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State-of-the-art
Projects for estimating the electricity end-use demand

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RESULT (summary)

This report is prepared within the KMB project "Electricity Demand Knowledge" (ElDeK). The objective of the project is to *increase the knowledge concerning electricity demand for different types of customers*, such as households and industrial customers (office buildings). This includes knowledge about electricity energy consumption [kWh] and power consumption [kW] – totally for different types of customers and specific for different end-use demands.

The objective of this report is to describe the status from previous projects focusing on electricity consumption and end-use demand for both household customers and non residential buildings (office buildings), focusing on achieved results and data requirements: Aspects relevant for the ElDeK project are:

- There is a general lack of metering data, but metering of end-use demand is both costly and time-consuming. A metering period of 2-4 weeks seems to be common.
- There is a large variation in the electricity consumption for appliances with high consumption, such as washing machines, tumble dryers and water heaters.
- The differences between non residential buildings are larger than for households, and it is more difficult to find common features for the buildings. The use of the building has a great influence on the energy consumption (operating time, installed equipment, etc.)

The report contains also a description of the status regarding data availability and metering of the total electricity consumption with use of smart metering technology. EU has plans for full deployment of smart metering within 2022 at the latest. Alternatives for metering of the electricity consumption of different appliances are also described. The ElDeK project will use plugs for power metering, connected to a central unit, to meter the electricity consumption for different electrical appliances.

The last part of the report is focusing on how meter data in the ElDeK project will be collected and analysed. In this project end-use demand will be measured with a time resolution of one minute, at customers with already installed technology for hourly metering of the total electricity consumption. 1 minute data will give information about electricity consumption per use of the different appliances. These data will be aggregated to hourly values and analysed in combination with hourly meter data of the total electricity consumption.

KEYWORDS		
SELECTED BY AUTHOR(S)	End-use demand	Metering criteria
	Household customers	Office buildings

TABLE OF CONTENTS

Side

1 INTRODUCTION

This report is prepared within the KMB project "Electricity Demand Knowledge" (ElDeK)[1]. The project started up in 2009 and the duration of the project is four years.

The objective of the project is to *increase the knowledge concerning electricity demand* for different types of customers, such as households and industrial customers (office buildings). This includes knowledge about electricity energy consumption [kWh] and power consumption [kW] – totally for different types of customers and specific for different end-use demands.

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

The objective of this report is to describe the status from previous projects focusing on the energy consumption and end-use demand for both household customers and non residential buildings (office buildings) (Chapter 2). The description is focusing on the achieved results and data requirements, and this will be a start-up for the ElDeK project.

The report also contains a description of the status regarding metering of the total electricity consumption with use of smart metering technology, and the possibility for metering of the electricity consumption of different appliances (Chapter 3). Smart metering technology is described since the ElDeK project will use these data in developing the planned mathematical and statistical methods.

The last parts of the report are focusing on how to analyse the meter data (Chapter 4) and criteria for collecting new meter data within the ElDeK project (Chapter 5).

[1] www.sintef.no/eldek

2 RESULTS FROM RELEVANT PROJECTS

This chapter summarises experiences and results from projects that are evaluated as relevant for the ElDeK project. The description is divided in two parts, where the first part is focusing on household customers and the second part is focusing on office buildings. The descriptions of the different projects are focusing on the achieved results and data requirements.

2.1 HOUSEHOLD CUSTOMERS

2.1.1 REMODECE

The overall objective of the REMODECE project[2] (Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe) was to contribute to an increased understanding of the energy consumption in the EU-27 households for the different types of equipment, including the consumers' behaviour and comfort levels, and identify demand trends. This should among other things be achieved via a common analysis of the measurement (and survey) campaigns of electricity consumption in households in EU countries.

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

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

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

Analysis of Measurement Campaign
Results from the measurements campaign in Norway are presented in Table 2.1 and Table 2.2.

Table 2.1 shows estimates of yearly energy consumption in electrical appliances: Mean value; minimum – and maximum consumption per household. The numbers in this table are not corrected for ownership level.

[2] http://www.isr.uc.pt/~remodece/

The annual energy demand per appliance (and per household) is calculated for an average household, where stratification is used to correct for biases in the measurement sample strata, see Table 2.2. (Stratification is further described in chapter 4.1.)

Table 2.1 Results from the Measurement Campaign in Norway. Annual Electric Energy in Households Corrected for Household Strata [1]

APPLIANCE	TOTAL Nº ANALYSED	MEAN VALUE[1] OF MEASURED YEARLY CONSUMPTION	MINIMUM OF MEASURED YEARLY CONSUMPTION	MAXIMUM OF MEASURED YEARLY CONSUMPTION
Unit	*N°*	*kWh/appliance*		
Water heater	26	2987	971	5570
Lighting	72	1000	-	-
Refrigerator w/o freezer	34	307	58	1325
Refrigerator w freezer	11	374	71	1028
Freezer	51	631	78	2120
Washing machine	74	209	39	978
Clothes dryer	30	267	49	1004
Dishwasher	40	206	69	693
Desktop PC	13	220	9	602
Laptop PC	18	87	11	424
Router for Internet	4	51	34	68
Wireless access point	2	74	41	106
Printer	1	26	26	26
TV CRT	31	172	21	891
TV LCD	10	223	24	696
TV Plasma	8	325	42	799
DVD recorder/player	8	21	3	37
HI-FI	4	103	22	240
Satellite/cable/air set top box	3	84	39	131
Heatpump/Air conditioner	3	1179	601	2270
Electric cooker/oven	20	280	58	695
Microwave oven	3	30	26	33
Water kettle	4	24	13	36
Total	*470*	*8880*	-	-

[1] Mean value is defined as the arithmetic average of measured appliances, and does not refer to the national average household - as ownership is not taken into account.

Apart from heating, hot tap water and lighting; freezer is the appliance requiring most energy in Norway. The average energy demand in freezers is more than 600 kWh per appliance per year. Refrigerators without freezer use about 300 kWh while refrigerators with freezer use about 370 kWh. Electric cooker use about 280 kWh. Washing machines use about 200 kWh, while clothes dryers use about 270 kWh.

Conventional televisions (CRT) use a little less and LCD TVs uses a little more than 200 kWh. Plasma TVs use a little more than 300 kWh in average. Lighting is calculated to about 1.000 kWh in average.

Hot water (water heater) uses about 3.000 kWh. Space heating is calculated to be between 10.000 and 12.000 kWh depending on outdoor temperature. This number also includes heat pumps and appliances not measured. Such appliances may be ventilation, vacuum cleaners, car engine - and compartment heaters etc. Heat pumps are omitted from the further analysis because it is a part of the space heating.

Table 2.2 shows measured and average energy consumption for a national average household, where both stratification and ownership are taken into account. The national average is then about 6.000 kWh for "all" measured appliances apart from heating (and heat pumps) and appliances not yet measured.

Table 2.2 Results from the Measurement Campaign. Annual Electric Energy demand in Households Corrected for Strata and Appliance Ownership [1]

APPLIANCE	MEASURED YEARLY CONSUMPTION	OWNERSHIP	AVERAGE YEARLY CONSUMPTION
Unit	*kWh/appliance*	*Percent*	*kWh/household*
Water heater	2987	85 %	2539
Lighting	1000	100 %	1000
Refrigerator w/o freezer	307	52 %	160
Refrigerator w freezer	374	66 %	247
Freezer	631	73 %	461
Washing machine	209	96 %	201
Clothes dryer	267	47 %	125
Dishwasher	206	88 %	181
Desktop PC	220	70 %	154
Laptop PC	87	72 %	63
Router for Internet	51	67 %	34
Wireless access point	74	25 %	19
Printer	26	61 %	16
TV CRT	172	70 %	120
TV LCD	223	50 %	112
TV Plasma	325	50 %	163
DVD recorder/player	21	75 %	16
HI-FI	103	100 %	103
Satellite/cable/air set top box	84	39 %	33
Electric cooker/oven	280	96 %	269
Microwave oven	30	10 %	3
Water kettle	24	50 %	12
Sum of measured	*7701*	-	*6031*

Figure 2.1 shows the percent distribution for different electrical appliances in Norway for 2006/2007. Space heating and hot water use about 75-80 % of the electricity in an average household depending on outdoor temperatures. This value also includes appliances not measured. The remaining appliances use about 20-25 %. Lighting amounts to about 6 %. Cooling devices, like refrigerators and freezers, amounts to 5 %. Other energy carriers, like oil and wood, are not taken into account. Heating is not temperature corrected in this analysis.

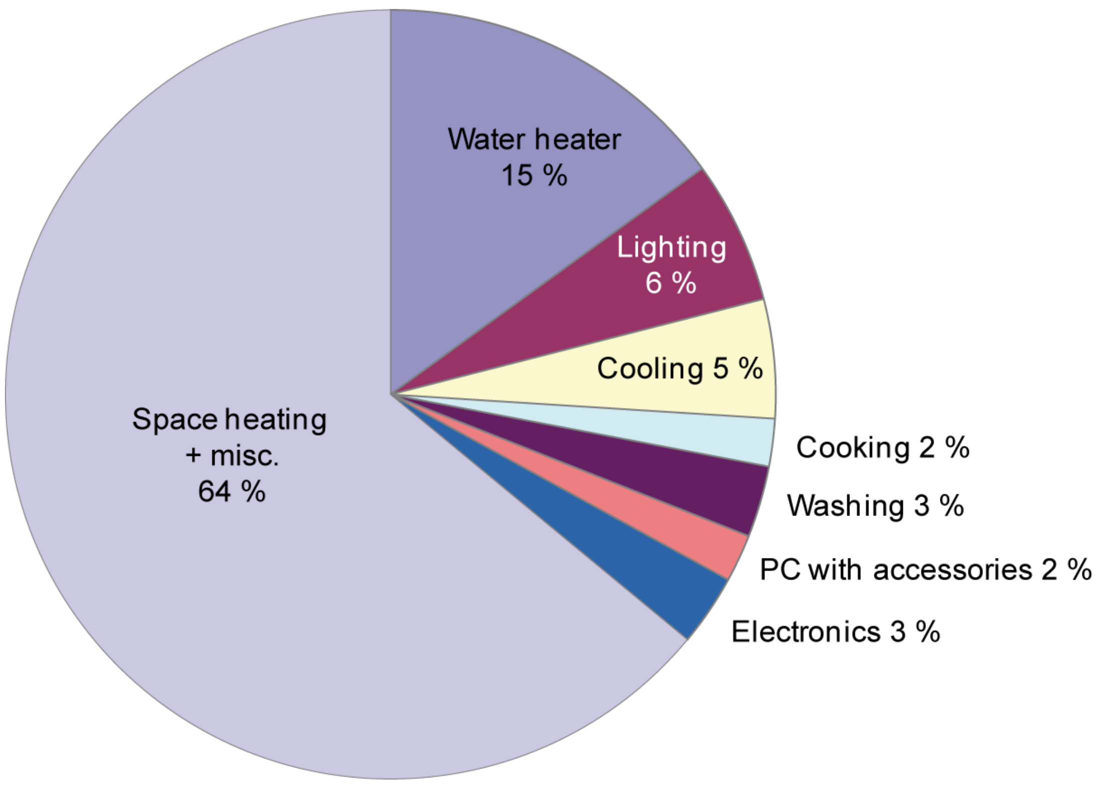


Figure 2.1 Percent Shares of Electrical End-Uses in Norway 2006/2007 [1]

2.1.2 Econometric models for calculation of end-use demand (Statistics Norway)

Statistics Norway[3] (SSB) has for the years 1990, 2001 and 2006 calculated the end-use demand for different electrical appliances at Norwegian households, with use of econometric models.

2.1.2.1 Methods for calculation

The econometric model is called Conditional Demand Analysis (CDA) and it utilises the difference between the holdings of different electrical appliances at household customers [2]. Household customers with a specific type of an electrical appliance are compared with household customers that do not have such an appliance, and the difference in electricity consumption can be ascribed to this type of appliance.

To be able to use this CDA-model it is necessary with metering of the total electricity consumption for a household, information about the household's holding of different electrical appliances and other relevant demographical and economical data.

The electricity consumption for a household is a function of the holding of electrical appliances and also the interactions between this holding and economical and demographical variables.

[3] www.ssb.no

The econometrical contingent demand function for electricity for household *i* is specified by:

$$x_i = x_0 + \sum_{j=1}^{S} \gamma_j D_{ij} + \sum_{j=1}^{J} \sum_{m=1}^{M} \rho_{jm} (C_{im} - \overline{C}_{jm}) D_{ij} + u_i \qquad (2.1)$$

where:

x_i	-	The result of the econometrical contingent demand function for electricity for the household.
x_0	-	The unspecified part of the electricity consumption for a household. (To be estimated in the model)
γ_j	-	Average electricity consumption for appliance *j* for household *i*. (To be estimated in the model)
D_{ij}	-	Dummy-variable. Equal to ‘1’ if the household has this appliance, and equal to ‘0’ if the household does not have this appliance.
ρ_{jm}	-	A regression coefficient. (Indicates the consistency between x_i and the interaction variables in third term of the equation (2.1).) (To be estimated in the model)
C_{im}	-	C_{im} (m = 1, 2, …, M) represents the economical and demographical variables that are characteristic for the household and the building, and which are important related to the electricity consumption (for example area, size, income and electricity price).
$\overline{C}_{jm}$	-	This is the average value of the economical and demographical values.
u_i	-	A stochastic residue term.

With the equation (2.1) the estimated electricity consumption per electrical appliance in kWh per year are calculated for the households.

Predicted expected electricity consumption for appliance *k* for the “average household” can be calculated as average electricity consumption for appliance *k* for the household customers that has appliance *k* multiplied with the share of households with appliance *k*. See equation (2.2):

$$x_k^p = \hat{\gamma}_k \overline{D}_k \qquad (2.2)$$

where:

γ_k	-	Can be interpreted as the difference in electricity consumption (kWh/year) between a typical (“average”) household with the appliance *k* and a typical household that do not have this appliance, i.e. the electricity consumption for an average household with appliance *k*.
$\overline{D}_k$	-	Dummy variable for appliance *k*.

The electricity consumption for different end-use demand is calculated with the basis in the coefficients estimated with use of equation (2.1) and the sample average for these variables (equation (2.2)).

Data

Data from the Survey of Consumer Expenditure in 2001 and 2006 was the basis of this analyse. A scheme with additional questions concerning energy was also used. These additional questions were modelled to analyse the end-use demand related to electricity. The econometrical studies were in 2001 based on micro data for 987 households [2], and 1005 households in 2006 [3].

Data of the electricity consumption is collected from the Distribution System Operators (DSOs) given by the households. Information about the outdoor temperature and yearly number of degree days is collected from the Meteorological Office. The price of electricity for each customer is calculated with basis in information from the Norwegian Competition Authority and Nordpool.

When performing estimates on data based on a specific selection of households, the results will strictly speaking only be valid for this selection. Disalignments in the selection imply that stated groups of households are either over- or under representative in the selection – related to all the households in Norway (the population). It is therefore necessary to correct (weigh) the data in such a way that the selection corresponds better with the distribution in the population.

The average electricity consumption in the weighed selection of households for 2001 was 17 382 kWh, and the value differed from 1 600 kWh to 56 400 kWh [2]. In 2006 the average electricity consumption in the weighed selection of households were 15 852 kWh, and the value differed from 504 kWh to 65 606 kWh [3].

The data from 1990 was collected from an Energy Survey in 1990, where approx. 1500 households participated. The data analysed with use of the ERÅD-model (See chapter 2.1.3).

2.1.2.2 Type of end-use demand

Estimated average electricity demand for different electrical appliances is presented in Figure 2.2 for 2001 and in Figure 2.3 for 2006.

According to Figure 2.2 electrical heaters used a little more than 3 500 kWh/year, electrical heater cables used approx. 1 600 kWh/year and central heating based on electricity used less than 150 kWh/year in 2001 [2]. In addition to a large amount of electricity used for heating, also washing machine, lighting and electrical water heater used a large amount of electricity.

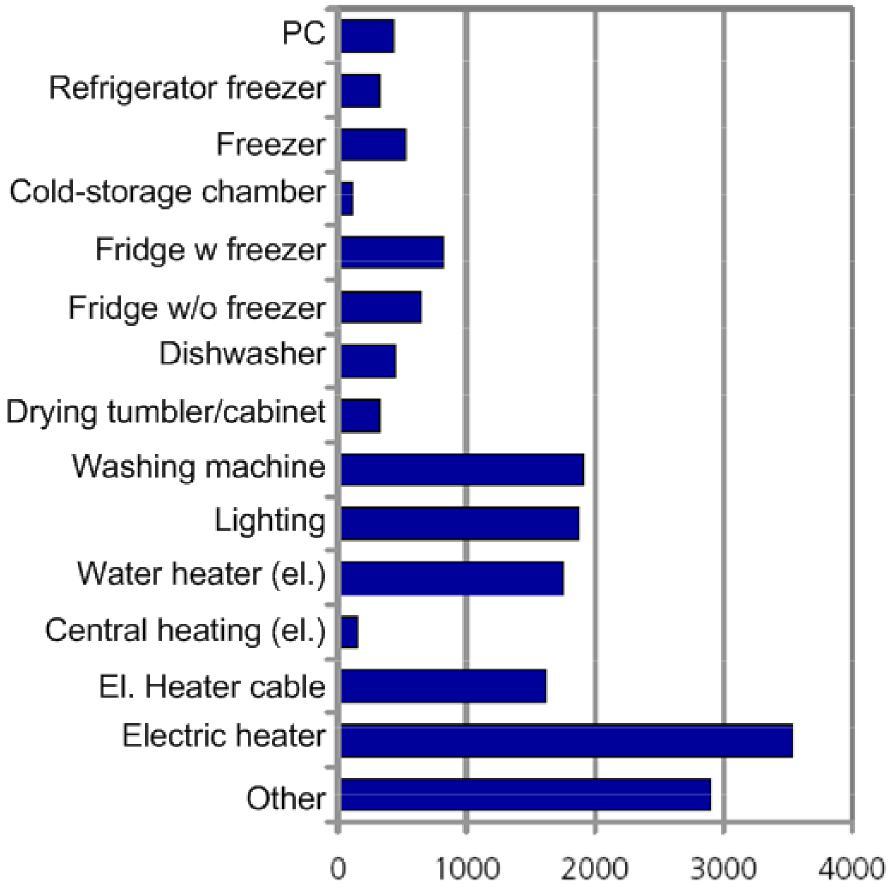


Figure 2.2 Electricity demand for different appliances. kWh, weighted selection 2001 [2]

According to Figure 2.3 there was a large electricity consumption related to water heater, electrical heaters, washing machine and PC in 2006 [3]. The average electrical consumption for “other” appliances was 3 110 kWh. The unspecified demand is consumption related to appliances not specified in the model used, such as stove, dishwasher, water kettle, microwave oven, coffee maker etc.

