increasing rapidly. For the model to gain its full potential this need should be accommodated.

When planning for unknown needs leaving room for modifications is always wise. The group suggests that the reporting module will be built in stages to allow more detailed consideration of user and owner needs. The basic tool to be developed at first stage should be very simple just supporting creating of scenarios and exporting them to third party tools like Excel or SPSS for reporting. In building the scenarios one needs some functions for displaying graphs and time series to check the results. At first stage, the tool specific reporting functionality could be built to on this basis and the more advanced reporting could rely on result downloads to specified software programs like Excel and SPSS. If only one is chosen it should excel which is available in most organizations without an extra cost.

As the role of reporting is important for the tool to fulfil its purpose the project group will in stage two (extension 2) map the reporting needs of the users (=owners) of the model and evaluate how the needs are best provided for. At least the following solutions are possible:

1. Country specific excel tools to provide for county specific often recurring reporting needs.
2. Common excel tool to provide for common often recurring reporting needs.

3. Specific reporting module to cater common reporting need developed.

Possible reporting functions are described in greater detail in appendix 3.

Reporting functionality based on downloads requires certain level of expertise of the model users. Same requirement applies to creating the scenarios. The flexibility of the model makes misguided use possible. If untrained people use the model, it is necessary to build warning systems and even inhibit use of certain alternatives available to expert users.

Wide user group would help the model to fulfil its potential in creating discussion. However, as with reporting one would expect this to happen in stages. The first users of the model will be members of the project work group plus one or two employees of the owner organizations. These people will acquire the expertise necessary for running the model at the course of model development. In addition, we expect them to have the language skills necessary to use English model. The needs to translate results into respective country languages can either be taken care of in the reporting module or provided case by case basis by the users.

Expanding the number of users and developing the reporting functionality thus go hand in hand. One can envisage a publicly available internet tool but number of issues need to be tackled before that is realistic. Level of sophistication of users has direct bearing to setting access rights to data and scenario options and to the need of developing separate reporting functionality. For experts transparent reporting increases the trust for model results. Laymen become confused with too many details. At this stage one should only leave the door open for making the model publicly available, for instance in specifying the database structure and the associated user rights.

6.3 MODEL FUNCTIONS

Built in functions are needed to maintain the data base and model structure and to create new and update old scenarios. Model functions fall into three broad categories:

1. Scenario and Database functions
2. Data exchange functions and
3. Reporting functions.

Scenario and database functions are the core of the model as they used to create the scenarios. Given the detailed structure of the model, number of issues need to be addressed. These include the definition how electricity consumption of the appliance is calculated and how the future values are estimated. The present definitions are shown in appendix 3. It is worth noting that these definitions need a detailed evaluation, as for some of the equations data does not exist and one has to provide other ways of setting in the data. For instance, instead of frequency of use of washing machine in different temperature, one might have estimated the specific consumption of washing machines and would like to use this data in the model. Also the general appropriateness of the formulas need be checked.

Most of the functions in the Danish model are proposed to be included also in the Nordic model. The exception is empty scenario, as establishing the scenario from scratch is immense task. If the database is kept centrally functions 8 and 9 in appendix 3 are irrelevant. In addition to the functions in the Danish model, in the Nordic model there must be possibility to label the created scenario as national or Nordic.

In addition to these basic tasks, there must be functions to support the special need in the Nordic setup – the exchange of data. This can be quite difficult, since the input quality and quantify may vary, and the need for changes thus varies too. Also the possibility to choose among different data sources for the copy purpose should be supported.

For each appliance type data holes and missing data series in the historical period can be repaired and/or calibrated. The methods for doing so is

#	Function	Implications
1	Fill in the gaps	This time series is repaired for the desired time period. The basis for the repair is selected among all time series known to the system, organized in a user friendly manner. This means the system knows what type of variable that is to be repaired, and searches for similar time series in the database, which are presented first. The repair it selves is based on statistical methods to optimize the fit, utilizing the existing data points to full extend.
2	Copy whole series	The user chooses from the system list of time available series, and copies the data into to variable. Tools for scaling must be available. I.e. scaling the data with the current population, dwelling stock etc.
3	Interpolation	Selecting between different statistical methods the user can choose to interpolate the time series to cover data holes. The methods include simple linear interpolation, as well as splines, quadratic interpolation and ARMA-model interpolation.
4	Back casting	Selecting between different statistical methods the user can choose to back-cast the time series to extend the historical period. The methods include simple linear interpolation, as well as splines, quadratic interpolation and ARMA-model interpolation.
5	Construct time series	Giving a formula based on recognizable symbols, the system calculates a new time series. A linear regression module.

Table 9. Data calibration tools.

6.4 ACCESS RIGHTS FOR DATABASE

The established model is presumed to be owned by all the participating Nordic countries, i.e. Finland, Norway, Sweden and Denmark as even partners. As a starting point all partners should have full read access to the data in the model and full write access to the country specific data in the common database. When operating the model, different operator types can be identified.

The user groups include at least the following experts, trainees and general public. Experts should be able to access all data and change country specific data. The trainees should be able to read data, but not have write access to key parts of the model. Furthermore, some of the results are likely to be available for the public through some standard reports. This access should of course be read only.