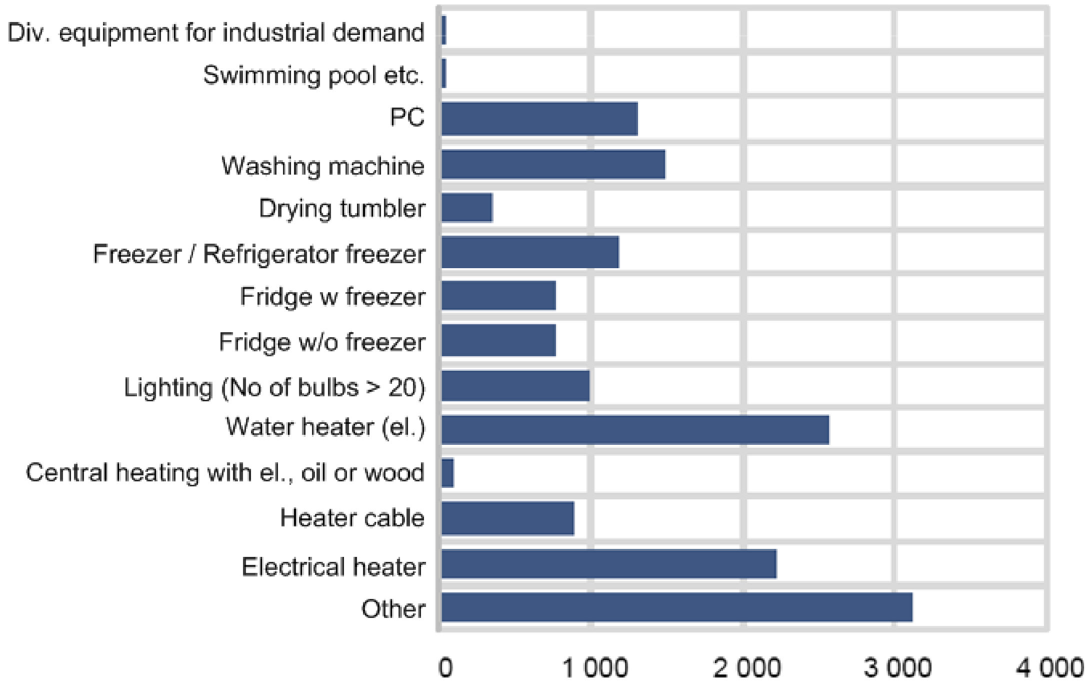


Figure 2.3 Electricity demand for different appliances. kWh, weighted selection 2006 [3]

2.1.2.3 Results

The temperature corrected electrical end-use demand for households in 1990, 2001 and 2006 are presented in Figure 2.4. The values are in percent.

The electricity consumption used for space heating increased from 23 % in 1990 to 31 % in 2001, and then it was decreased to 24 % in 2006 [3]. The electricity consumption for washing and fridge were relative stable for all the three years. The demand for lighting was reduced from 2001 to 2006, but this was due to an underestimation performed in the analysis for 2006.

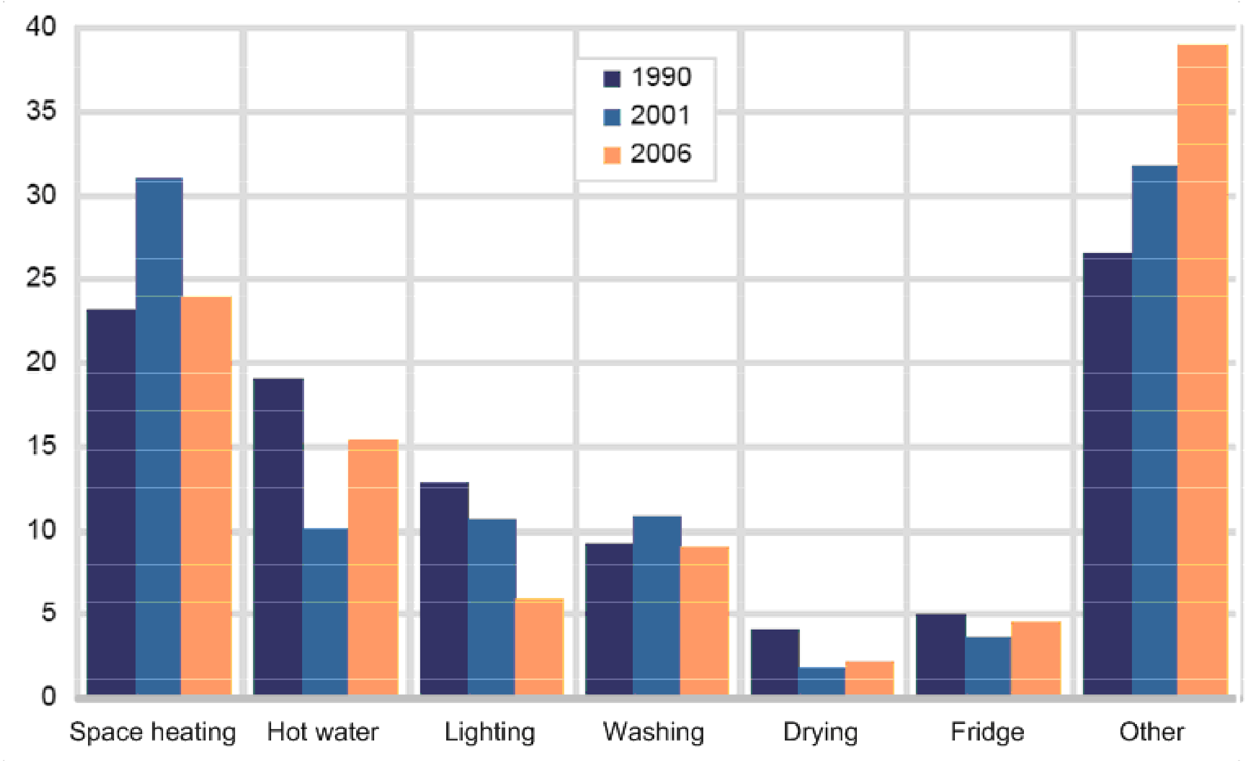


Figure 2.4 Temperature corrected electrical end-use demand for households in 1990, 2001 and 2006, Percent [3]

The electricity consumption related to “other” increased a lot from 2001 to 2006, mainly due to an increase in the households’ income level [3].

2.1.3 ERÅD-model (EnergiRÅDgivning)

Statistics Norway and Energidata A/S calculated the end use demand in households based on the Energy Survey of Statistics Norway in 1990 with use of the tool “ERÅD” [4].

The energy survey of 1990 was sent to 4000 Norwegian households of which just above 50 % replayed. The objective of the survey was to show connections between energy use and other parameters traditionally connected to energy use and to evaluate conditions that might be of importance for energy savings. The energy survey was done in cooperation between Statistics Norway and Energidata A/S.

A simulation of the end use demand was calculated based on information from 2013 households with the model “ERÅD”. ERÅD was developed to generate individual energy efficiency advices for households and non-residential buildings based on a complete diagnosis of the energy and power demand. The model calculates an estimate of the energy consumption of a single building and gives a basis of an evaluation of energy efficiency measures with investment costs and energy savings. ERÅD is short for “EnergiRÅDgivning”. It was developed in the 1980s by Energidata A/S and it was mostly used in the period 1985-1995.

ERÅD calculates the energy consumption of each building based on:

- Building data (insulation thickness, type of windows, areas of walls, ceiling, floor, windows etc.)
- Climate data of the location (temperature, wind, sun)
- Information of equipment and lightning
- Use of the building (number of persons, period of use etc.)

The energy consumption is calculated based on average energy consumption of different equipment and information on number of equipment. The energy use of hot water heating is calculated based on information of the frequency of use. The average energy consumption by end-use is based on practice from several years. The calculated energy use was compared to the actual energy use and uncertain parameters of the model were corrected in order to minimize the difference. The electricity consumption of space heating was the most uncertain parameter according to the analysts [2]. The model also include parameters of coefficient of thermal transmittance of different walls, ceiling, floors and windows, indoor temperature, airchange rates, efficiencies of different heating systems etc.

Some results of the analyses with ERÅD are presented in Table 2.3, Table 2.4 and Figure 2.5.

Table 2.3 Energy end-use (kWh/year and household) [4]

	Space heating	Hot water	Lightning	Other	Total
Farm houses	19 200	4 400	2 200	4 400	30 200
Single family house	15 600	4 500	2 100	4 200	26 300
Row house	9 500	3 500	1 600	3 400	18 000
Appartments	5 800	2 700	900	2 400	11 900
Total	12 300	3 900	1 700	3 700	21 500
Total share	57 %	18 %	8 %	17 %	100 %

Table 2.4 Electricity end-use (kWh/year and household) [4]

	Space heating	Hot water	Lightning	Other	Total
Farm houses	7 900	4 600	2 300	4 700	19 500
Single family house	8 300	4 700	2 200	4 400	19 600
Row house	6 000	3 600	1 600	3 500	14 700
Appartments	3 800	2 600	1 000	2 600	10 000
Total	6 700	4 000	1 800	3 800	16 300
Total share	41 %	24 %	11 %	24 %	100 %

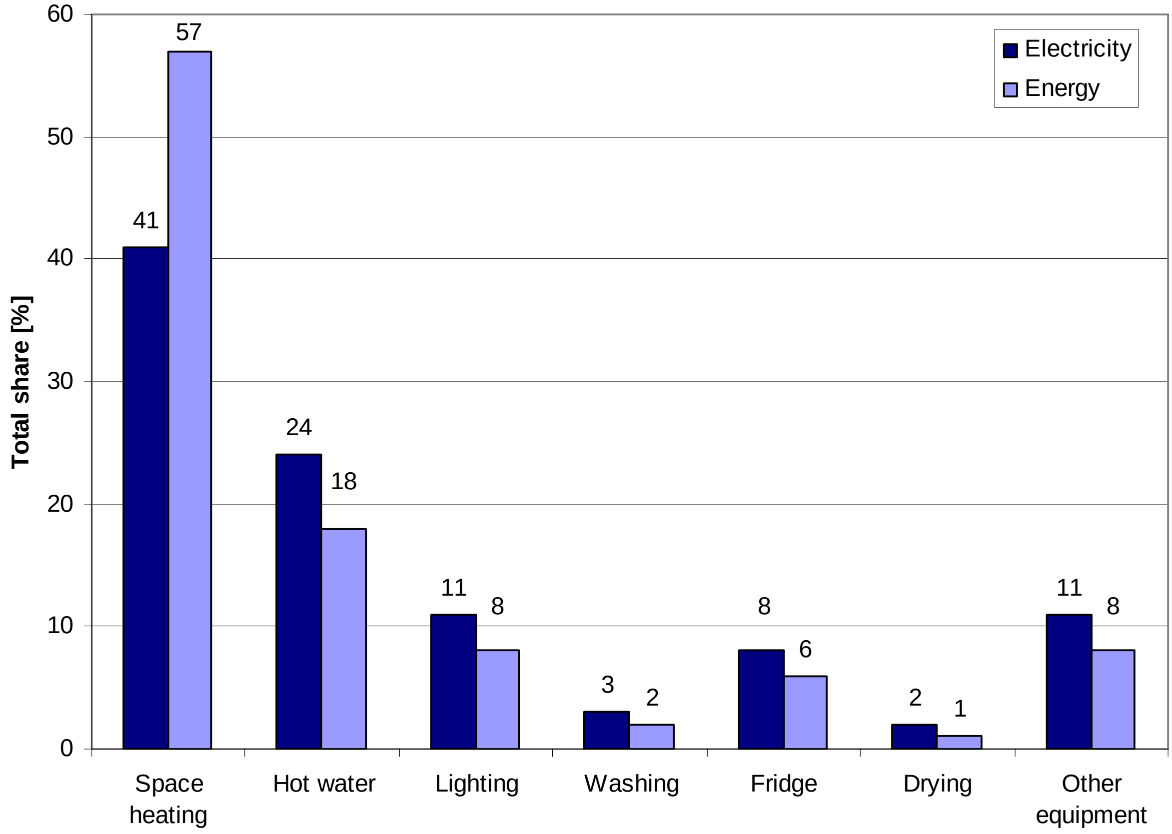


Figure 2.5 Energy and electricity end-use by use of ERÅD 1990 [2]

2.1.4 Sweden - End-use metering campaign in 400 households

The project “End-use metering campaign in 400 households in Sweden, assessment of the potential electricity savings” was financed by the Swedish Energy Agency [7]. The project was a part of the agencies’ program “Improved energy statistics in buildings and industry”.

The first objective of this project was to precisely describe the state and structure of the specific-electricity use in the residential sector, and to give an overview of the consumption for residential buildings. This project will contribute with information/results that can be used as reference information for actors working with modelling and forecasting of electrical consumption. The second objective was to evaluate the potential savings that can be achieved in the households by substituting efficient appliances for the appliances in place.

The monitoring campaign was scheduled from August 2005 to December 2007, but due to difficulties to find valid households, the campaign was extended to December 2008. The measurement campaign was performed in Sweden.

Plan for metering within project

The goal of this study was to monitor all main electric appliances for 400 households and 20 common areas in residential blocks:

- 40 households were measured for one year. (20 households could be metered at the same time.)
- 360 households were monitored for one month. (26 metering equipment sets were used.)

All the main electrical appliances were monitored at a time step of 10 minutes. Direct measure was performed on the rest.

Metering equipment

Several types of metering devices were used in the monitoring campaign.

- **Lampmeter –** were used to measure the consumption of light sources that draw a constant electrical power (incandescent bulbs, CFL, etc.). All the light points with constant power were metered. The lampmeter measuree the time during which the light source was switched on. The power was measured separately when the lampmeter was installed.
- **Wattmeters –** were used to measure the consumption for most of the other types of electrical appliances (cold, audiovisual, computer site etc.). The wattmeter was connected in series with the appliances, with the wattmeter directly plugged into the wall sockets and the household appliance connected in the trailing socket of the wattmeter.
- **Main switchboard –** was used to measure some appliances (mainly heating and water heating). These measurements were performed with use of the Multivoies system installed in the fuse box.
- **Thermometers –** were used to measure the internal and external temperatures.

Pictures of the different metering equipment are presented in [7].

The Swedish energy agency was responsible for choosing the households where measurements should be performed. The households should be a good picture of the different type of household present in Sweden. The households were spilt in different categories, as presented in Table 2.5, Figure 2.6 and Figure 2.7.

Table 2.5 Categories of households [7]

Categories	Apartments	Houses
Building types	51%	49%
Average surface area for the household	76 m^2	127 m^2

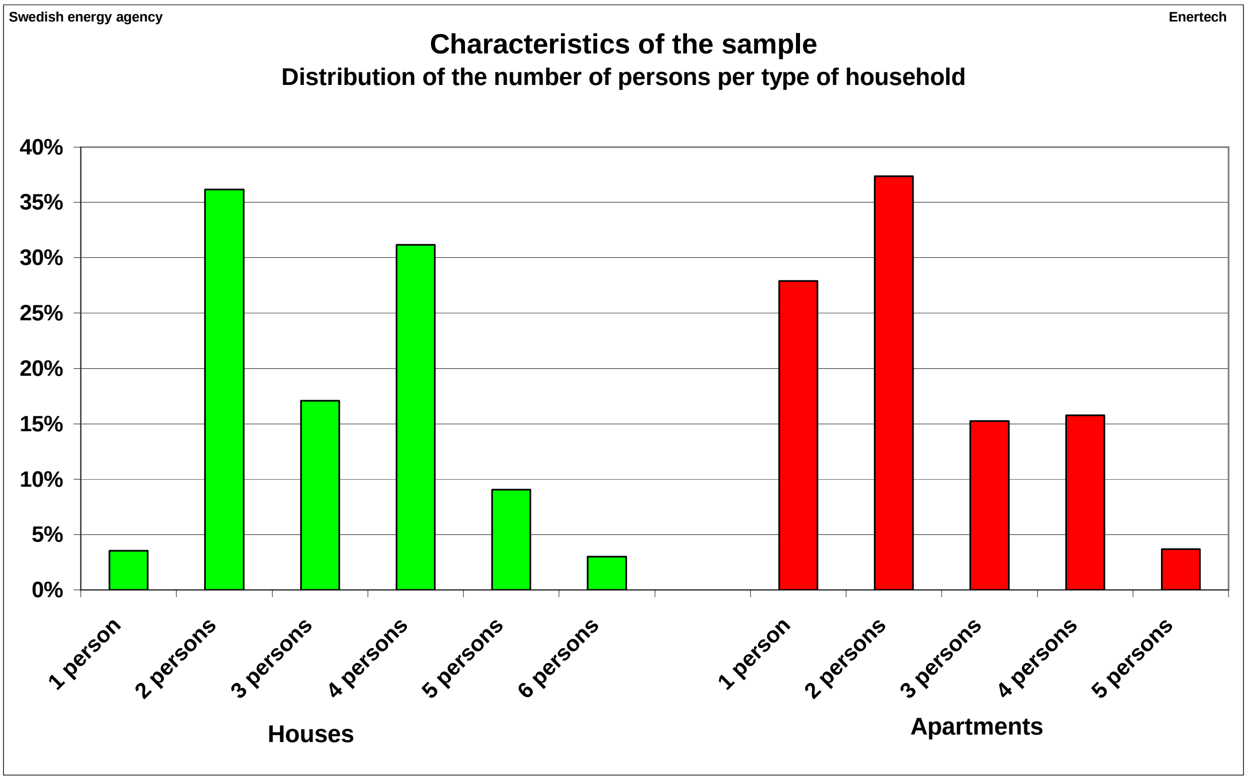


Figure 2.6 Distribution of the number of persons per type of household [7]

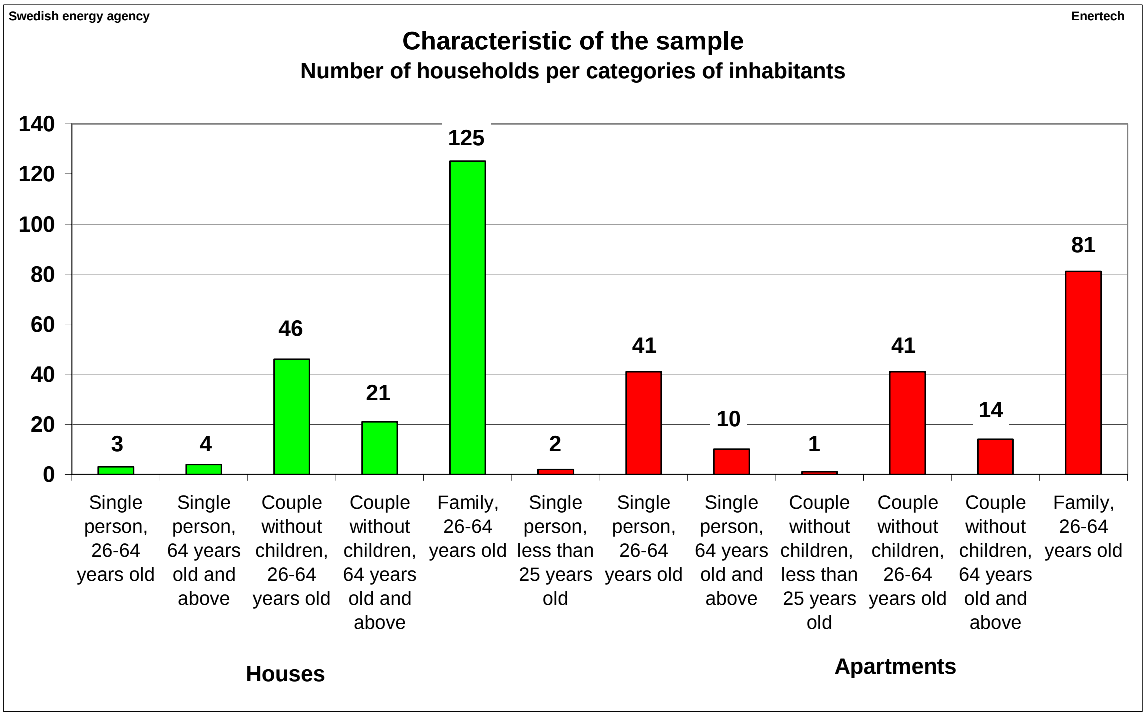


Figure 2.7 Number of households per categories of inhabitant [7]

Results

According to Figure 2.7 the largest category of household is family, 26-64 years old. This category includes couples with a child (or children) or a single person with a child (or children).