This span of access levels should be supported by the chosen access structure. The setup for the existing Danish model is quite simple. A database administrator (DBA) that operates the model will be selected through a tender. When appointed, the DBA has full access rights. Also the board of owners can have a copy of the model installed, enabling them to do own analysis. This is also with full access, but changes can only be made on national data.

To comply with all demands the following structure is proposed:

User level	Initial accesses	Rights	Grant rights
Database administrator (DBA)	One login	Read/write all data	Can create users on all levels
Super user	One from Finland One from Sweden One from Norway One from Denmark	Read all data/write all national data	Can create Special Users and Users
Special user	-	Read/write national data level	None
User	-	Read only	None

Table 10. Proposed user access structure.

The DBA's role is assumed to be given to an entrepreneur by the NICHE-model owner board, possibly through a multi-year tender. To avoid administrative cost and to avoid interruptions it is recommended that the contract should be at least X years long. The DBA can change everything in the model database and software, and is also supposed to do so, when the owner board decides changes. The DBA can create additional Super users. This could have been laid out to the primary Super User in each country. It is assessed though, that some control with this is better held at a central place.

The Super Users can change all national data and read all data from other countries. This is set up to enable users helping each other in the data input phase across country borders – which is somewhat expected to be the case at start – without having trouble with access. When the model setup has matured, the typical operator will be a Special User.

A Special User level is suggested, to satisfy the needs for limited access, even though some write access is allowed. This is to say, the data responsibility for each country is in the hands of the countries themselves.

Lastly the User level is the public access.

6.5 DESIGN PROPOSALS

6.5.1 DIALOGS

The winner of the tender for creating the model setup should give examples for these dialogs

- Dialog for setting up general copy functions for historical period - defaults

- The instantiated view is inheriting the defaults, which are then changeable
- Db-admin/access dialog

For all other dialogs the Danish model software will be available to the tender winner for inspiration.

6.5.2 DATABASE TABLES

A database diagram for the Danish model will be issued to the tender winner, serving as a starting point. The extra Nation layer must be reflected in the table keys, as well as the dynamics of the segmentation in general. Also the dynamics of the calculation principle for each appliance introduces new tables and attributes compared to the Danish database.

6.5.3 IT-CHOICES

The system is suggested to be implemented in a Microsoft Windows platform. This means development of the software in Microsoft Visual Studio creating a .Net 2.0 solution with a Microsoft SQL Server 2005 (or later) database.

The physical placement of the server is unimportant, and may just be where adequate access speed and server capacity is available at the lowest price.

6.5.4 LANGUAGE

The model language is proposed to be English. This means all visible as well as invisible (for the user) text in menus and labels.

The programming source code should also consist of English variable names as well as English comments in the code and English names for database fields and tables.

7 DATA REQUIREMENTS OF THE NORDIC MODEL

7.1 PRESENT SITUATION

7.1.1 HOUSING STOCK

Availability of data on housing stock varies between countries. The segmentation suggested in table 8 fits especially poorly for Sweden, where data is created on basis on tax records. In Denmark row houses are presently not a segment in the Danish model when farmhouses on the other hand are. Within this structure the differences can be handled. Eg. for Denmark the solution would be to create a new row houses segment for Denmark and fill that with available number of the dwelling stock and bulking the farm houses with the Single family houses. For the Sweden the segment row houses and weekend cottages are simply left empty because data is not available.

Dwelling category	NO	FI	SWE	DK
Single family houses	1974-	1974-	1974	1974-
Row houses	1974-	1974-	included in houses	1974-
Flats	1974-	1974-	1974	1974-
Weekend cottages	1974-	1974-	included in houses since 2001	1974-

Table 11. Present availability of data, housing stock. Assuming model start in 1974.

7.1.2 APPLIANCES

In order to evaluate the viability of the building of the common model the data availability was assessed. The details are shown in the appendix 2. The general conclusion is that enough data is available for calibrating the country specific models at a reasonable level of accuracy.

The first step here is to collect presently available data to a coherent data set. Borrowing data from neighbours is meant to be intermediate solution to solving the lack of data. Though comparison of available data suggests that this solution does not carry too a high risks, one needs to devote resources for more systematic data collection.

7.2 DATA COLLECTION IN THE FUTURE

Several alternatives exist for improving the availability of data. At present all Nordic statistical authorities collect some data relevant to the model. Given the increased importance of this area Eurostat is evaluating the data needs and is planning to initiate statistical procedures for conducting household surveys on household energy / electricity use. It is too early to say whether and to what extent this development will reduce the cost of maintaining the data.

Today the update cycle for the Danish data is two years. In Norway, a survey of ownership levels will if future plans are realised be carried out every third by Statistics Norway. In Finland and Sweden discussions are going on, but no definitive plans exist. At minimum, the ownership data should be collected every third year. Data on the use of appliance should also be collected regularly.

The organization of the data collection is an issue that affects the maintenance cost of the model. If the data is collected as part of the official statistics, no extra resources need be devoted to collecting the data. The disadvantage is that the decisions what to include in data collection are not solely determined from the needs of this particular model.

8 ROAD MAP

8.1 DEFINITION OF GOAL AND FUNDING

The first decision to be made is the definition of whether and what kind of model is developed. To develop the model two basic alternatives exists:

1) The cheapest option is to copy of the present Danish model in all four countries and calibrate the copies in the project.