In [7] the electricity consumption is presented for each household category. In this chapter only the results for the largest household category are presented, i.e. "house, family, 26-64 years old".

The relative contribution from different electrical appliances is presented in Figure 2.8 and Figure 2.9. The results presented in the first figure are including electricity for space heating. The second figure presents the relative contribution for all the electrical appliances – without electricity used for space heating.

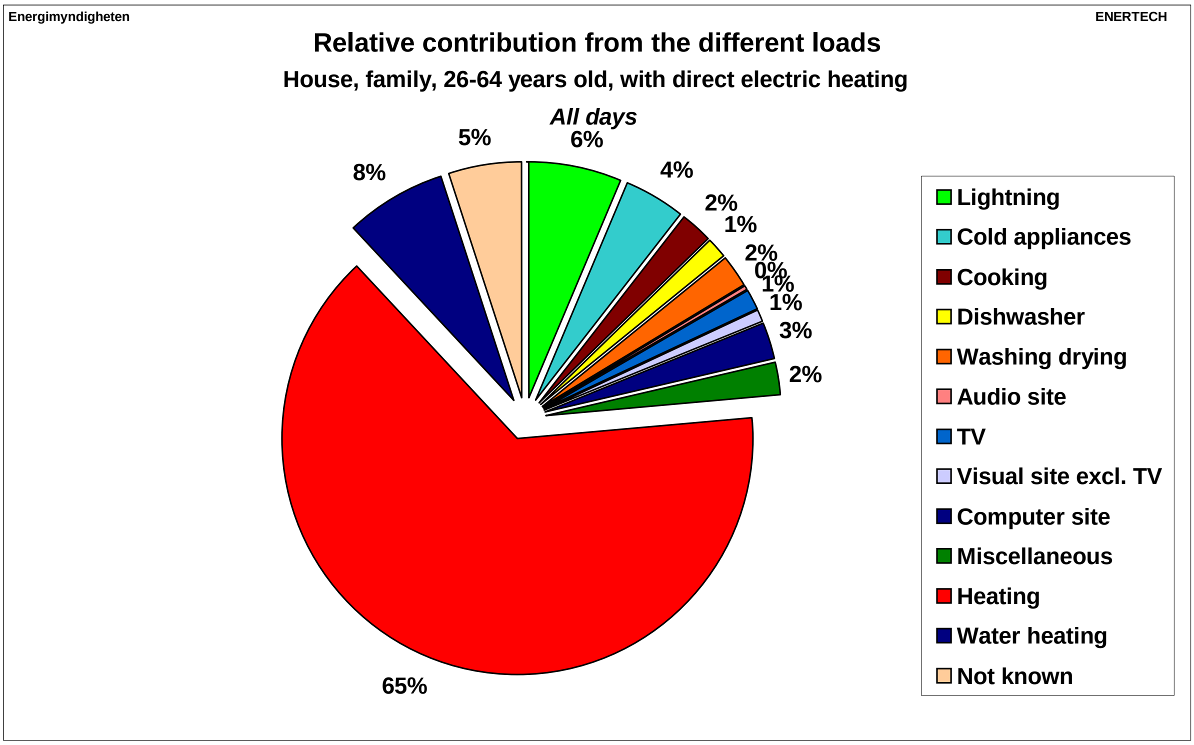


Figure 2.8 Relative contribution from the different loads - Houses with direct electric heating - All days [7]

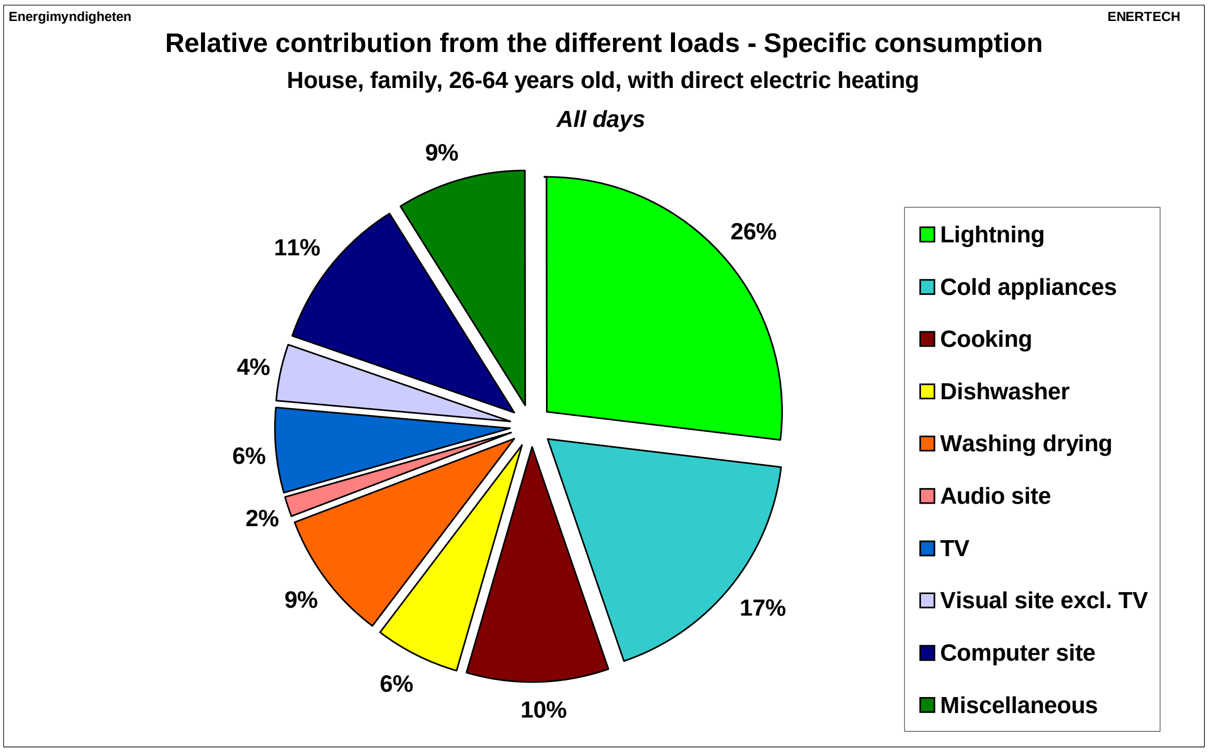


Figure 2.9 Relative consumption from the different loads for the specific consumption - Houses with direct electric heating - All days [7]

Conclusions

The project in Sweden represents the biggest measurement campaign ever made in Europe. The high number of household monitored and analysed gives a precise overview of the electrical consumption, and important information regarding calculation of potential savings.

The conclusions from [7] are:

- The total potential electrical saving per household in Sweden ranges from 600 to 1.800 kWh/year depending on the type of household.
- The following priority actions should be carried out for Demand Side Management (DSM) concern cold appliances, lighting, audiovisual and computer sites:
    - Replacing the inefficient cold appliances by the best ones can save up to 560 kWh/year per household.
    - Replacing the incandescent and halogen light bulbs by compact fluorescent lamps would reduce the annual consumption by 650 kWh for certain households.
    - Choosing a laptop instead of a desktop and reducing the Standby consumption can save up to 550 kWh/year for the computer site.
    - Using only audiovisual appliances with Standby powers less than 0,5 Watt can reduce this site consumption by 160 kWh/year.

2.1.5 Finland - Electricity use in households

A Finnish study of electricity use in households was performed in 2007-2008 with the following objectives [8]:

- Decomposition of total consumption to appliance categories
- Household feedback information
- Calculation of saving potential

The electricity use in different types of households is also presented (single family houses, row houses and flats), as well as electricity use in reference households (type of dwelling, number of persons, electrical heating or not, etc.).

The survey was a web-questionnaire answered by 2700 and a mail questionnaire answered by 340 households. The survey data were weighted for representativiness. The metering consisted of plug-in metering in 82 households all over the country and fuse-metering in 9 households in Helsinki using BaseN's technology.

The electricity use by appliance category in the studies of 1993 and 2006 are presented in Table 2.6.

Table 2.6 The electricity use by appliance category in the studies of 1993 and 2006 [8]

Appliance Category GWh	1993	2006
Cold Appliances	2 215 (30 %)	1 461 (13 %)
Lighting	1 541 (21 %)	2 385 (22 %)
Audiovisual appliances	537 (7 %)	834 (8 %)
Computer sites	n.a.	407 (4 %)
Cooking	796 (11 %)	653 (6 %)
Dishwashers	125 (2 %)	261 (2 %)
Washing machines and driers	316 (4 %)	391 (4 %)
Sauna stoves	606 (8 %)	852 (8 %)
Floor heating (1)	≈ 0	206 (2 %)
Heating equipment	483 (7 %)	621 (6 %)
Other electricity	623 (8 %)	2 572 (23 %)
Car heating	226 (3 %)	218 (2 %)
Outside lighting	n.a.	89 (1 %)

2.1.6 Denmark - ELMODEL-Bolig

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. The model development started in the middle of the 1980'ies as an initiative from the Danish

Electricity utilities. 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.

Today, ELMODEL-bolig is the common tool for energy forecasts of the Danish residential sector of Energinet DK, Dansk Energi – Net, Energistyrelsen and Elsparefonden in Denmark. The model uses information of the stock of electrical appliances collected every second year since 1974 from approx. 2000 households, representatively distributed in Denmark, different residential houses etc. The model includes approx. 30 individual appliances, described with coverage, frequency of use and specific electricity consumption, volume and life time. The data are processed to be representative for Denmark through weight factors. Based on this information, the model makes forecasts of the electricity consumption of the Danish residential sector, where the impact of assumptions of individual electrical appliances is calculated. More information about ELMODEL-bolig is available at http://www.elmodelbolig.dk/.

The end-use is as far as possible based on monitoring of electricity use, from investigations or from manufacturers, but if this is not available, the consumption is calculated. The electricity utilities have a database of information from the manufacturers of appliances named ELDA. Most commonly the annual electricity consumption per appliance is calculated based on electricity use per appliance combined with information of frequency and size. The information of use of appliances is collected from omnibus surveys every second year.

Measured data are from tests of appliances by the Consumer Council (washing machine, dish washer, freezer, baking machine, hot water heater etc.) or are measured in different projects. Two measuring projects are:

- Cooking - 100 households, cooking plates, micro wave ovens (1999)
- EURECO -100 households in Odense (se details at the end of this chapter).

In Table 2.7 and Table 2.8, the electricity use of new appliances in 1980, 1995 and mainly 2006 is presented [9].

Table 2.7 Electricity use of new appliances in Denmark (kWh/year). Translated from [9]

APPLIANCE	1980	1995	LATEST CONSUMPTION	YEAR OF UPDATING
Circulation pump	490	175	245	2006
Misc. small appliances	315	595	700	2006
Electric baking oven	130	120	105	2006
Mini oven	-	100	85	2006
Hotplate	190	155	210	2006
Low energy bulb	-	10	9	2002
Electric water heater	2410	2035	1885	2006
Electric heating	6300	5800	5650	2006
Colour TV 1	250	190	260	2006
Colour TV 2	55	90	135	2006
Gas boiler	-	155	136	2004
Incandescent lamp	37.3	32	26	2002
Halogen bulb	-	12.4	21	2002
Combined fridge/ freezer	670	470	345	2006
Chest freezer	680	385	245	2006
Refrigerator with ice box	430	325	225	2002
Refrigerator without ice box	320	245	170	2006
Fluorescent tube	-	24.3	24	2006
Microwave oven	-	55	35	2006
Oil boiler	290	175	235-400	2004
Dishwasher	525	330	260	2006
PC - stationary	-	185	210	2006
PC - laptop	-	-	55	2006
B/W TV	90	75	-	2006
Upright freezer	565	425	265	2006
Tumble dryer	535	315	340	2002
Water bed	-	750	750	2006
Washing machine	410	300	210	2006
Video	-	75	23	2006

Table 2.8 Electricity consumption of new appliances in different types of Danish households (kWh/year). Translated from [9]

APPLIANCE	APPARTMENT	SINGLE FAMILY HOUSE	FARM HOUSE	ALL DWELLINGS	YEAR OF UPDATING
Circulation pump	245	246	245	245	2006
Misc. small appliances	570	840	870	700	2006
Electric baking oven	95	115	115	105	2006
Mini oven	75	95	95	85	2006
Hotplate	180	225	240	210	2006
Low energy bulb	9	8	13	9	2002
Electric water heater	1455	2225	2380	1885	2006
Electric heating	3850	7050	8450	5650	2006
Colour TV 1	260	260	260	260	2006
Colour TV 2	135	135	135	135	2006
Gas boiler	136	136	136	136	2004
Incandescent lamp	26	26	26	26	2002
Halogen bulb	21	21	21	21	2002
Combined fridge/ freezer	345	345	345	345	2006
Chest freezer	185	245	280	245	2006
Refrigerator with ice box	215	235	235	225	2002
Refrigerator without ice box	140	180	180	170	2006
Fluorescent tube	24	24	24	24	2006
Microwave oven	35	36	36	35	2006
Oil boiler	235-400	235-400	235-400	235-400	2004
Dishwasher	235	265	265	260	2006
PC - stationary	210	210	210	210	2006
PC - laptop	55	55	55	55	2006
Upright freezer	200	295	295	265	2006
Tumble dryer	285	350	370	340	2006
Water bed	750	750	750	750	2002
Washing machine	165	215	215	210	2006
Video	23	23	23	23	2006

End-use of electricity in the residential sector in 2006 is presented in Figure 2.10. Stand-by mode of appliances use in average 8 % of the electricity consumption of Danish households. The end-use is analysed for different sizes of the households, different age structure of the persons, different types of houses (apartments, detached houses and farming houses), as well as a geographical division in houses east and west of Storebælt.

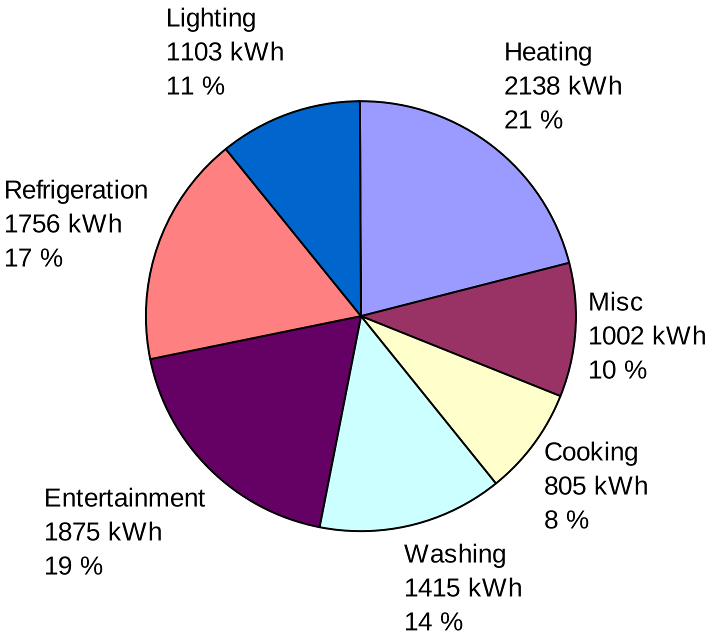


Figure 2.10 ELMODEL-bolig: End-use electricity consumption in the Danish residential sector 2006 [10]

EURECO

The lighting measurements performed in ELMODEL-bolig were a part of a European SAVE project named EURECO, taken place in 1999 - 2001. In this project a French method for monitoring of 400 European households was adopted. At each household, individual electrical end-use was monitored every ten minutes over a full month of operation. In addition, the overall electricity consumption and the temperature in the kitchen were monitored at the same frequency. A detailed questionnaire was also used to survey the participants. The name of the measurement system was DIACE, using power line carrier technology that does not need any wire link. Measured data was transmitted via the power line every 10 minutes to a collector. Light in the households were individually monitored using a “Lamp-meter” developed by Enertech society [11], [12]. The Danish measurements were performed in 85 detached houses and 15 apartments. The results were compared with the data of ELMODEL-bolig, see Table 2.9. The average electricity end-use in the 100 households in Odense is presented in Figure 2.11.

Table 2.9 Comparison of average electricity consumption and coverage between the EURECO project (Odense) and ELMODEL-bolig [13]

Appliance	Average el. consumption in kWh			Contribution rate in %		
	Odense	Elmodel bolig	Difference	Odense	Elmodel bolig	Difference
El-cooker	140	105	18	88	86	2
Cooking plate	180	233		86	85	1
TV + Video + HiFi	211	230	-19	163	155	8
Deep freezer	420	453	-33	49	50	-1
Upright freezer	522	458	64	29	21	8
Fridge-freezer	564	471	93	25	50	-25
Refrigerator w freezer	389	310		78	22	7
Refrigerator w/o freezer		251			49	
Dish washer	349	308	41	49	46	3
Tumble dryer	349	352	-3	49	39	10
Washing machine	291	285	6	91	75	16
Lighting	452	557	-105	26 lamps	22 lamps	4 lamps
Standby	308	328	-20			
PC equipment	162	149	13	85	84	1

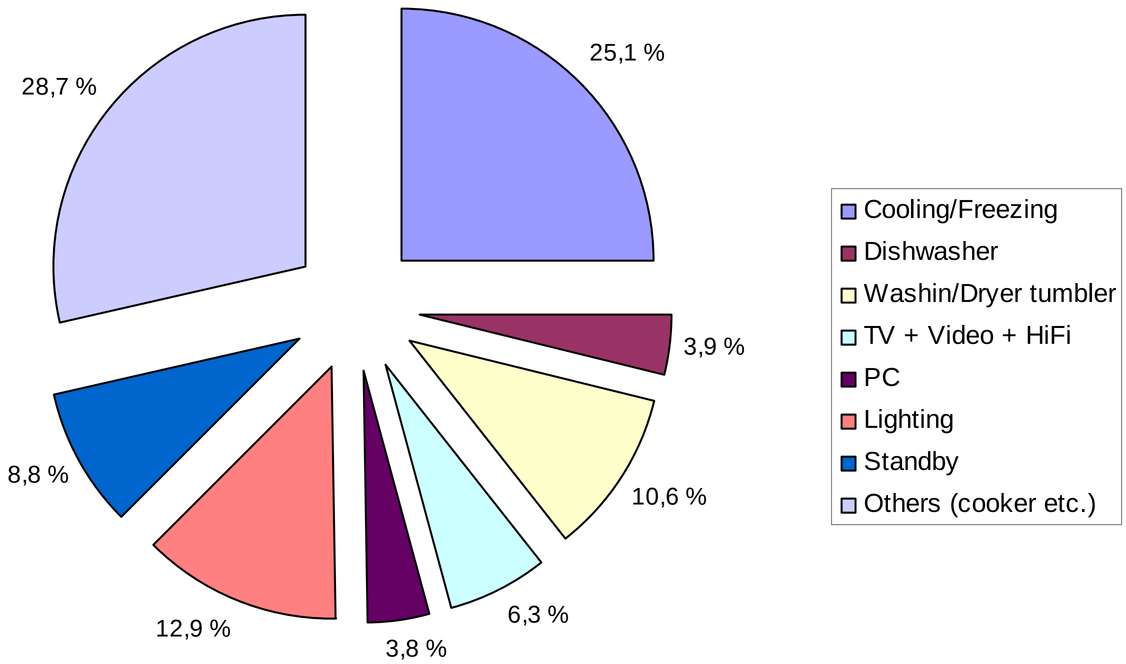


Figure 2.11 Average electricity end-use of 100 households in Odense [13]

2.1.7 Nordic household model - Pre-study

The Nordic NICHE group is an unofficial forum for exchange of ideas and experiences in energy efficiency-related research of households that was established in 2008. The group found the extending of the Danish ELMODEL-bolig an idea worth looking into. The Nordic Council funded a pre-study to assess costs and benefits in detail [14].

The pre-study report concludes that there is a gap in availability to data. It 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, but the cost of these studies prohibits them carried out often and thus a tool to disaggregate the statistical data would be useful.

The structure of a common Nordic model is described in the pre-study as shown in Table 2.10 and the suggested appliances are presented in Table 2.11. In order to evaluate the viability of the building of the common model the data availability was assessed. For Norway almost no data exists on unit consumption and frequency of use, while some data exist on ownership levels and sales figures, see Appendix 2. The project group has made preliminary enquires whether there is interest in respective countries to develop the model and such interest exists.

Table 2.10 Proposed structure of a common Nordic electricity end use model [14]

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 2	Appliance list including division into ON / Standby consumption

Table 2.11 Suggested appliances in a common Nordic electricity end use model, [14]

Miscellaneous		
	1.	Miscellaneous Consumer Electronics
	2.	Miscellaneous other
	3.	Elevation and water beds
	4.	Electrical cars
	5.	Car heater
Cooking		
	6.	Electric oven
	7.	Electric stove
	8.	Micro wave oven
	9.	Cooker hood

Heating		
	10.	Circulation pump
	11.	Electric space heating
	12.	Electric water heater
	13.	Furnace
	14.	Electric floor heating
	15.	Supplementary electric space heating
	16.	Sauna
	17.	Heat pump – air/air
	18.	Heat pump – air/water
	19.	Heat pump – soil, hydro reservoirs/water
	20.	Electric towel dryer
	21.	Drying closets
	22.	Boot dryer
	23.	Ventilation
	24.	Heat exchanger
Entertainment		
	25.	CRT TV
	26.	LCD TV
	27.	Plasma TV
	28.	OLED TV
	29.	Stationary PC (incl. screen)
	30.	Laptop
	31.	DVD
	32.	Video
	33.	Stereo
	34.	Surround sound
	35.	ADSL
	36.	Set-top box – simple
	37.	Set-top box – advanced
	38.	Digital photo frame
	39.	Mobile HDD
	40.	Cordless phone
	41.	Clock radio
	42.	Imaging equipment – inkjet (printer, scanner, copier)
	43.	Imaging equipment – laser (printer, scanner, copier)
Cooling		
	44.	Combined fridge/freezer
	45.	Fridge with ice box
	46.	Fridge without ice box
	47.	Chest freezer
	48.	Upright freezer
	49.	Wine Cabinet

Washing	
	50. Washing machine 51. Tumble dryer 52. Combined washer/dryer 53. Dishwasher
Lighting	
	54. Incandescent lamps (traditional light bulbs) 55. Linear fluorescent lamps (LFL) (typical in kitchens) 56. Compact Fluorescent lamps (CFL) ("saving bulbs") 57. Halogen lamps (maybe split into high/low voltage) 58. Diode lamps

2.1.8 Summary – Household customers

In this chapter the methodologies used in the different projects described in chapter 2.1 are presented.

Table 2.12 Projects evaluated for household customers

Project	Description of work	Strength	Weakness
REMODECE (Chp. 2.1.1)	Measurement of end-use demand with 1 minute interval at 100 Norwegian households. Stratification of data based on survey.	• Measurements represent actual data • Estimated loads are actual loads • Surveys regarding ownership, demographical data etc. used for stratification. Possible to calculate the consumption for national average households. • Possible to calculate total demand per use of an appliance • Load profiles	• Expensive data acquisition due to measurements • Time consuming • Limited size of sample. Smaller samples give larger confidence bands around estimated averages. • Electrical heating is not measured • Updating requires new measurements

Project	Description of work	Strength	Weakness
Econometric model Statistics Norway (Chp. 2.1.2)	Conditional Demand Analysis (CDA) Calculations of end-use demand at approx. 3 * 1000 Norwegian households, based on total electricity use and surveys	• A lot of different data available via survey • Moderate costs for data acquisition • Large sample possible • Typically large samples • Explanatory model, i.e. easy for making inferences • Updating of the data for analysing trends are possible at reasonable costs.	• High degree of collinearity. The estimation results can be non- significant for appliances that nearly all customers have. • Non-constant variance (Heteroscedasticity) • Assumption of fixed value for the coefficients for the appliance dummies ignores two important sources of variation: intensity of use can vary between households, as well as size and capacity. • Not consumption per use of an appliance • No load profile
ERÅD (Chp. 2.1.3)	Calculation of end-use demand per year at approx. 2000 Norwegian households based on practice and surveys.	• A lot of different data available via surveys • Moderate costs for data acquisition • Large sample possible	• A lot of parameters (energy and power consumption for different appliances, period of use, consumer behaviour) have to be estimated based on the surveys • Only yearly consumption. No load profile • Old data

Project	Description of work	Strength	Weakness
Sweden – measurement of end-use demand (Chp. 2.1.4)	Measurements of end-use demand at 400 Swedish households (40 households measured for one year, and 360 households measured for one month.) 10 minutes interval for main electrical appliances, and direct measurement of the rest of the appliances.	• Measurements represent actual data • Surveys used for i.a. demographical data • Load profile available • Measurement of end-use demand ona monthly and yearly basis	• Expensive data acquisition due to measurements • Time consuming • Limited size of sample (for the yearly measurements) • Updating requires new measurements and surveys
Finland – measurement of end use demand (Chp. 2.1.5)	Measurement of end-use demand at Finnish households (82 with plug-in metering and 9 with fuse-metering) and surveys of 2700/340 households (web/mail).	• Measurements represent actual data • Surveys used for i.a. demographical data • Moderate costs for data acquisition via surveys	• Expensive data acquisition due to measurements • Time consuming • Limited size of sample • Updating requires new measurements and surveys
ELMODEL-bolig Denmark (Chp. 2.1.6)	A forecasting model based on Measurement of electricity consumption per type of appliance, calculations and surveys every 2nd year since 1974. Surveys collect information such as ownership and frequency of use. Bottom-up model.	• Measurements represent actual data • Surveys are used for information regarding ownership, use and demographical data • Moderate costs for data acquisition via surveys • Periodical surveys gives tendency concerning changed consumption	• Measurements performed per appliance and not related to the consumption pattern per customer • Expensive data acquisition due to measurements • Expensive and time consuming to keep updated

The Nordic Household model (Chp. 2.1.7) is not included in Table 2.12 since this is not a project focusing on finding information about the electricity consumption, but rather a pre-study describing a possible structure of a common Nordic model concerning end-use demand. The Nordic Household model is a preliminary structure plan for appliances that are of relevance for metering in the ElDeK project. This model contains no data about energy consumption – only a suggestion of how to structure a model concerning end-use demand.

The different projects presented in chapter 2.1 have been focusing on the electricity consumption for different electrical appliances at household customers. A summary of the electricity consumption per year and households for these projects are presented in Table 2.13. The results differ both between the countries and between the different projects, and they are difficult to compare. They are presented here to show the variations in the results.

Table 2.13 Electricity end-use (kWh/year and household)

	Space heating	Hot water	Light-ning	Dish-wash.	Wash-ing-mach.	Drying	Cooling /freezing	Cook ing	Other equip.	Total
REMODECE (Table 2.2)	Not metered	2539	1000	181	201	125	160[2] 247[3] 461[4]	269	(See Table 2.2)	
SSB 1990	3333	3365	2280	964	1629	726	897 + ?		3729	16923
SSB 2001	5304	1754	1872	450	1906	327	644 + ?		5125	17382
SSB 2006	3220 (3970[1])	2568	985	Incl. in other	1493	359	762 (+ 1181)		6464	15852
ERÅD 1990	6700	4000	1800	Incl. in wash	450	300	1300		1750	16300
STEM – one family houses [7]	11595[5] 5547[6] 8378[7]	2269	1021	193	209	194	818	402		
STEM – Multiple family houses [7]	Not incl.	Not incl.	574	152	163	236	633	320		
Finland	827		2474		652[2]	Incl. in wash	1461	653	4883	10950
ELMODEL-bolig	2138		1103	Incl. in wash	1415		1756	805	2877	10095
Odense			452	349	261[1]	Incl. in wash	802			3764

[1] Temperature corrected [2] Refrigerator w/o freezer [3] Refrigerator w freezer
[4] Freezer [5] With direct electric heating [6] Without direct electric heating
[7] All customers included (Global)

2.2 NON RESIDENTIAL BUILDINGS / OFFICE BUILDINGS

2.2.1 Guide for calculations of energy end-use

The handbook "Enøk Normtall" is a guide of the need for energy and power in buildings, when energy efficient measures are implemented [15]. The data is based on given assumptions/ reference values (e.g. U-values, ventilation air flow, operational hours, efficiencies etc.). The basic reference values of the need of energy and power are calculated based on these reference values and climate data of a normal year. The reference values are based on Norwegian standards and regulations and on experience data from different projects and on assessments of energy efficient solutions. There are guidelines for nine different types of buildings, each with three levels and seven zones of climate.

The building types are:

- Offices
- Nursing homes
- Storehouses (16 °C)
- Kindergarten
- School (without gym)
- University (without gym)
- Single family houses
- Undetached houses
- Apartment buildings

The energy end use of offices in climate zone 1 (the south of Norway, inland) and the three different levels are presented in Table 2.14. In Figure 2.12 the energy end use in offices in the inland in the south of Norway, using the building regulations of 1997, is presented.

Table 2.14 Energy end-use in offices in the inland in the south of Norway (kWh/m²) [15]

Level	Old buildings	Building regulations 1987	Building regulations 1997
Heat	79	48	30
Ventilation	32	35	24
Hot water	10	10	10
Pumps/fans	17	21	17
Lightning	32	32	26
Cooling	4	4	4
Misc.	24	24	24
Total	198	174	135

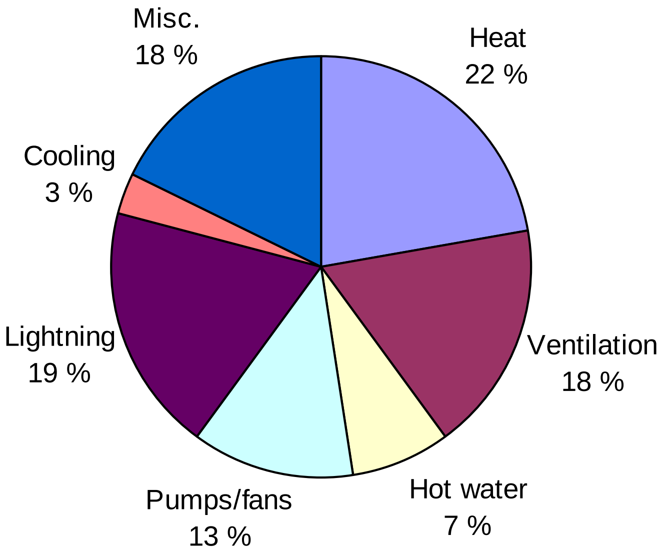


Figure 2.12 Energy end use in offices in the inland in the south of Norway, using the building regulations of 1997 [15]

According to the new building regulations (TEK 2007), the net energy demand of new office buildings should not be more than 165 kWh/m² heated area and year [16]. A basis for the calculations is presented in Table 2.15.

Table 2.15 Basis for the calculations of energy frames in TEK 2007 (kWh/m², year) [16]

	House	Block of flats	Kindergarten	Office buildings	School	University	Hospital	Nursing home	Hotel	Sports centre	Commercial building	Cultural buildings	Small industry, workshops
Space heating	54/52*	32/30	70/67	31/33	40/39	31/33	67/57	54/49	67/61	51/48	50/45	74/65	71/67
Ventilation heat	6/7	8/7	32/26	29/21	34/27	33/24	51/42	47/38	36/29	47/40	43/34	32/26	30/25
Hot water	30/30	30/30	10/10	5/5	10/10	5/5	30/30	30/30	30/30	49/49	10/10	10/10	10/10
Fan and pumps	7/8	10/10	22/23	22/22	24/25	27/27	54/54	48/48	35/35	22/23	41/42	24/24	21/21
Lighting	17/17	17/17	21/21	25/25	22/22	25/25	47/47	47/47	47/47	21/21	56/56	23/23	19/19
Technical equipment	23/23	23/23	5/5	34/34	13/13	34/34	47/47	23/23	6/6	3/3	4/4	3/3	23/23
Space cooling	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Ventilation cooling	0/0	0/0	0/0	19/24	0/0	23/30	38/50	0/0	26/31	0/0	37/47	19/26	18/21
Total net energy demand	137/ 137*	121/ 118	160/ 152	165/ 165	143/ 137	179/ 179	333/ 327	248/ 234	245/ 239	192/ 185	240/ 237	185/ 178	192/ 186

2.2.2 Energy use in buildings within service industries (Statistics Norway)

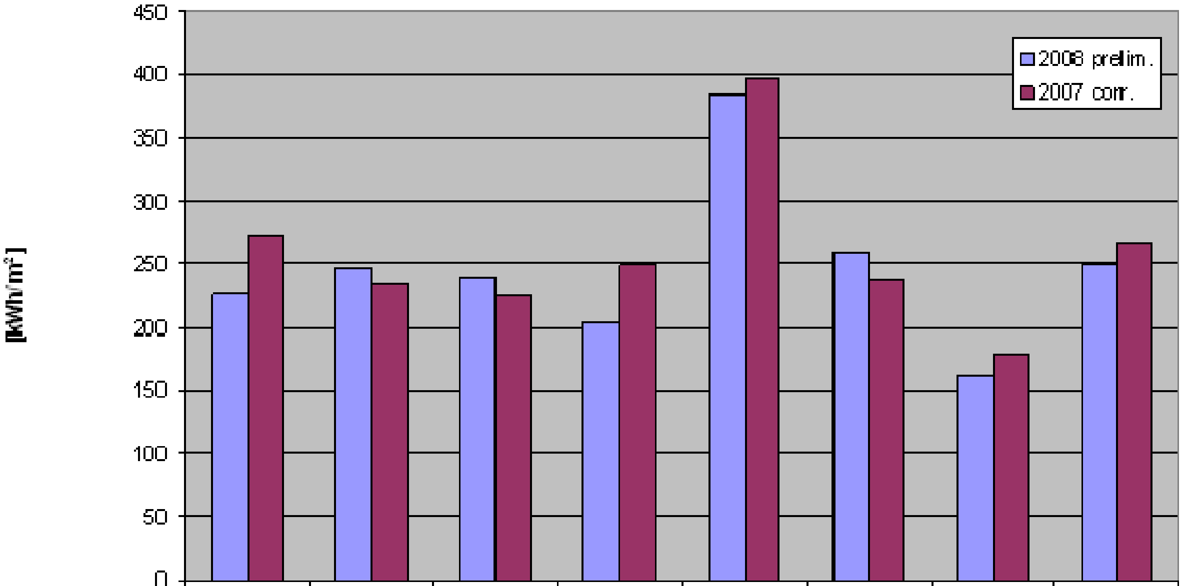
Statistics Norway presents information about the energy use in different types of buildings within the service industry [17]. The description of the commercial customers contains information about energy use per square meter (energy intensity), heating equipment in buildings and energy intensity per energy carrier.