2) The more expensive option is to opt for a truly common web based model with common database and basic reporting structure. Within this option the reporting structure can be created in number of ways as described in chapter 6.2. We show cost estimates for two alternatives: excel reporting and a common reporting tool.

In terms of maintaining the data the pros of central new designed database are the following:

- Maintaining single database requires less work than maintaining four databases.
- With one database data can be made available to all users and thus borrowing and cross checking data is possible. With four databases this is difficult to achieve.
- The database structure and segmentation are designed to reflect the new needs, not based on the existing one of the present Danish model.

In terms of maintaining the software the pros and cons of the web based tool are the following:

- Every user has the same software.
- In centrally maintained software all additions and corrections are available all users at once. New version of the software is only installed once.
- The net application is accessed via browser, which is a standard in most computer installations.
- The con of browser interface is the present quality of built in reporting facilities. These are expected to improve with time.
- Web software is easy to scale for more users.

The first point can be considered as both a pro and a con. When everyone uses the same software, no tailor made features are available. In case of four copies of the present software local versions with tailored features are likely to appear. This will reduce the scale advantages of having a common model, when say EU instructions with respect to bottom up calculations need to be implemented in at least four versions of the software instead of one.

Tailor made features typically serve local needs and when one cannot resort to those, one needs to provide the needed flexibility within the software. One of issues to solve is the enumeration of appliances (see 6.1

and appendix 1 for suggestions). The second issue is the suitability of definition of formulas presented in appendix 4. This suitability needs to be addressed for each country and appliance with respect to data needs versus data availability. In addition, for each appliance the size of possible bias in the formula needs to be assessed. This kind of work is best carried out simultaneously with the project by a group representing the expert users.

The project group has made preliminary enquiries whether there is interest in respective countries to develop the model. Such interest exists and the project group suggests that Energy Efficiency Task Force contacts the relevant parties to see whether high enough commitment can be achieved to start the project and which of the alternatives presented one should aim for.

Table 12 presents the costs for the alternatives. The project structure is described in greater detail in next chapter.

Alternative **Resource need in man months**	**1) Copying and Calibrating the Danish Model**	**2) Common Database & Excel Reporting**	**3) Common Database & Web Reporting**
Project work group Data collection and preparation Communication and meetings Testing Training	 0,5-1 MM /country 1 MM - 1 MM	 0,5-1 MM /country 2 MM 0,5-1 MM 0,5 MM	 0,5-1 MM /country 2-3 MM 1-1,5 MM 0,5 MM
Software development Adaptation / Creation of software Database	 1 MM 3 MM (1 /country)	 5-6 MM 4 MM	 7-10 MM 4 MM
Administration Contracts Project	 0,5-1 MM 0,5 MM	 1 MM 1-2 MM	 1 MM 1-2 MM

Table 12: Cost estimates in man months for the alternatives.

Of the resource need software development and potentially administration will be outsourced. A cost of one man month is estimated to be 16 000 € or 118 000 DKK. Thus the external cost for the alternative 1 will be around 80 000 € (590 000 DKK). In addition, one will need to meet possible licence fee for utilizing ELMODEL bolig and the cost of providing data and training personnel to use the model. The external cost of this development divided between Finland, Sweden and Norway is app. 27 000 €.

The external cost for alternative 2 will be around 192 000 € (1 416 000 DKK). Depending on the precise specification of features in alternative 3 the added cost to alternative 3 will vary from 32 000 € to 80000 € (236 000 - 590 000 DKK). The external costs of alternatives 2 and 3 would basically be divided between all four countries. The cost per country for alternative 2 would be 48 000 €. However, one should allow for a compensation paid to the owners of ELMODEL bolig for using the model and its database as a starting point. This compensation is not included in the calculation.

The project group finds it likely that funding for the external costs to develop the model can be applied e.g. from Energy Research Council (Nordisk energi forskning). However, it is necessary that the parties undertaking the development are ready to commit enough money to maintain the data requirements of the model. In addition, they need to commit personnel to development of the model. Otherwise, the benefit of learning from one another will not materialize. Presently the annual cost of maintaining the Danish model is about 275 000 DKK and the cost of data collection is 125 000 DKK. At minimum, one needs to meet the maintenance costs for the model. If we assume that extending the model will double the annual maintenance cost to approximately 70 000 € (512 000 DKK), the maintenance cost per country would be 17 000 €.

In addition to this the data collection cost need to be met. Today the annualized Danish cost is about 32000€. Some scale advantages exist and it is possible that this cost will later disappear as the requirements for public statistics in the area are developed. The annual maintenance cost per country is expected to range from 17 000 € to 45 000 € depending on how the issue of data collection is solved.

8.2 ORGANISING THE DEVELOPMENT PROJECT

In organising the development project one has to consider both decision making and carrying out the necessary work efficiently. The parties committed to fund the project will want to take part in decision making, yet each and every one of them need not participate in discussing technical details of the model.

Bearing this in mind we suggest following structure:

- Steering Group for the project representing all funding parties
- Project Work Group
- Development team of the software provider

The Steering Group is to nominate the project co-ordinator and the members of the Project Work Group. In addition, it will supervise the project and take all major decisions. The Project Work Group will prepare the material for these decisions and the project co-ordinator is responsible for these being presented.

The Project Work Group is to consist of project administrator (co-ordinator), one or two representatives for each participating country and expert consultant familiar with the Danish application. The software developer will assign one participant to the Project Work Group.

The Project Work Group will take care of other project work but soft ware development. These tasks include data collection, testing and approving the software and planning for the roll out and the first use and maintenance period. Funds for this kind of work need to be provided, though funding can take the form of providing personnel.

The bulk of costs in this phase will result from software development. Given the estimated size of the project (80 000 € to 140 000 €) and involvement of public funding, public tendering process needs to be implemented. The Project Work Group will evaluate the tenders and the Steering Group will make the final decision.

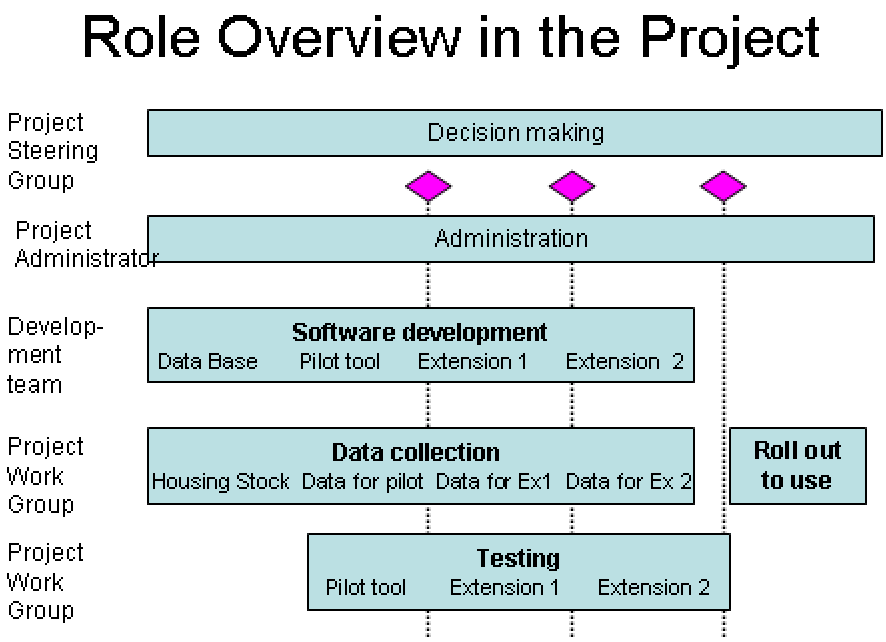

Figure 2. Suggested roles in the project to build the model.

8.3 DEVELOPMENT PROJECT

Figure 2 show the roles of project organisation and planned phasing of the project. After design of the database the scenario tool to manage the database and create reports is developed in three stages.

At the first stage one is to develop the tool for reporting cold appliance, home electronics and lighting with option to include washing. This set of appliances comprises the largest end-use components and it is large and varied enough to help to bring forth issues that need further attention. In addition, in this stage one is able to see whether the chosen software environment is functioning well enough.

The Project Work Group is to perform the testing of a pilot tool and to draw a list of issues that need to be solved. In addition, the Work Group is to evaluate whether solving the issues is possible and how much time solving them will take. On basis of this evaluation, the Group is to make a suggestion for the Steering Group whether to start the next phase or not. In case the list of problematic issues is too long, the Work Group is to suggest termination of the project.

The tool is then enlarged to its final scope in two extensions. The first extension could cover the appliances available in the present Danish tool and the second extension would add new appliances. Given the relative significance of certain new appliances in some countries (such as saunas in Finland) they could be included in the first extension. The need to have a check point between the two extensions can be assessed at the first check point after seeing how smoothly the development of the pilot tool went.

The last stage in the project is the roll out of the tool and arranging the first period of maintenance. The project work group is to make a plan for the roll out including the course / seminar needed to familiarize the users with the system. In addition, the Work Group will make a plan for the first period of maintenance. This plan will describe how and by whom the system is maintained. It will mention the expected data updates and development of possible additional feature (like reporting module) for the system. In case, the Steering Group decides to hire an agent to main the model, the Work Group will take care of hiring such an agent.

8.4 USE AND MAINTENANCE

Two aspects of the use and maintenance need to be discussed. The first aspect is that of making decisions on model maintenance. It is obvious that the decision taker will be the model owners, who will choose a Database Administrator) for that purpose.

Establishing a user forum to bring forth ideas and to discuss development needs is likely to be useful. At its simplest this forum could be maintained on a dedicated web page. The maintenance of the user forum could be taken care by the Database Administrator.

The Danish model is operated and maintained by an entrepreneur selected through a tender. It is likely that some level of central control is needed also for the Nordic model. Given that the model language is English, at least one local actor is needed to generate reports on respective country languages. This local actor should also have responsibility of inputting the local data.

Data collection is discussed in chapter 7.2.