The statistic concerning energy use in buildings within the ser industries is focusing on all the different types of buildings within this type of industry. In the ElDeK project the main focus is on office buildings, and therefore only the information regarding the office buildings is presented in this chapter.

2.2.2.1 Energy intensity [kWh/m2]

For service industries there is a large variation in the use of energy per square meter – both between and within different building types [17]. An explanation of this can be differences in building constructions, area of application, the amount of electrical equipment and the scope of implemented energy efficiency measures. The specific energy use for different industrial buildings varied from above 1000 kWh/m^2 to under 100 kWh/m^2. According to preliminary figures for 2008, the average purchase of energy use in 5000 industrial buildings within service industries was 227 kWh/m^2.

The energy use per square meter for different types of buildings in service industries are presented in Figure 2.13. The values for 2008 are preliminary values presented in [17] and the values for 2007 are from [18]. The values for 2007 are temperature corrected to a mean year, and corrected for geographical differences based on the local number of degree days in relation to the number of degree days for Oslo. Geographical skewed distribution will therefore not influence the numbers in a large degree.



	Service industries in total	Office buildings in total	Office and adm. buildings	Banks and post offices	Radio and TV	Other office buildings	Schools and kindergarten	University
2008 prelim.	227	247	239	204	385	259	160	249
2007 corr.	271	233	226	249	396	237	179	267

Figure 2.13 Average energy intensity for selected buildings within the service industries. kWh/m2. Values for 2008 are preliminary [17], and values for 2007 are corrected for difference in temperature and location [18].

The buildings with the highest energy intensity per square meter, such as Radio and TV production companies, had extremely energy intensive equipments, high levels of activity and period of use. Buildings with low energy use, such as schools and kindergarten, had limited technical equipment and a short period of use.

2.2.2.2 Heating equipment

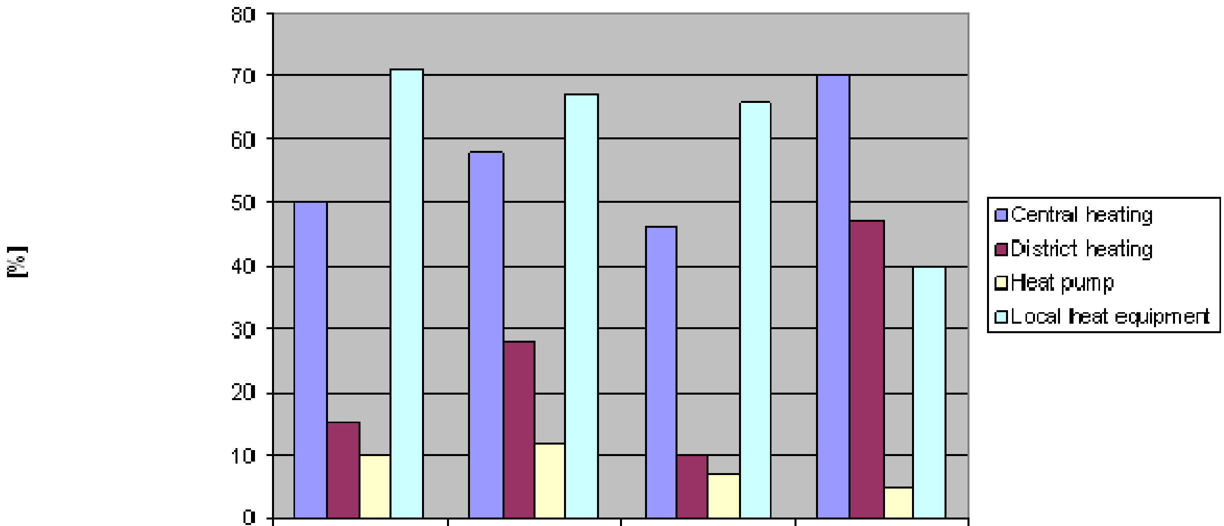
Electricity was the largest used energy source in most building types, and it accounted for 82,3 % of total energy use. The total area in buildings within service industries was 22,5 mill. m^2.

For some buildings, mainly universities, colleges and sports centres, district heating accounts for a substantial share of total energy use. The share of district heating accounted for 11,5 % of total energy use in buildings.

2,8 % of total energy use is covered by heating oil. Other energy sources such as pellets and gas were important energy sources for some large buildings, but in total these energy sources accounted only for a minor share of the total energy use. Wood is little used in industrial buildings.

The use of heat equipment such as central heating, district heating, heat pump and local heat equipment, for some selected building types are presented in Figure 2.14 [17].

Half of the buildings within the category “service industries” had central heating as their main heating source, while 15 % used district heating and 10 % had heat pumps. Electric heaters were the most common heating equipment in industrial buildings, but some buildings had electrical floor heating, wood ovens or other equipment for local heating. Many buildings had these types of heating equipment in addition to central heating, district heating and heat pumps.



	Service industries in total	Office buildings	Schools and kindergarten	University
Central heating	50	58	46	70
District heating	15	28	10	47
Heat pump	10	12	7	5
Local heat equipment	71	67	66	40

Figure 2.14 Heat equipments in selected buildings in service industries. Preliminary figures 2008 [17]

2.2.2.3 Energy carriers

Figure 2.10 illustrates the energy consumption for a selection of buildings within the service industry. The line in the graph shows the energy intensity for each building types. The energy intensity is estimated as total energy consumption divided on total heated area in the buildings. This is equivalent with the data presented in Figure 2.15. The bars in the figure illustrate the percentage use of different energy carriers such as: electricity, district heating, heating oil, gas, wood and pellets.

The figure shows that electricity is the main energy carrier used in the selected buildings, and it varies from 68,1 % for Universities to 95,7 % for office buildings working with radio and TV. District heating is largest for Universities with 28,9 %. Gas, wood and pellets represent only a small part of the energy consumption.

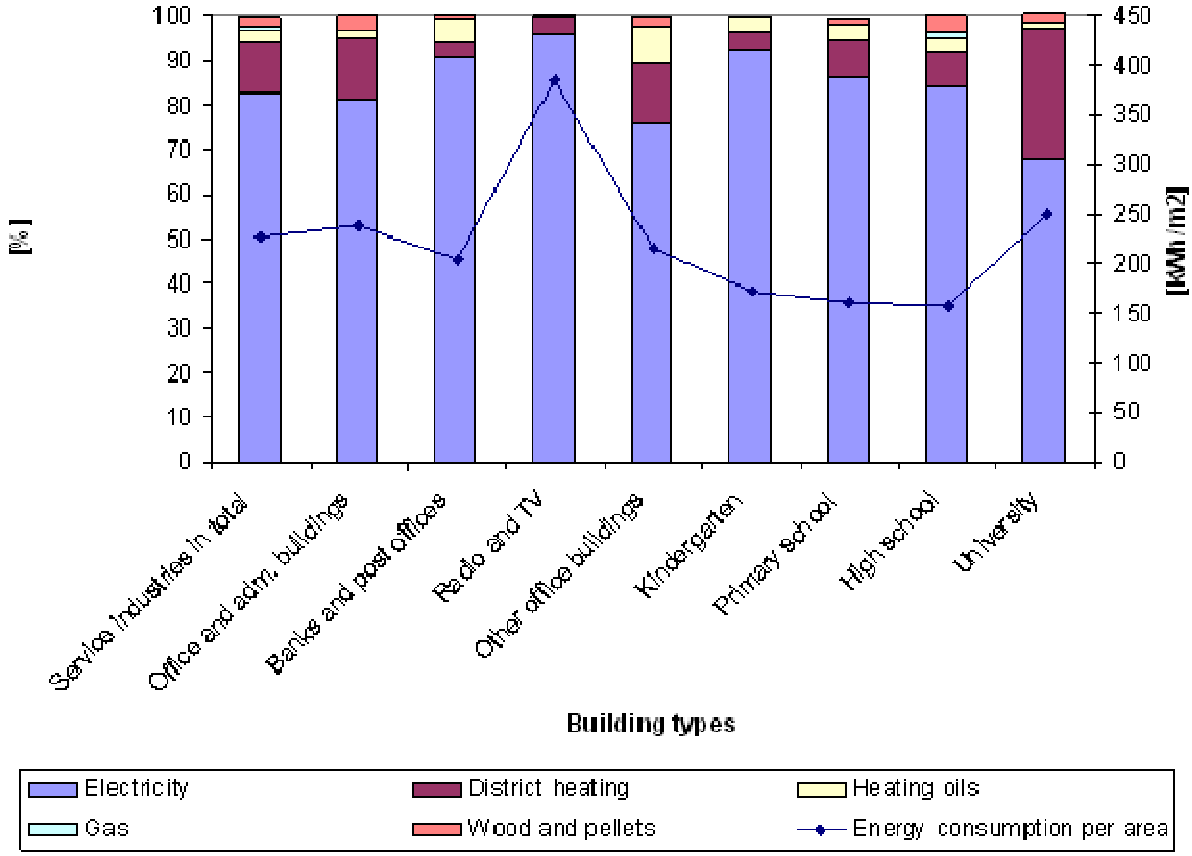


Figure 2.15 Energy consumption per area and divided per energy carrier in buildings in service industries. Preliminary figures 2008 [17]

2.2.3 "Model buildings" - Modellbyggprosjektet

In 1999 a measuring project was initiated by the Building operator (Byggoperatør) of NVE[4] to establish the energy end use in tertiary buildings [19]. The energy use in 26 buildings was measured from the autumn 2000 to the autumn 2001. The energy consumption was registered every hour in 12 months. The end-use categories were as described in the Norwegian Standard NS3032. Five different building types were analysed; children schools, nursery homes, university buildings, super markets and office buildings. The resulting end-use is presented in Table 2.16.

[4] In 2002 Enova took over the management of this Building operator.

Table 2.16 Energy end-use in non-residential buildings [19]

	Children schools	Nursery homes	Universities	Super markets	Offices
Number of buildings	7	4	4	3	8
Heat	51 %	23 %	24 %	7 %	30 %
Ventilation	19 %	30 %	15 %	12 %	18 %
Hot water	5 %	9 %	5 %	1 %	2 %
Pumps/fans	6 %	8 %	23 %	9 %	19 %
Lightning	10 %	22 %	19 %	13 %	13 %
Cooling	0 %	0 %	11 %	2 %	4 %
Misc.	9 %	9 %	4 %	57 %	14 %

The office buildings included in the project were:

- Drammensvn. 165
- Glommen Skogeier forening
- Grimstad Rådhus
- Nasjonalbiblioteket i Mo i Rana
- Norcontrol
- Næringsbygget Røstad
- Okkenhaugvn. 4
- Statoil Forus Vest

The cost of meters were approx. 100-200 000 NOK for each of the measuring projects, after trying to simplify as much as possible. One of the conclusions of the project is therefore that the benefit of expensive metering equipment has to be carefully evaluated before started. Typical metering simplifications are:

- Three-phase metering: in stead of metering all three phases during the entire measuring period, the phases were checked during a shorter time, and one or two of the phases were metered all the time
- The power of motors with fixed speed was metered a shorter time and the operational time was measured all the period.
- Typical lightning equipment was measured, not all lightning, and the operational time was measured all along.
- Some of the water-borne heating systems were measured by clamp-on ultra sonic meters and the difference in temperature (if the water flow was constant).

One of the objectives of the project was to evaluate the quality of the “Normtall” tool described in 2.2.1. Some of the conclusions were that calculated energy use of:

- heating differs too much from measured values (both higher and lower)
- ventilation in offices is too high compared to measured data
- hot water is higher than measured values
- fans and pumps are generally lower than measured values

2.2.4 Load Modelling of Buildings in Mixed Energy Distribution Systems

In [20] a method for load modelling of buildings in mixed energy distribution systems is presented[5]. The method estimates design of load profiles, yearly load profiles, load duration profiles and annual expected energy demand for a specified planning area, all divided into heat and electricity purposes. The heat load demand includes end-uses such as space heating, ventilation heating and hot tap water, while electricity load demand includes end-uses such as lighting, pumps, fans, and electrical appliances.

The models presented in [20] are based on meter data from the following building categories:

- Single family houses (SH) and Apartment blocks (AB) (Total: 91)
- Office buildings (OB) (7)
- Educational buildings (EB) (15)
- Hospital buildings (HB) (4)
- Hotels and restaurants (HR) (5)

The numbers in brackets represent the total number of buildings within each category. The letters in brackets represents the abbreviation used in this thesis.

In Figure 2.16 the monthly consumption pattern for both district heat and electricity for the specified office buildings for January to December (2005) are presented. The district heat consumption depends on seasonal variations such as climatic conditions, and the electricity consumption is rather constant throughout the year.

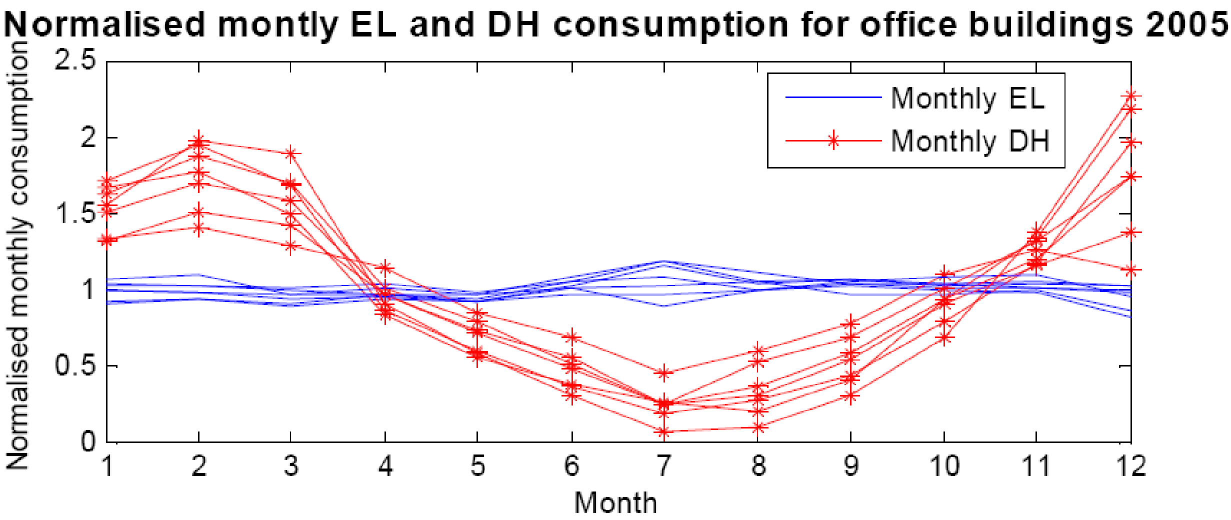


Figure 2.16 Normalised monthly district heat and electricity consumption patterns for selected office buildings from January to December 2005 [20]

[5] The method is presented in a doctoral thesis, prepared within the project "Sustainable Energy Distribution Systems" (SEDS)

The main focus in this study related to the method for load modelling was on load profiles for district heating and electric load. The load profile has not been further specified in detailed related to the electricity consumption for different electrical appliances.

The generalised load profiles for district heating and electricity consumption are presented in Figure 2.17 and Figure 2.18.

The main characteristics of the heat load profiles for office buildings are due to the operation of the ventilation system. The generalised design of heat load profiles for office buildings are presented in Figure 2.17.

The different office buildings included in the analysis had quite similar electricity load profiles and this was also closely related to the working hours.

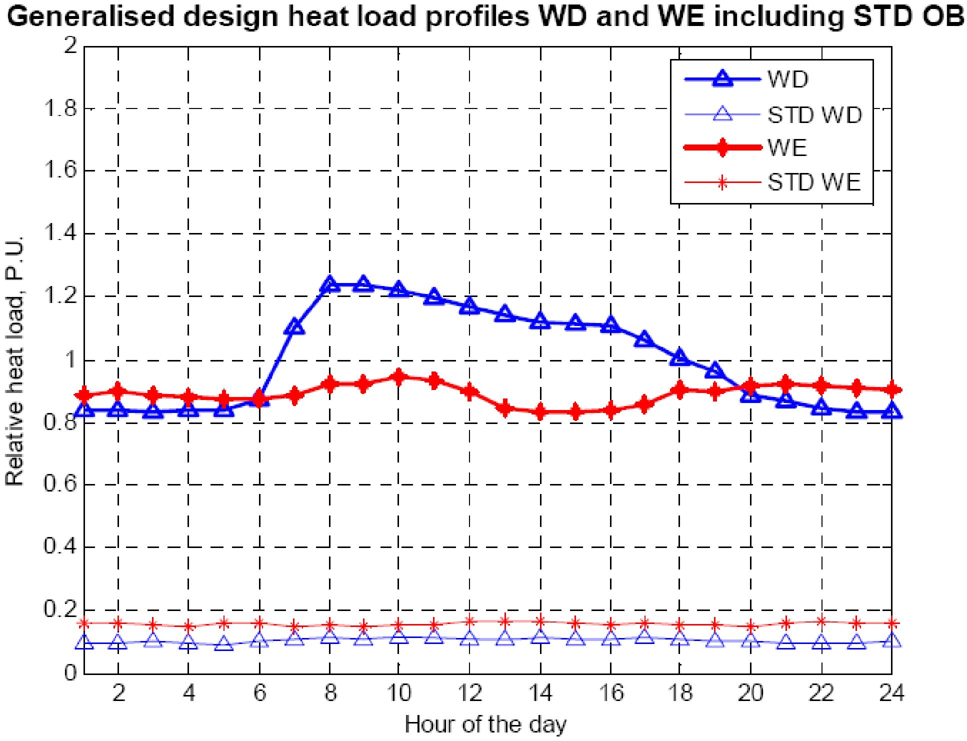


Figure 2.17 Generalised design heat load profiles for office buildings, weekdays and weekends [20]

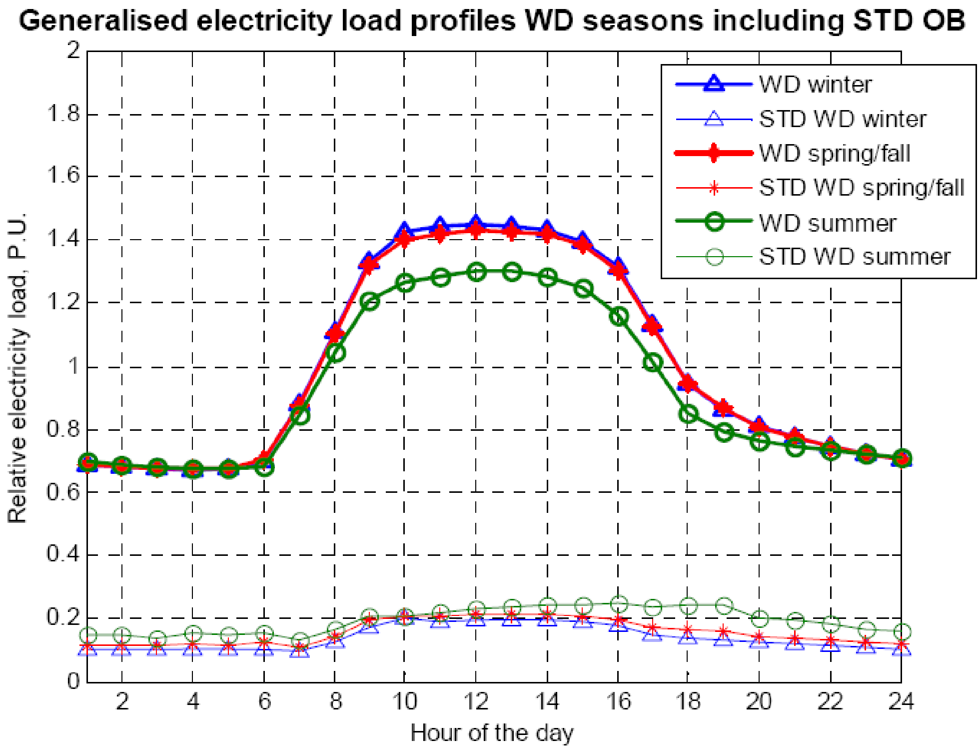


Figure 2.18 Generalised electricity load profiles for office buildings, weekdays, for all seasons, including standard deviation [20]

WD = Weekdays, WE = Weekends, STD = Standard Deviation

2.2.5 Sweden – Yearly energy statistics for non-residential premises

Energimyndigheten in Sweden presents a yearly statistic focusing on the energy consumption for the service industry [21]. This statistic contains information about energy consumption on a yearly basis. The objective of this statistics is to inform about heating sources, energy demand and area in non-residential premises. The results are based on surveys that Statistics Sweden (SCB)[6] performs on behalf of Energimyndigheten.