APPENDIX 1: PRESENT AND FUTURES END USES IN ELMODEL BOLIG

Present ELMODEL bolig	**Suggested extension for Nordic ELMODEL bolig**
Appliance	**Appliance**
MISC	**MISC**
Miscellaneous (maybe split into consumer electronics and other)	Miscellaneous CE (Vacuum cleaner, Burglar alarm, Motion sensor, Light sensor, Satellite disc, DAB radio, Ghetto blaster, Projector, Hair dryer/styler, Table oven, Table Raclette, Soft Ice machine, Ice cube machine, Coffee machine, Espresso machine, Electric kettle, Toaster, De-humidifier, Electric blanket, Therapy lamp, (Christmas) light chain (in/out door), Electric lawn mower and hedge cutter, Charger for mobile phone, Hand-vacuum cleaner, Toys, Tools, Baby alarm, Answering machine etc.)
	Miscellaneous Other (Garden fountain, Garage opener, Domestic drain pump, Wine cabinet, Aquarium, Solarium, Patio heater, Jacuzzi, Outdoor spa pool, Swimming pool etc.)
Elevation beds (and water beds)	Elevation beds (and water beds)
	Electrical car
	Car heater
Cooking	**Cooking**
Electric oven	Electric oven
Electric stove (cooking plates)	Electric stove
Micro wave oven	Micro wave oven
	Cooker hood
Heating	**Heating**
Circulation pump	Circulation pump
Electric space heating	Electric space heating
Electric water heater	Electric water heater
Gas burner	Furnace (oil, gas, wooden fuel elements, ...)
Oil burner	Electric floor heating
Supplementary electric space heating	Supplementary electric space heating
	Sauna
	Heat pump - air/air
	Heat pump - air/water

	Heat pump - soil, hydro reservoirs/water
	Electric towel dryer
	Drying closets
	Boot dryers
	Ventilation
	Heat exchanger
Entertainment	**Entertainment**
Colour TV (may be split into CRT, LCD, Plasma and OLED)	CRT TV
	LCD TV
	Plasma TV
	OLED TV
Stationary PC (incl. screen)	Stationary PC (incl. screen)
Laptop	Laptop
DVD	DVD
Video	Video
Stereo	Stereo
	Surround sound
	ADSL
	Set-top box – simple
	Set-top box – advanced
	Digital photo frame
	Mobile HDD
	Cordless phone
	Clock radio
	Imaging equipment – inkjet (printer, scanner, copier)
	Imaging equipment – laser (printer, scanner, copier)
Cooling	**Cooling**
Combined fridge/freezer	Combined fridge/freezer
Fridge with ice box	Fridge with ice box
Fridge without ice box	Fridge without ice box
Chest freezer	Chest freezer
Upright freezer	Upright freezer
	Wine Cabinet
Washing	**Washing**
Washing machines	Washing machines
Tumble dryer	Tumble dryer
	Combined washer/dryer
Dishwasher	Dishwasher

Lighting	**Lighting**
Incandescent lamps (traditional light bulbs)	Incandescent lamps (traditional light bulbs)
Linear Fluorescent lamps (LFL) (typical in kitchens)	Linear Fluorescent lamps (LFL) (typical in kitchens)
Compact Fluorescent lamps (CFL) ("saving bulbs")	Compact Fluorescent lamps (CFL) ("saving bulbs")
Halogen Lamps	Halogen Lamps (maybe split into high/low voltage)
	Diode lamps

APPENDIX 2: AVAILABILITY OF DATA IN NORDIC COUNTRIES

The headings in the columns are following: O)wnership levels, (S)ales figures, (F)requency of use and (U)nit consumptions.

The code of the table are following:
X = data series available at biannual basis, X data available, reliability not good
C = data available for some years but clearly less frequent than every second year
X or C marked with same color means that for example: data is available for TV's but not distinguished by TV type

	Relevant since	NO				FI				SWE				DK			
Appliance		**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**
MISC										**X**							
Miscellaneous			C							X				X			X
Miscellaneous Other														X			X
Elevation beds (and water beds)	1985													X		X	X
Electrical car	A2015													X		X	X
Car heater	B1970					C		C						X		X	X
Cooking																	
Electric oven	B1970	x	C	C		C	X	C	C	X				X	X	X	X
Electric stove	B1970					C	X	C	C	X				X	X	X	X
Micro wave oven	1985	x	C			C	X	C	C	X				X	X	X	X
Cooker hood			C				X			X				X	X	X	X
Heating																	
Circulation pump	B1970					C				X		X		X	X	X	X
Electric space heating	B1970	C				C			C	X		X		X		X	X
Electric water heater	B1970	C				C			C	X		X		X	X	X	X
Furnace (oil, gas, wooden fuel elements, ...)	B1970	C				C			C	X		X		X	X	X	X
Electric floor heating		C				C				X		X		X		X	X
Supplementary electric space heating	B1970	C				C				X		X		X		X	X
Sauna	B1970	C				C			C	X		X		X			X
Heat pump - air/air	1992	C					X		**X**	X		X		X	X		X
Heat pump - air/water	1976	C					X		**X**	X		X		X	X		X
Heat pump - soil, hydro reservoirs /water	1976	C					X		**X**	X		X		X	X		X
Electric towel dryer	B1970									X		X		X			X

	Relevant since	NO				FI				SWE				DK			
Appliance		**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**
Drying closets	B1970					C		C	C	X							
Boot dryers										X							
Ventilation	1980					C		C	C	X		X		X			
Heat exchanger	B1970					C			C	X		X					
Entertainment																	
CRT TV	B1970	C	C			C	X	C	C	X		In the Swedish meatering study TV includes all DVDm, VCR etc. Computers are called for computer site including printer etc..		X	X	X	X
LCD TV	1995	C	C			C	X	C	C	X				X	X	X	X
Plasma TV	1995	C	C			C	X	C	C	X				X	X	X	X
OLED TV	2000	C				C	X	C	C	X				X	X	X	X
Stationary PC (incl. screen)	1985	C				C	X	C	C	X				X	X	X	X
Laptop	1990	C				C	X	C	C	X				X	X	X	X
DVD	1995	x	C			C	X	C	C	X				X	X	X	X
Video	1980	C	C			C	X	C	C	X				X	X	X	X
Stereo	1980		C							X				X	X	X	X
Surround sound										X				X		X	X
ADSL	1995					C	X	C	C	X				X		X	X
Set-top box – simple	2000		C			C	X	C	C	X				X		X	X
Set-top box – advanced	2000					C	X	C	C	X				X		X	X
Digital photo frame	2005									X							X
Mobile HDD														X			X
Cordless phone			C											X		X	X
Clock radio			C											X		X	X
Imaging equipment – inkjet (printer, scanner, copier)														X		X	X
Imaging equipment – laser (printer, scanner, copier)														X		X	X
Cooling																	
Combined fridge/freezer	1975(?)	C	C			C	X	C	C	X	X	X	X	X	X	X	X
Fridge with ice box	B1970	C	C			C	X	C	C	X	X	X	X	X	X	X	X
Fridge without ice box	B1970	C				C	X	C	C	X	X	X	X	X	X	X	X
Chest freezer	B1970	C	C			C	X	C	C	X	X	X	X	X	X	X	X
Upright freezer		C	C			C	X	C	C	X	X	X	X	X	X	X	X

	Relevant since	NO				FI				SWE				DK			
Appliance		**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**	**O**	**S**	**F**	**U**
Washing																	
Washing machines	B1970	C	C	C		C	X	C	C	X	X	X	X	X	X	X	X
Tumble dryer	1980	C	C	C		C	X	C	C	X	X	X	X	X	X	X	X
Combined washer/dryer	1980					C	X	C	C	X	X	X	X	X	X	X	X
Dishwasher	B1970	C	C	C		C	X	C	C	X	X	X	X	X	X	X	X
Lighting																	
Incandescent lamps (traditional light bulbs)	B1970						X				X	X	X	X			X
Linear Fluorescent lamps (LFL) (typical in kitchens)	B1970						X				X	X	X	X			X
Compact Fluorescent lamps (CFL) (“saving bulbs”)	1990						X				X	X	X	X			X
Halogen Lamps (maybe split into high/low voltage)	1990						X				X	X	X	X			X
Diode lamps							X							X			X

APPENDIX 3: MODEL MENU AND MOST IMPORTANT FUNCTIONS

This appendix describes the existing model from technical angle.

The table below shows the menu structure of the model. The most important database, scenario and report functions are described in tables 2 and 3.

Files	**Edit**	**Project**	**View**	**Reports**	**Help**
Database Export to ASCII-file Exit	Appliance data Dwelling stock data	Dwelling stock Appliances	Time series Graphs Latest log Actual database System tools	Report generator	Content About ELMODEL-bolig

Table 1. Menu structure of Danish model, translated.

Some key functions in **Files | Database** are described below.

#	Function	Implications
1	Activate current scenario	The scenario showed (by name, description etc.) on the screen is made the current for the user.
2	Find scenario	Search facility to locate the desired scenario. When the number exceeds 10 scenarios, a search facility is necessary
3	Create empty scenario	Creates a new scenario without any sort of copying data from existing scenarios. Maybe not relevant here.
4	Create with no building stock	Copies the current scenario to a new, but without copying building stock figures. Can be relevant if one were to create a new country, not wanting the existing country building stock figures to confuse.
5	Create complete copy	Creates a new scenario as a copy of the current
6	Create hybrid	Creates a new scenario based on selected segments from one or two other scenarios.
7	Delete scenario	Deletes current scenario
8	Import scenario	Imports an earlier exported scenario. Relevant when creating scenarios locally – not relevant here.
9	Export scenario	Exports a locally created scenario – not relevant here.
10	Import from Excel	Imports scenario from Excel spreadsheet (with distinct format)
11	Export to Excel	Exports scenario to Excel spreadsheet

Table 2. Database functions in current model.

Key functions for assessing forecasts and reporting:

#	Function	Implications
1	View | Time series	Opens a dialog where multiple time series values can be compared
2	View | Graphs	Opens graph dialog where multiple time series can be plot in overlay as function of time
3	Reports | Report generator	The user can specify which segments, dwellings types, and appliances should be included. Furthermore the user specifies which variables are shown as time series or graphs. When selecting more than one single stratum, the user can specify how the report should aggregate, if at all. I.e. if selecting all dwelling segments and the user wants to see the ownership level, the user can select to aggregate the dwelling segments using dwelling stock weights to see a national level ownership level.