According to this statistics district heating has been the dominant energy source for heating since the beginning of 1980’s. In 2008 district heating was used in 68% of the buildings. Electricity was the second most common energy source for heating, but only 6% of the buildings used this. Heating with just use of oil gas been heavily reduced. The share of buildings heated with use of only oil has been reduced from approx. 50% in the beginning of 1980s to 2% in 2008 [21].

An illustration of the volume of building areas for each energy source in the period from 1976 to 2008 is presented in Figure 2.19. The numbers are in million square meters.

[6] SCB = Statistiska Centralbyrån, http://www.scb.se/

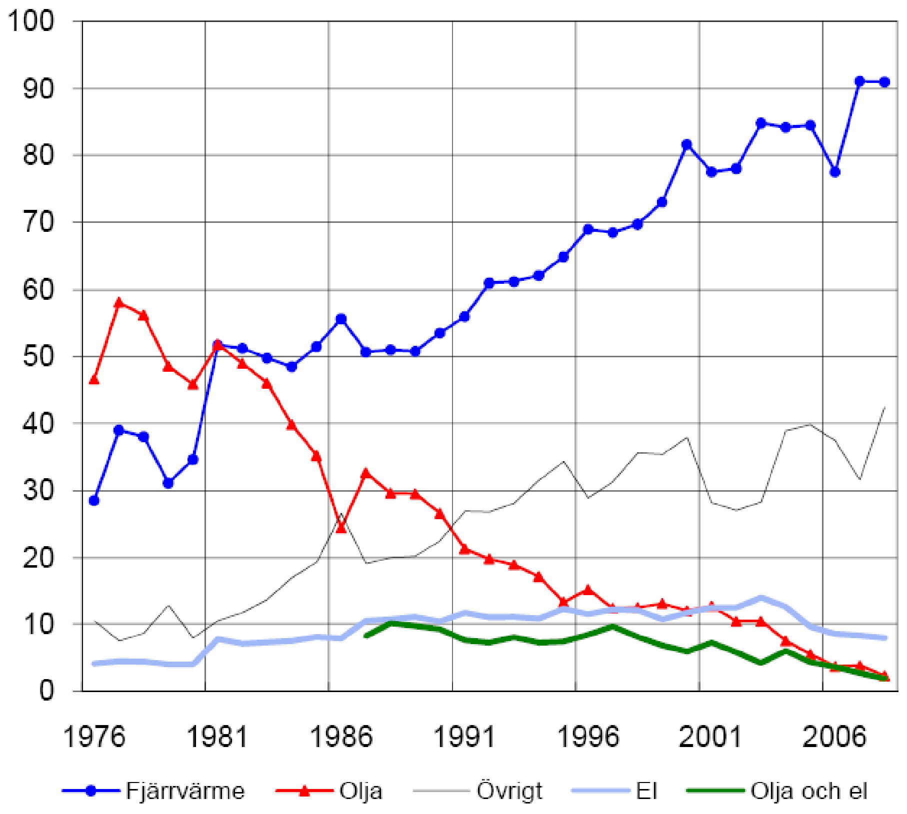


Figure 2.19 Building areas for each energy source, 1976 - 2008, mill. m2 [21][7]

2.2.6 Sweden - Energy statistics in office buildings (STIL2)

Energimyndigheten in Sweden is working for an improved national energy statistics for the different buildings. An improved energy statistics for 123 different office and administrative buildings is presented in [22]. The work is performed with the project "Stegvis STIL"[8]

The electricity consumption for different end-use is analysed, and specific electricity consumption is calculated with basis in the buildings area (BRA_t[9]). For this group of buildings, the average specific electricity consumption is 108 kWh_{el}/m^2.

The buildings included in the energy statistics had to fulfil the following criteria:

- The total area should be between 200 m^2 and 30 000 m^2.
- At least 80% of the building should be used as offices.
- The buildings included in the project should not deliver heat or electricity further to other buildings.
- One year of data related to existing installation and tenants should be available, incl. the energy consumption of the tenants.

[7] From 2007 and onwards the information is sorted per building and not per apartment. A consequence of this is that the share of composite heating system is reduced in the figure
[8] http://www.energimyndigheten.se/sv/Energifakta/Statistik/Forbattrad-energistatistik-i-bebyggelsen/Inventering-av-energianvandningen-i-lokaler-/
[9] BRA_t = Temperate available area

- The buildings should have a limited number of tenants with their own metering of electricity (max 12-15).
- The owner, the administrator and the manager of the buildings should contribute with necessary information.

In general, the consumption of energy differs a lot among the different buildings. Lighting and ventilation is the appliances that represents the largest consumption of electricity, with 37,5 % of the total electricity consumption. Computer/server room, PC-units and refrigerating machines represent a large share of the total electricity consumption.

For the office and administration buildings included in this analysis, businesses use 53% of the total electricity consumption and apartments use 47%. The specific electricity consumption for businesses and apartments are presented in Table 2.17.

Table 2.17 Specific electricity consumption per end-use [22]

Electricity consumption	**All buildings**			**Share [%]**
	Min. [kWh/m^2]	**Max. [kWh/m^2]**	**Average [kWh/m^2]**	
Lighting	6,6	53,3	23,0	21,2 %
Computer/server room	0,0	84,0	10,7	9,9 %
PC units	0,8	829,8	15,4	14,2 %
Other appliances	-	-	8,0	7,4 %
Printer	*0,0*	*6,6*	*1,1*	*1,1 %*
Copying machine	*0,0*	*7,8*	*1,6*	*1,5 %*
Compressed air	*0,0*	*5,3*	*0,4*	*0,4 %*
Kitchen/Canteen	*0,0*	*9,3*	*2,4*	*2,2 %*
Commercial kitchen	*0,0*	*18,4*	*0,7*	*0,6 %*
Washing equipment	*0,0*	*13,5*	*0,2*	*0,2 %*
Engine heater	*0,0*	*116,6*	*1,5*	*1,4 %*
Total offices	**-**	**-**	**57,0**	**52,7 %**
Ventilation	0,8	56,4	17,9	16,5 %
El heat and heat pumps	0,0	184,1	6,5	6,0 %
Other property-el.	-	-	9,5	8,8 %
Pumps	*0,0*	*39,2*	*5,5*	*5,1 %*
El. condensation cooler	*0,0*	*16,4*	*0,8*	*0,7 %*
Elevator	*0,0*	*6,0*	*0,7*	*0,6 %*
Circulation fan	*0,0*	*79,4*	*2,6*	*2,4 %*
Refrigerating machine	0,0	158,4	10,6	9,8 %
Total property –el.	**-**	**-**	**44,5**	**41,1 %**
Others	**-**	**-**	**6,8**	**6,2 %**
Total	**-**	**-**	**108,2**	**100,0 %**

The distribution of the electricity consumption on different electrical appliances for the buildings included in the analysis is presented in Figure 2.20.

Figure 2.21 shows the electricity consumption for different end-uses, when electricity used for heating purposes is excluded.

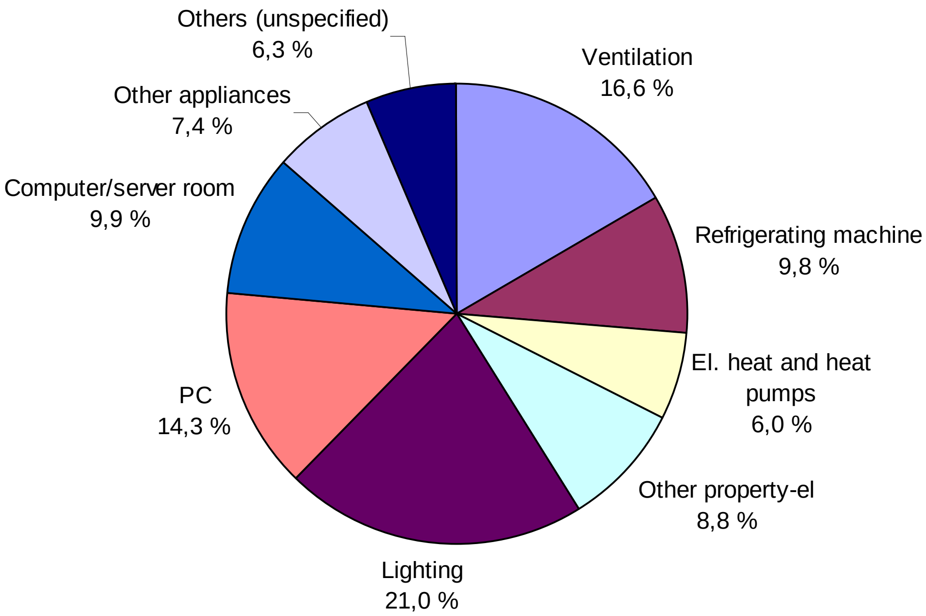


Figure 2.20 Specific electricity consumption for different end-uses [22]

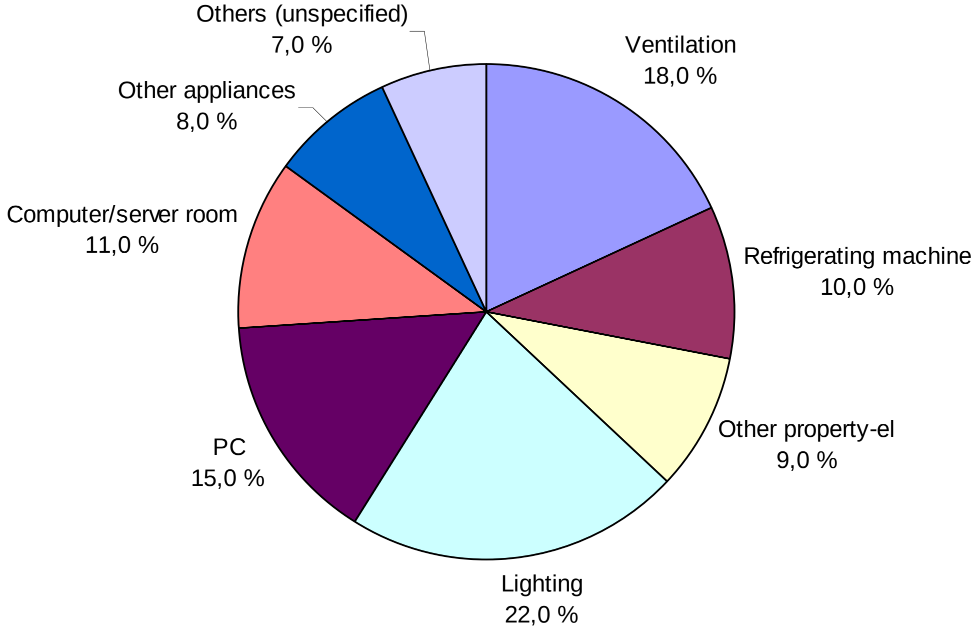


Figure 2.21 Specific electricity consumption for different end-uses, without electricity used for heating purposes [22]

2.2.7 IEE project - EL-TERTIARY

The Intelligent Energy Europe (IEE) project EL-TERTIARY was initiated in order to collect and evaluate existing data and to extend the knowledge concerning electricity consumption for various end-uses by metering and surveying technologies in selected case studies in 12 EU countries: Germany, France, Belgium, Netherlands, Greece, Italy, Portugal, Latvia, Czech Republic, Bulgaria, Romania, and Hungary. It was carried out in 2006-2008. A total of 123 buildings were measured/ analysed and the majority was office buildings (53). The end-uses were: lighting, air conditioning, ventilation, refrigeration, office equipment, motor systems (others than for heating, ventilation, etc.), hot water and electric heating. The project also included a review of existing studies and data of electricity consumption in the tertiary sector. The following description is from the project report [23].

EL-TERTIARY developed a methodology and a tool for collecting empirical data on the electricity consumption of tertiary buildings. The core of the methodology is a highly flexible database that allows the input of an unlimited number of buildings and building systems. It considers basic data such as floor area, climate zone, building type and state of different building parts as well as “operational data”, such as energy consumption and information on “systems”, i.e. the defined types of use: lighting, air conditioning, ventilation, office equipment, etc. There are options to describe the characteristics of the defined systems (location, power, time of use, etc. – adequate items for each type of system) and metering information (metering strategy, period, power, consumption, etc.). The method was placed and tested for 123 case studies during the project.

In most cases, the combined use of existing energy bills and on-site assessment of individual systems is a very effective way to evaluate the energy consumption of the buildings and to identify saving potentials. The audits can easily be complemented by short-term metering especially of non-dynamic systems like air handling units, office equipment, large pumps, etc.

The case studies showed that the metered data are only useful if the results can be evaluated on the basis of a good documentation of rooms, systems etc. Therefore the database created a set of mandatory general building data, like geometrical data, and optional information about the usage on the one hand and the different technical systems linked to the usage on the other.

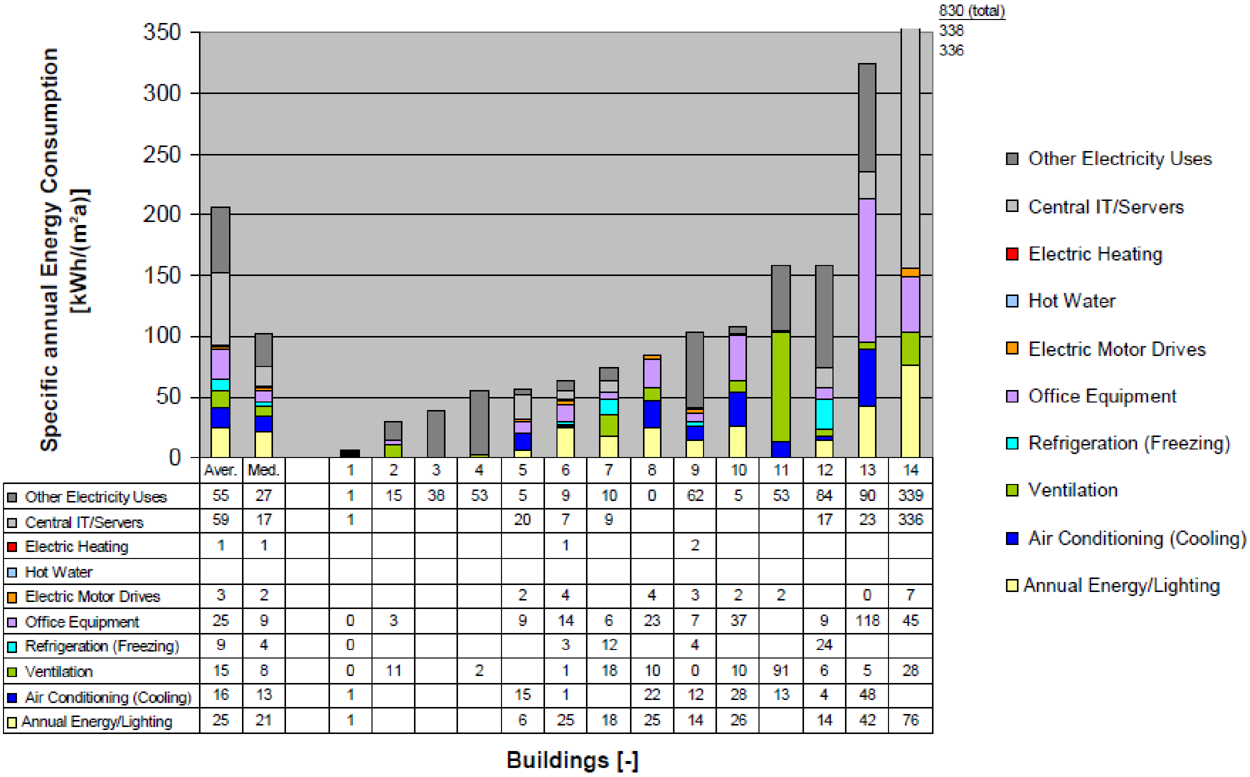
The “reports” represent one of the most important features of the programme. To create reports on building types or different systems or to get an overview of the database content, the tool uses an embedded reporting services application. The user can select the data to be shown for the chosen group of buildings like net floor area, annual consumption of electricity, etc.

Office buildings and schools are most frequent within the sample. Buildings from all the construction periods between "before 1918" and "after 1984" and various buildings sizes are represented. The specific annual electricity consumption per m^2 gives a first impression of the performance of a building. Installed power, operating hours and electricity consumption were analysed on a systems' level (lighting, ventilation, etc.) per type of room, e.g. lighting in classrooms in schools, ventilation in offices or cooling in supermarket salesrooms.

EL-TERTIARY used a methodology that distinguished between building audit (description of the building) and metering data. Buildings are described in a top down approach starting with general information on the whole building like owner, geometry, type, age etc. In addition all technical systems – lighting, ventilation, air conditioning/ cooling, motor drives etc. can be described very detailed. To buildings and all systems the auditor can add metering results. The database allows entering only absolute values (e.g. kWh) and no specific and thus calculated values (W/m²). For all metered values correlating absolute variables can be added (e.g. the supplied area, number of hotel beds). This is to avoid calculations by the auditor that can not be checked if not plausible.

The database contains information on 123 buildings from 12 European countries. Office buildings (53) and schools (38) were most frequent within the sample. Most of the buildings are located in the Central Atlantic (59) and Continental (41) climate zone. 54 buildings have been constructed after 1984, 17 before 1918. The sizes range from 23 buildings with less than 2.000 m² to three buildings with more than 50.000 m². Most buildings have a net floor area between 2.000 and 5.000 m² (30) or between 5.000 and 10.000 m² respectively (48).

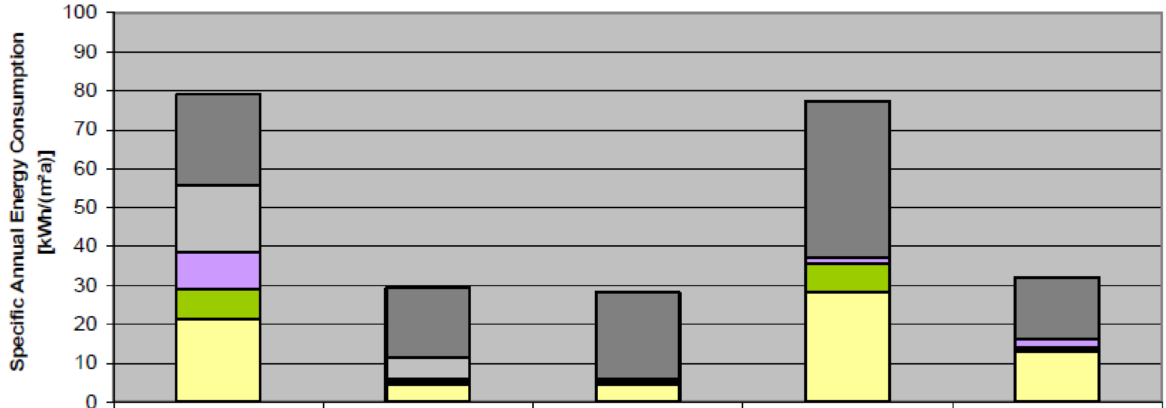
Figure 2.22 shows the composition of the electricity consumption in office buildings as a result of pilot actions in the countries involved. Apparently all partners had different opportunities to audit the buildings. In most buildings the lighting systems have been assessed whereas motor drives have been evaluated rarely. The buildings also show large differences for the systems.



	Aver.	Med.		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Other Electricity Uses	55	27		1	15	38	53	5	9	10	0	62	5	53	84	90	339
Central IT/Servers	59	17		1				20	7	9					17	23	336
Electric Heating	1	1							1			2					
Hot Water																	
Electric Motor Drives	3	2						2	4		4	3	2	2		0	7
Office Equipment	25	9		0	3			9	14	6	23	7	37		9	118	45
Refrigeration (Freezing)	9	4		0					3	12		4			24		
Ventilation	15	8		0	11		2		1	18	10	0	10	91	6	5	28
Air Conditioning (Cooling)	16	13		1				15	1		22	12	28	13	4	48	
Annual Energy/Lighting	25	21		1				6	25	18	25	14	26		14	42	76

Figure 2.22 Composition of electricity consumption of office buildings [23]

The added median is 102 $kWh_E/(m^2a)$ and the total median is 79 $kWh_E/(m^2a)$. The difference indicates the incomplete and heterogeneous results in some parts. Nevertheless the results show plausible values for the total consumption compared to the median value of 85 kWh$_E$/(m^{2}a) for all evaluated office buildings.



	Office	School	Retail	Hotel	Hospital
Number of Buildings	14	12	2	4	2
Other	23,2	17,9	22,3	40,4	15,7
Central IT	17,3	5,6	0,0	0,0	0,0
Office equipment	9,3	0,8	0,8	1,3	2,5
Ventilation	7,9	0,3	0,4	7,4	0,8
Lighting	21,3	4,8	4,8	28,2	13,1

Building Types

Figure 2.23 Mean composition of energy consumption in buildings [23]

Both different building types and different systems were studied. The detailed data for lighting and ventilation systems are the largest. The complete results of the metering campaign can be downloaded using the reporting services of the EL-TERTIARY tool: http://el-tertiary.ed-bs.de.

Analysis of existing studies

The analysis of existing studies and data of electricity consumption in the tertiary sector was the basis of the construction of the database. Not all case studies include all types of systems, some rather concentrated on certain electricity consumers such as air-conditioning, ventilation or lighting. However for many of the buildings analysed it was possible to establish an electricity balance for the whole building. The average electricity balance of 35 office buildings is shown in Figure 2.24.

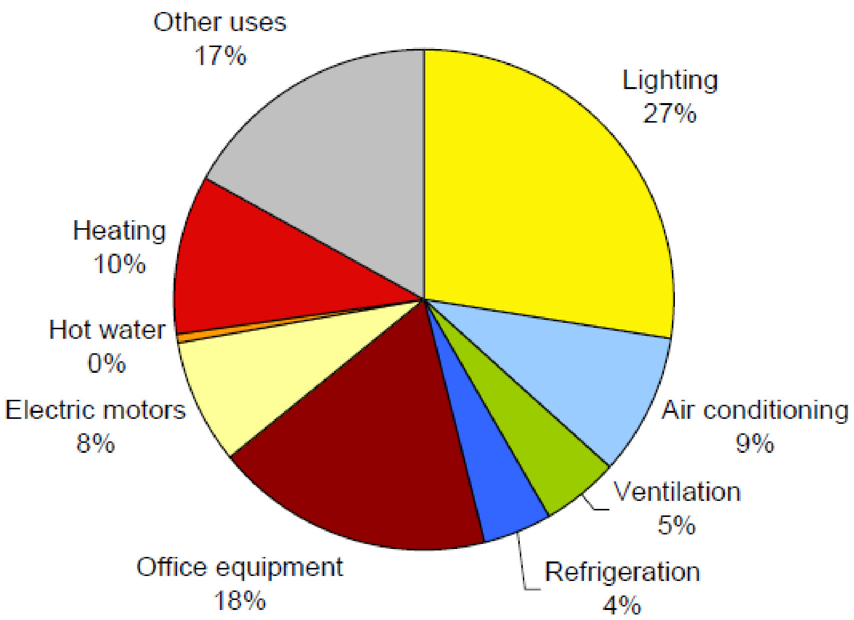


Figure 2.24 Electricity consumption per end-use in offices [23]

The data reveal a very heterogeneous picture concerning the methodology used, the number of cases involved and the split level of end-uses. Some studies present the results of individual building audits, others calculate extrapolations for a whole sub-sector on a national level covering many thousands of buildings. Figure 2.25 shows the methods of determining the different types of electricity end-uses.

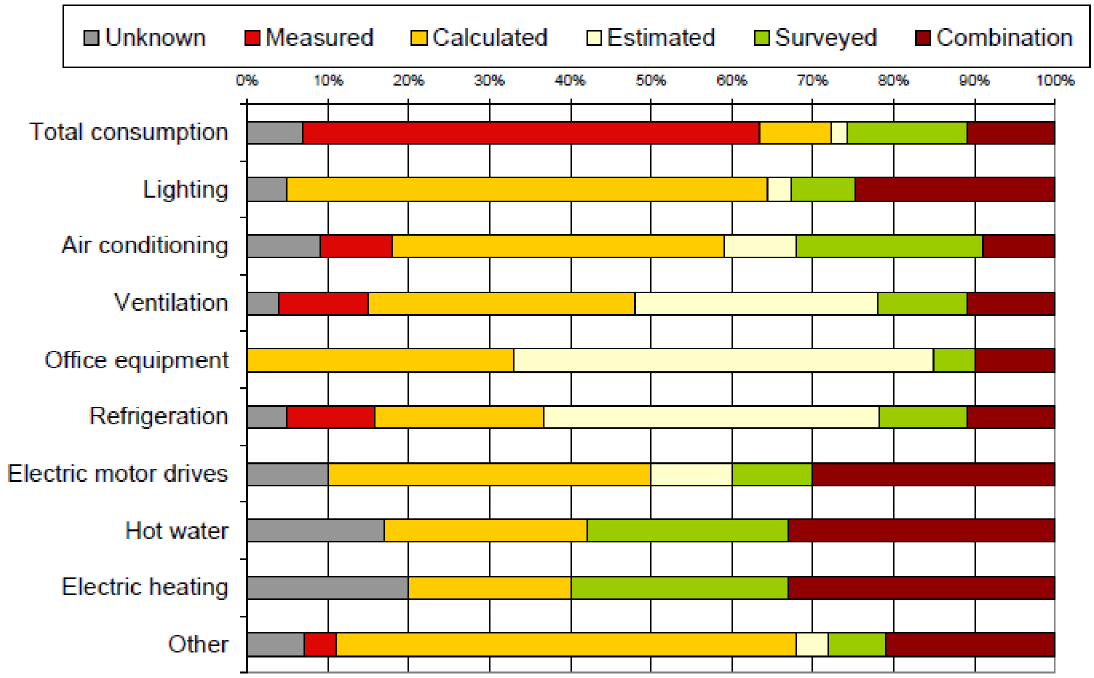


Figure 2.25 Methods of determining the different types of electricity end-uses [23]

Figure 2.26 presents the share of different end-uses in several countries based on the review of existing studies of EL-Tertiary [24].

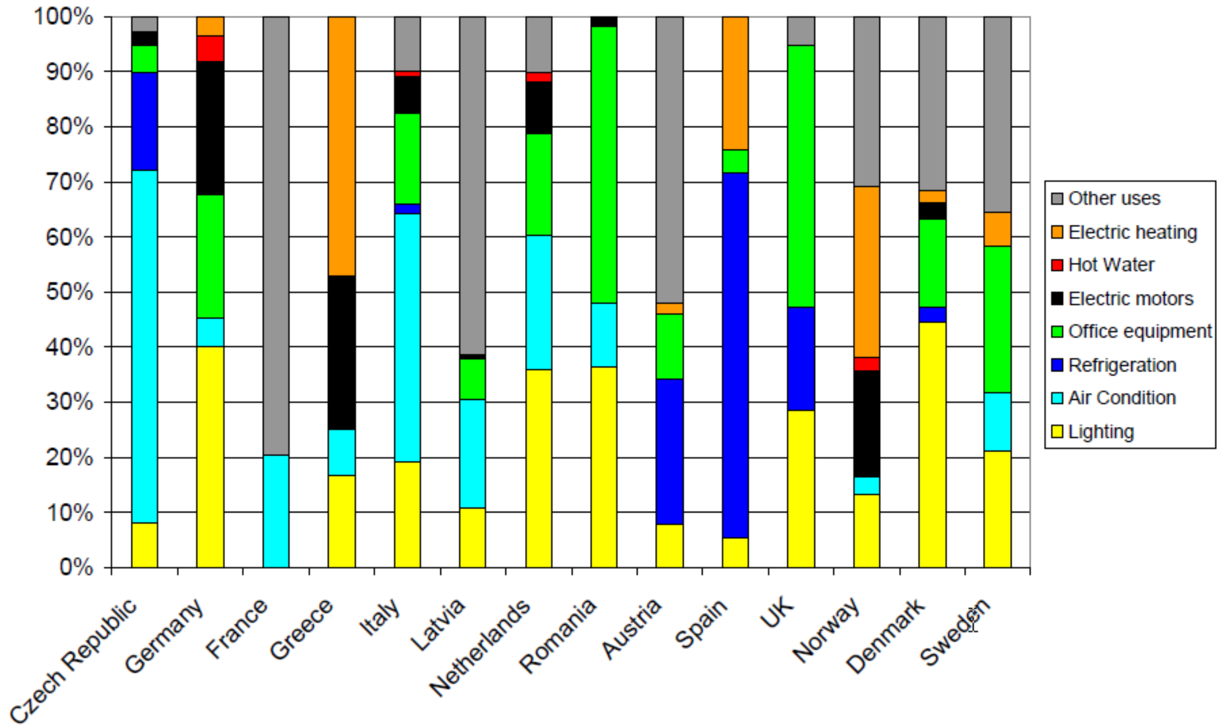


Figure 2.26 Specific electricity consumption in office buildings split in end-uses [24]

Some measuring recommendations from the EL-TERTIARY project are presented in Appendix 3.

2.2.8 Summary – Non residential buildings

Relevant projects focusing on the electricity consumption for different end-use demand at non residential buildings (mainly office buildings) are presented in chapter 2.2. The different projects are using different methodologies, and a summary of these are presented in this sub chapter.

Table 2.18 Projects evaluated for non residential buildings

Project	Description of work	Strength	Weakness
Calculation of energy end-use (Enøk Normtall) (Chp. 2.2.1)	Guide for the energy and power consumption in different building types. Information about end-use demand.	• Recommendations based on measurements • Energy specified in kWh/m2 • 9 building types, 3 levels and 7 zones of climate	• No load profile
Energy use in buildings within the service industry (Chp. 2.2.2)	Statistic of energy consumption for different types of buildings within the service industry.	• Moderate costs for data acquisition • Large sample possible	• No load profile
Model buildings (Chp. 2.2.3)	Measurement of energy consumption in 26 buildings (5 building types). Metering of end-use demand for one year.	• Measurements performed at different building types	• Expensive data acquisition due to measurements • Time consuming • Limited size of sample for each building type
Load Modelling of Buildings in Mixed Energy Distribution Systems (Chp. 2.2.4)	Measurement of total electricity consumption for 5 building types (7 office buildings).	• Models for different building types	• Limited size of sample for each building type • Energy consumption only divided into heat and electrical purposes. Not loads.
Yearly energy statistics for non-residential premises (Chp. 2.2.5)	Statistic of energy consumption for different types of buildings within the service industry.	• Moderate costs for data acquisition • Large sample possible	• No load profile
Energy statistics – STIL2 (Sweden) (Chp. 2.2.6)	Measurement of end-use demand at 123 different office and administrative buildings	• Measurement per end-use	• Expensive data acquisition due to measurements • Time consuming
EL-TERTIARY (Chp. 2.2.7)	Measurement of end-use demand at 123 buildings in 12 countries (53 office buildings). Top-down methodology.	• Measurements performed in several countries	• Expensive data acquisition due to measurements • Time consuming

2.3 DISCUSSION OF DIFFERENT METHODS FOR ESTIMATING ELECTRICITY END-USE DEMAND

Based on the literature review, the following aspects will be of relevance for the ElDeK project:

- The metering period has in most cases been 2-4 weeks.
- There is a large variation in the electricity consumption for appliances with high consumption, such as washing machines, tumble dryers and water heaters.
- “Other equipment” varies a lot, both in energy use and in appliances included and it would be useful to get a better knowledge of this.
- The list of appliances in Table 2.11 can be used as a classification of appliances in households.
- The differences between non residential buildings are larger than for households, and it is more difficult to find common features for the buildings.
- The range of use for the different buildings has a great influence on the energy consumption (Operating time, installed equipment, etc.)

3 DATA AVAILABILITY AND THE EXTENT OF HOURLY SMART METERING

The state of the art and principle for metering of total electricity consumption and metering of end-use demand are described in this chapter. The description is focusing on the principle for metering – without describing details about available technology.

Metering of energy consumption is important to get information about actual consumption, and also as inputs regarding what to focus on in attempts to change the consumption pattern and reduce the consumption of energy and power. Metering itself does not reduce the energy consumption or changes the consumption pattern, but it may be an "enabler" for implementing energy efficiency and/or demand response.

3.1 SHORT INTRODUCTION TO THE NORWEGIAN POWER MARKET

In the Norwegian deregulated power system where the Distribution System Operator (DSO) and the power supplier are two separate actors. This implies that all customers have separate tariffs for the energy and the use of the power network. The design of the network tariff is strictly governed by the monopoly regulation. The energy contract is based on a contract between the power supplier/retailer and the customer.

The main actors related to the power system are presented in Figure 3.1, grouped as monopoly actors and market participants.

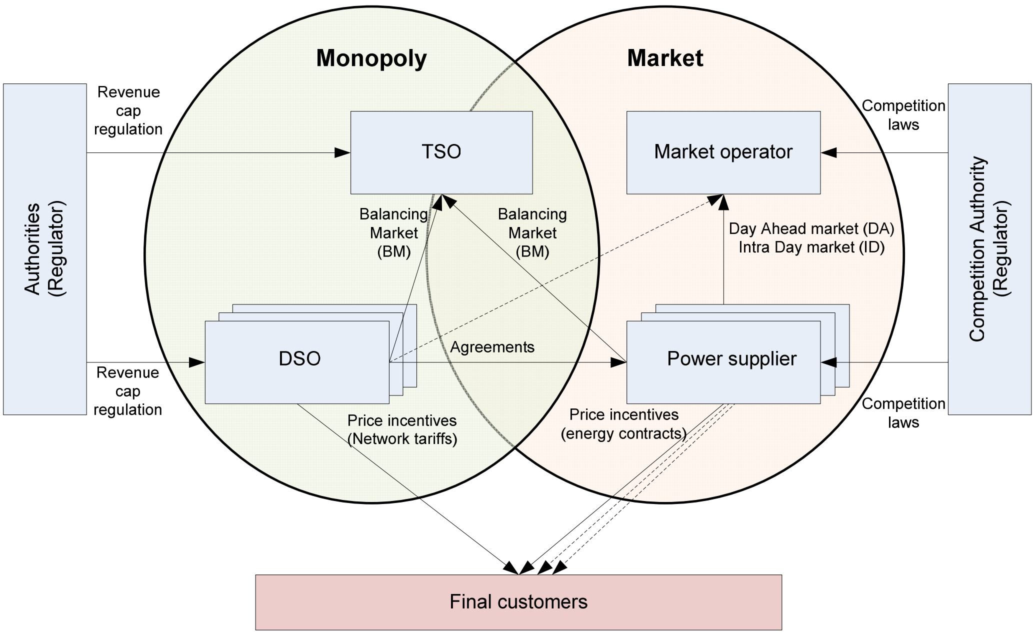


Figure 3.1 Monopoly actors and market players

For the Transmission System Operator (TSO) there is an overlap between these roles, because the TSO is under monopoly regulation, and also has a role as the organizer of the Balancing Market (BM). The market operator (NordPool) is the organizer of the Day Ahead (DA) and the Intra Day (ID) market.