Table 3. Reporting functions in the current model.

APPENDIX 4: CALCULATION PRINCIPLES FOR MODEL APPLIANCE LIST

Both as it is now in ELMODEL-domestic, and some suggestions for improvements.

E_{ON} = annual consumption in kWh, in ON-mode.
E_{STD} = annual consumption in kWh, in modes other than ON-mode (but connected)
F = Average annual frequency of use
EPU = Average energy per use, in kWh
EPS = Average annual energy consumption per square meter, in kWh/m^2
A_{heat} = Average heated area in m^2
P_{ON} = Average power level for ON-mode
P_{STD} = Average power level for not ON-mode (but connected)
H_{ON} = Annual hours in ON-mode
H_{STD} = Annual hours in not ON-mode (but connected)
R_{OFF} = Fraction of time the appliance is unplugged / turned completely off
DDF = Degree days factor relative to reference year
NP = Average number of persons in household
E_{Prod} = annual consumption in kWh, in total, from producer data
$E_{class, i}$ = Average annual energy consumption in kWh for energy class i
$w_{class, i}$ = sales weight for energy class i
$F_{P, i}$ = Average annual frequency of use for machine programme i
$E_{P, i}$ = Average consumption in kWh for one use of machine programme i
$E_{i\ P, j}$ = Average consumption in kWh for one use of machine programme j, for energy class i machines
$E_{ap\ i}$ = Average annual ON-mode consumption for small appliance i
$E_{STD\ ap\ i}$ = Average annual not ON-mode consumption for small appliance i
$O_{ap\ i}$ = Ownership level for small appliance i

TR references a technical report of power levels and unit energy consumptions, continuously updated in ELMODEL-domestic
FEHA denotes the Danish association of white goods importers
ELDA is the Danish database for white goods on market

DMI is the Danish Metheorologic Institute

Appliance	**Formula**	**Data sources**	**Possible improvement**	**Additional sources**
MISC				
Miscellaneous (split into consumer electronics and other)	$E_{ON} = \sum E_{ap\ i} * O_{ap\ i}$ $E_{STD} = \sum E_{STD\ ap\ i} * O_{ap\ i}$	$\mathbf{E_{ap\ i}}$, $\mathbf{E_{STD\ ap\ i}}$ from TR $\mathbf{O_i}$ from questionnaire		
Elevation beds (and water beds)	$E_{STD} = P_{STD} * 8760 / 1000$	$\mathbf{P_{STD}}$ from TR		
Electric car	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$	$\mathbf{P_{ON}}$ from TR $\mathbf{H_{ON}}$ from TR/questionnaire? $\mathbf{P_{STD}}$ from TR $\mathbf{H_{STD}}$ from TR		
Electric car heater	$E_{ON} = P_{ON} * H_{ON} / 1000$	$\mathbf{P_{ON}}$ from TR $\mathbf{H_{ON}}$ from questionnaire		
Cooking				
Electric oven	$E_{ON} = F * EPU$ $E_{STD} = P_{STD} * 8760 / 1000$	**F** from questionnaire **EPU** from TR $\mathbf{P_{STD}}$ from TR	Sales fractions for each energy class weighted together with EPU averages for each energy class	Sales fractions from FEHA EPU averages from ELDA
Electric stove	$E_{ON} = F * EPU$ $E_{STD} = P_{STD} * 8760 / 1000$	**F** from questionnaire **EPU** from TR $\mathbf{P_{STD}}$ from TR		
Micro wave oven	$E_{ON} = F * EPU$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = 8760 * (1-R_{OFF})$	**F** from questionnaire **EPU** from TR $\mathbf{P_{STD}}$ from TR $\mathbf{R_{OFF}}$ from questionnaire		

Appliance	Formula	Data sources	Possible improvement	Additional sources
Heating				
Circulation pump	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from TR	Sales fractions for each energy class weighted together with P_{ON} averages for each energy class	Sales fractions from Elsparefonden P_{ON} averages for each energy class from TR
Electric space heating	$E_{ON} = EPS * A_{heat} * DDF$	**EPS** from TR **A_{heat}** from questionnaire **DDF** from DMI		
Electric water heater	$E_{ON} = 850 kWh * NP$	**NP** from questionnaire	Average annual consumption by heater size * heater size distribution	Average annual cons. by heater size from TR, heater size distribution from questionnaire
Gas burner	$E_{ON} = E_{prod}$	**E_{prod}** from TR		
Oil burner	$E_{ON} = E_{prod}$	**E_{prod}** from TR		
Electric floor heating	$E_{ON} = EPS * A_{heat} * DDF$	**EPS** from TR **A_{heat}** from questionnaire **DDF** from DMI	EPS calculated as installed power per m^2 * annual hours in use	Installed power per m^2 from TR, annual hours in use from questionnaire
Supplementary electric space heating	$E_{ON} = EPS * A_{heat}$	**EPS** from TR **A_{heat}** from questionnaire		
Saunas	$E_{ON} = F * EPU$	**F** from questionnaire **EPU** from TR		
Heat pumps (maybe split into air/air, air/water, liquid/water)	$E_{ON} = EPS * A_{heat} * DDF$	**EPS** from TR **A_{heat}** from questionnaire		

Appliance	Formula	Data sources	Possible improvement	Additional sources
		DDF from DMI		
Electric towell dryer	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from questionnaire / TR		
Ventilation	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$	**P_{ON}** from TR **H_{ON}** from TR **P_{STD}** from TR **H_{STD}** from TR		
Heat exchanger	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from TR		
Entertainment				
Colour TV (maybe split into CRT, LCD, Plasma and OLED)	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Stationary PC (incl. screen)	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Laptop	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
DVD	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Video	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Stereo	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR		

Appliance	Formula	Data sources	Possible improvement	Additional sources
	$E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Surround sound	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
ADSL	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Set-top box (split into simple and advanced)	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Digital photo frame	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Mobile HDD	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Cordless phone	$E_{ON} = 0$ $E_{STD} = P_{STD} * 8760 / 1000$	**P_{STD}** from TR		
Clock radio	$E_{ON} = P_{ON} * 8760 / 1000$	**P_{ON}** from TR		
Imaging equipment (split into inkjet and laser technologies)	$E_{ON} = P_{ON} * H_{ON} / 1000$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = (8760- H_{ON})* (1-R_{OFF})$	**P_{ON}** from TR **H_{ON}** from questionnaire **R_{OFF}** from questionnaire		
Cooling				
Combined fridge/freezer	$E_{ON} = \sum E_{class,\ i} * w_{class,\ i}$ $E_{STD} = P_{STD} * 8760 / 1000$	**$E_{class,\ i}$, $w_{class,\ i}$** from ELDA **P_{STD}** from TR		
Fridge with ice box	$E_{ON} = \sum E_{class,\ i} * w_{class,\ i}$	**$E_{class,\ i}$, $w_{class,\ i}$** from ELDA		

Appliance	Formula	Data sources	Possible improvement	Additional sources
	$E_{STD} = P_{STD} * 8760 / 1000$	**P_{STD}** from TR		
Fridge without ice box	$E_{ON} = \sum E_{class, i} * w_{class, i}$ $E_{STD} = P_{STD} * 8760 / 1000$	**$E_{class, i}$, $w_{class, i}$** from ELDA **P_{STD}** from TR		
Chest freezer	$E_{ON} = \sum E_{class, i} * w_{class, i}$ $E_{STD} = P_{STD} * 8760 / 1000$	**$E_{class, i}$, $w_{class, i}$** from ELDA **P_{STD}** from TR		
Upright freezer	$E_{ON} = \sum E_{class, i} * w_{class, i}$ $E_{STD} = P_{STD} * 8760 / 1000$	**$E_{class, i}$** from ELDA **$w_{class, i}$** from FEHA **P_{STD}** from TR		
Washing				
Washing machines	$E_{ON} = \sum E_{class, i} * w_{class, i}$ $E_{class, i} = \sum F_{P, j} * E_{i P, j}$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = 8760 * (1-R_{OFF})$	**$w_{class, i}$** from FEHA **$E_{i P, j}$** from ELDA **$F_{P, j}$** from questionnaire **P_{STD}** from TR **R_{OFF}** from questionnaire		
Tumble dryer	$E_{ON} = \sum E_{class, i} * w_{class, i}$ $E_{class, i} = \sum F_{P, j} * E_{i P, j}$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = 8760 * (1-R_{OFF})$	**$w_{class, i}$** from FEHA **$E_{i P, j}$** from ELDA **$F_{P, j}$** from questionnaire **P_{STD}** from TR **R_{OFF}** from questionnaire		
Combined washer/dryer	$E_{ON} = \sum E_{class, i} * w_{class, i}$ $E_{class, i} = \sum F_{P, j} * E_{i P, j}$ $E_{STD} = P_{STD} * H_{STD} / 1000$ $H_{STD} = 8760 * (1-R_{OFF})$	**$w_{class, i}$** from FEHA **$E_{i P, j}$** from ELDA **$F_{P, j}$** from questionnaire **P_{STD}** from TR **R_{OFF}** from questionnaire		
Dishwasher	$E_{ON} = \sum E_{class, i} * w_{class, i}$ $E_{class, i} = \sum F_{P, j} * E_{i P, j}$ $E_{STD} = P_{STD} * H_{STD} / 1000$	**$w_{class, i}$** from FEHA **$E_{i P, j}$** from ELDA **$F_{P, j}$** from questionnaire		

Appliance	Formula	Data sources	Possible improvement	Additional sources
	$H_{STD} = 8760 * (1-R_{OFF})$	**P_{STD}** from TR **R_{OFF}** from questionnaire		
Lighting				
Incandescent lamps (traditional light bulbs)	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from questionnaire / TR	Graduation of both P and H when number of light sources increases	
Linear Flouroscent lamps (LFL) (typical in kitchens)	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from questionnaire / TR	Graduation of both P and H when number of light sources increases	
Compact Flouroscent lamps (CFL) ("saving bulbs")	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from questionnaire / TR	Graduation of both P and H when number of light sources increases	
Halogen Lamps	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from questionnaire / TR	Graduation of both P and H when number of light sources increases	
Diode lamps	$E_{ON} = P_{ON} * H_{ON} / 1000$	**P_{ON}** from TR **H_{ON}** from questionnaire / TR		