The figure also indicates the network tariff and the energy contract that the final customers receive from the monopoly side and from the market side, respectively. The customers are free to choose power supplier, and they can change the power supplier weekly. The DSO is hence the only actor that has a permanent relationship with the final customers.

3.2 SMART METERING

3.2.1 Implementation status

Due to technological innovation and cost cutting through market liberalisation, different smart metering systems have been implemented in the past few years. In July 2009 Sweden completed a full roll-out of smart meters to all their (residential) customers. In many other countries, pilot projects and public consultations concerning smart metering are on the agenda [25].

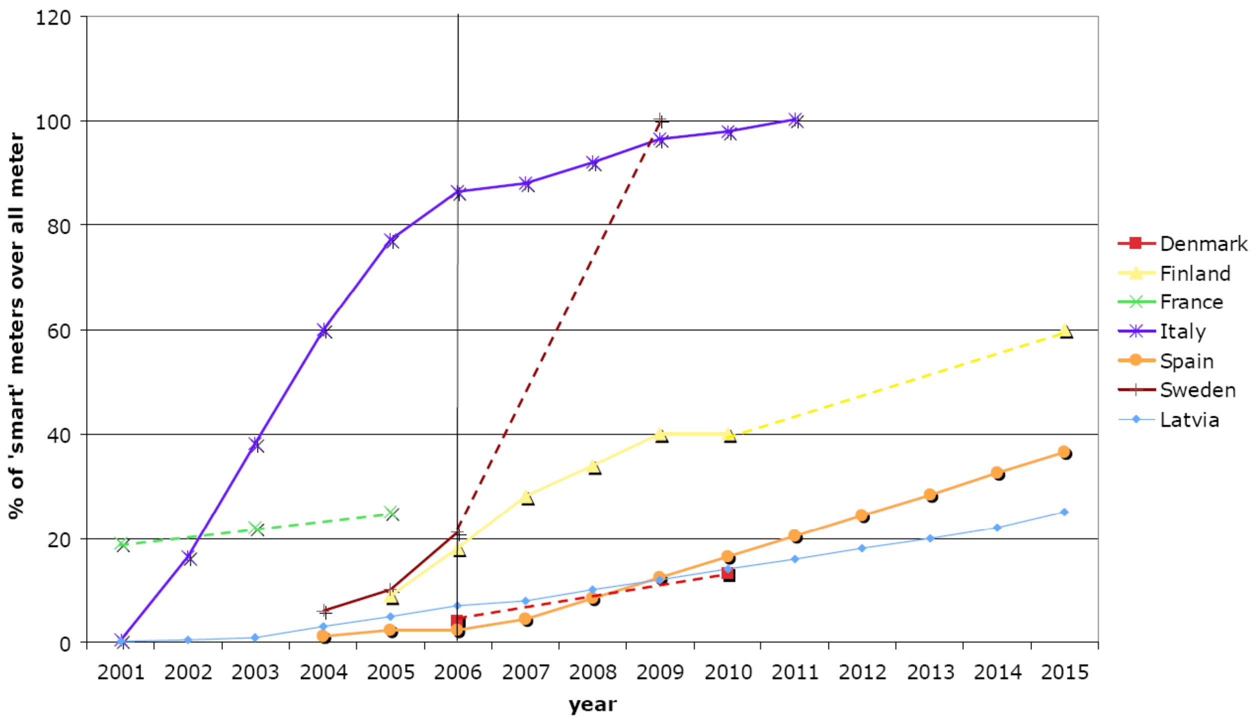


Figure 3.2 Smart meters installation: Expected evolution in the electricity sector [25]

The main reasons for this metering innovation differ among the countries, but one common incentive is the introduction of the EU-directive 2006/32/EC [26] on energy end-use efficiency and energy services (ESD), that in Article 13 requires that customers should get an informative energy bill, based on their actual consumption. The objective of this requirement is to increase the customers' consciousness regarding energy use, and smart metering is possible the only solution to achieve this.

Another incentive is the introduction of the EU-directive 2005/89/EC [27] concerning measures to safeguard security of electricity supply and infrastructure investment, that in Article 5 requires that Member States within EU shall take appropriate measures to maintain a balance between the demand for electricity and the availability of generation capacity.

Additionally, the introduction of the binding targets for EU for 2020 to among others to reduce the greenhouse gas emissions by 20%, ensure 20% of renewable energy sources in the EU energy mix and reduce the EU global primary energy use by 20% [28], have increased the focus on smart metering.

In April 2009 the European Parliament voted to support the rollout of smart metering within the European Union. The Electricity Directive foresees full deployment by 2022 at the latest, with 80% of consumers equipped with smart metering systems by 2020 [29].

The new regulations in Norway concerning Automatic Meter Reading (AMR)/Smart metering, will also increase the focus on the benefits and area of application for this technology. One topic is which functionalities the DSOs have to implement to their customers, but another important topic is which **additional functionalities** the DSOs should implement for example to reduce management costs or to fulfil other requirements from the authorities.

Several actors such as customers, DSOs, Power suppliers etc. may benefit from the implementation of smart metering technology but these benefits are not always easy to quantify.

Examples of benefits for DSOs concerning management of distribution systems are, [25]:

- *Remote connections and disconnections.* There is no need for visiting the customer premises. In addition it may also be possible to limit the amount of electricity that the customer can use ("electrical fuse").
- *Faster fault location and faster reconnection after outages.* Meter data used as a basis for locating faults can contribute to a more efficiently operation of the network.
- *More accurate calculation of network losses and reactive power.* Smart metering will give more information about the consumption in the network, and therefore contribute to a more correct metering and make it easier to identify problem areas with high electrical losses.
- *More accurate monitoring of continuity of supply and voltage quality.* An increased amount of data based on smart metering automatically transferred to the DSO will increase the number of available measures of power quality.

3.2.2 Prevailing regulations regarding metering

The prevailing Norwegian requirements regarding metering and settlement of the electricity consumption are specified in the regulations [30]. The DSO is responsible for all the meter values from metering points in his power network (§3-2).

The requirements regarding metering of the electricity consumption differ according to the *consumption volume* in each metering point. The following requirements are specified in [30]:

- All metering points should be metered at least yearly.
- Household customers with a yearly consumption larger than 8.000 kWh shall be metered periodically 12, 6 or 4 times per year. The time between the readings should be approximately equal. One of the meterings should be performed at the turn of the year.
- All energy input (production) to the power network shall have hourly metering.
- Metering point with a yearly consumption larger than 100.000 kWh shall have hourly metering of their consumption.

The requirement for hourly metering of the consumption for customers with a yearly consumption larger than 100.000 kWh implies that about 4% of a total of 2.5 million metering points in Norway have hourly metering [31]. Over 60% of the total yearly consumption in Norway (approx. 125 TWh/year) has hourly metering.

In 2005/2006 a survey was performed to find the status concerning technology for AMR/Smart metering. This work was performed within the research project “Market Based Demand Response”[10] (MBDR). According to this survey 10 DSOs had performed full-scale establishment of AMR, and 18 DSOs were planning to do this [32].

For small customers (< 100.000 kWh/year) the AMR technology was mainly used for reading the meters on a weekly or monthly basis. This metering frequency was principally chosen due to requirements in the regulations regarding change of power suppliers and periodical settlement of the consumption [32].

3.2.3 Process towards large-scale smart metering in Norway

A discussion document concerning changes in the regulations for metering and settlement was published in the autumn 2008 [33]. The changes were planned to come into force 1. January 2014. In [33] it was among other things mentioned that it should be possible to connect external equipment to the AMR-system, but it was not specified what kind of equipment this should be – not the communication capacity nor the communication speed.

Due to a lot of responses in the first public hearing the discussion document in 2008 was followed up by an additional hearing document [34].

[10] http://www.energy.sintef.no/prosjekt/mabfot/

The suggested new regulation (§3-11) concerning smart metering was as follows [34]:

"The DSO shall install technology for smart metering in every metering point. The metering system shall among other things contribute with data necessary to accomplish change of power supplier and for settlement of network services.

All meter value shall:

a) *be registered and stored in the metering point until they are transferred to the central system at the DSO.*
b) *be stored with a registration frequency of maximum 60 minutes, and*
c) *be transferred to the DSO at least once a week.*

The metering system shall also:

a) *be able to store data with a registration frequency of 15 minutes,*
b) *make it possible to collect meter values instantaneous on request from the DSO,*
c) *with one second accuracy register the time of and the duration of all instances when the voltage is under 50% of the nominal value, and data shall be transferred from the customer to the DSO,*
d) *be able to connect and communicate with external equipment, where the communication and the interfaces are based on open and non-proprietor standards,*
e) *be able to register and store data at the customer site, in case of power outages,*
f) *be able to prevent misuse of data and that the system prevents unwanted access to the systems both locally and centrally.*

If the customer claims it, the DSO shall install metering system for registration of local production. The customer shall cover the extra costs related to this.

Metering points with a yearly consumption less than 1000 kWh can be excepted from the requirements for smart metering.

The DSO shall free of charge offer the customer information about their own consumption. The information shall be available via internet. A third-party can with authority from the customer, free of charge get access to settlement data from the DSO."

After the second hearing round, the final decision regarding full-scale implementation of smart metering in Norway was postponed. The reason for this postponement was that international standards were described as an important prerequisite to secure a real competition between service vendors, vendors of metering technology and communication equipment and between other vendors of different software systems, and that European standards within this area were expected to be available at the earliest during the first half-year of 2010 [35].

According to a letter dated 2. July 2010 NVE expect that a decision regarding new regulations can be taken during first six months of 2011, and that full-scale deployment of smart metering can be completed within 1.1.2018 [36].

3.2.4 Possible functionality regarding smart metering

In relation to the prospective large-scale implementation of smart metering in Norway, a requirement specification is under development [37]. The final version will be available when final requirements from the Authorities are presented. This requirement specification is developed in cooperation between SINTEF Energy Research, EnergiAkademiet (prev. EBL Kompetanse) and the seven largest DSOs in Norway. The requirement specification is focusing on *functionality*.

The requirement specification contains requirements that can be included in the negotiation for smart metering technology – but at the end it is each DSO that decides themselves which functionalities they want to include in their smart metering technology, as long as the requirements from the Regulator are fulfilled. The document will be available for all interested parties, such as DSOs, power suppliers and vendors.

In the preliminary version of this report the meter value chain for smart metering is described, as illustrated in Figure 3.3. The blue boxes are the main elements in the meter value chain. The other boxes are additional equipments/software systems.

The meter value chain starts at the meter point at the customer site. A meter node consisting of both a meter and a meter terminal (can be integrated or in two separate parts), is connected to the meter point. Registered data in the meter terminal is transmitted to the central system at the DSO, via the communication system.

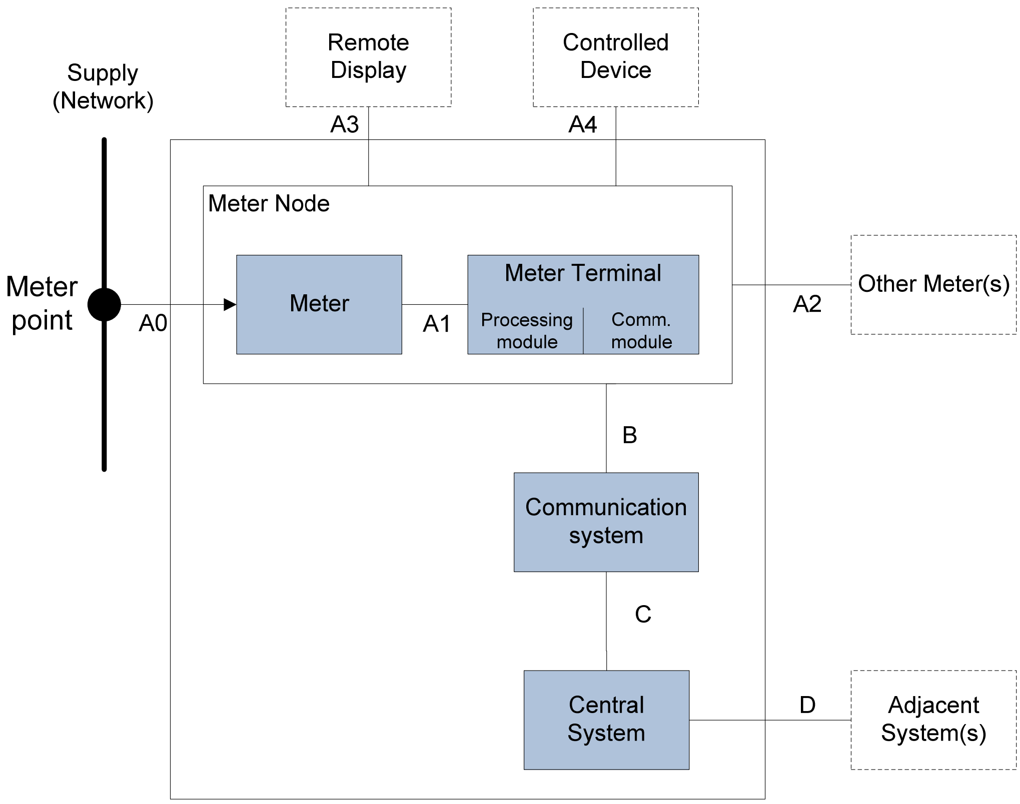


Figure 3.3 Meter value chain for smart metering [37]

The main elements in this meter value chain are related to metering of the electricity. Other meters for metering of the consumption of other energy carriers such as water, gas and district heat, can also be implemented. The same communication system and central system can be used.

In the additional hearing document concerning smart metering it was suggested that it should be possible to connect external equipment to the metering system, and the metering system should be able to communicate with external equipment. The communication and the interfaces should be based on open and non-proprietor standards [34]. In Figure 3.3 this is illustrated with the boxes with dotted lines for “Remote display” and “Controlled Device”.

External equipment
As illustrated in Figure 3.3 external equipment such as remote display and controlled device can be connected to the smart metering system.

External equipments can be:

- Display - showing customers information about their actual electricity consumption. This can be performed in real time[11].
- Control system – for optimisation of the electricity consumption to reduce the consumption volume and/or the cost of electricity[12].
- Different sensors – for different alarms or to reduce the energy consumption (sensors for temperature, presence, burglary, fire, water leakage, etc.)

What to meter
In the requirement specification for full-scale implementation of smart metering [37], it is specified that the meter shall register energy and power in all 4 quadrants. This means that the meter should be able to both meter active and reactive consumption and production of electricity. This is illustrated in Figure 3.4.

[11] Dependent on the chosen technology, the information can be presented in costs or energy/power, and the information can be based on the total consumption for the household, the consumption for a specific appliance or the consumption connected to a specific electric cable from the fuse box.
[12] The electricity consumption can for example be controlled via reduced temperature in defined periods (day/night), dependent on whether persons are present or not (absence-button), or load shifting based on price signals from the power market (dependent on the energy contract for the customer).

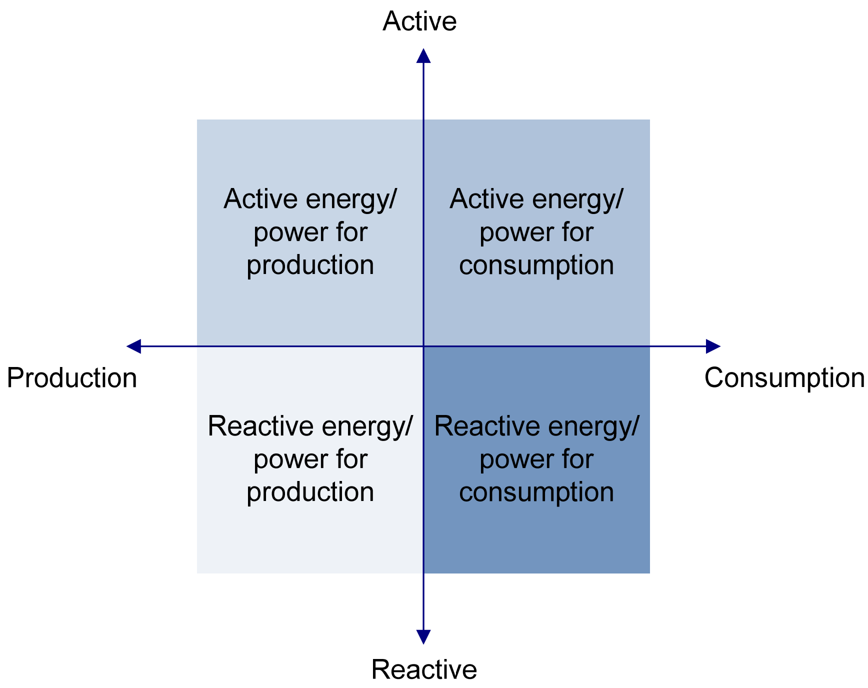


Figure 3.4 Metering of energy and power in 4 quadrants

By including the requirement for metering in all 4 quadrants, this will be an extension of today's requirement for metering. Today, a meter with the possibility for metering in all 4 quadrants will be a more expensive meter than a "standard" meter for just metering of the energy consumption. This new requirement is included in the specification because it is expected that the amount of decentralised power production will increase and if all the DSOs include this requirement, the new "standard" meter will have this new functionality at limited (or zero) increase in cost.

3.3 METERING OF END-USE DEMAND

Metering of end-use demand require more metering equipments than metering of the total electricity consumption for a customer, and for some metering systems a metering equipment has to be installed at every appliance that use electricity. Metering of end-use demand is both time consuming and costly, and is not common in daily life. It has mainly been used in research projects – with a limited number of customers.

Type of metering results
Metering of electricity consumption can either be performed by summing up the total energy consumption for a period, or the consumption can be registered with a defined time resolution. With the second alternative, the metering results in time series with the consumption per point in time (for example every 1., 5., 15. or 60. minutes).

Possibility for remote reading
Remote reading of the metering equipment is a benefit, since data can be taken home every night and data is maximum lost for a day in case of equipment fails [38]. This is especially a benefit for

long campaigns. If there is not a possibility for remote reading, it is recommended that the metering equipment has enough internal storage for the whole metering period.

Time resolution
The time resolution chosen for the metering period should be evaluated based on available technology, available storage capacity in the metering equipment (in case of no remote reading), the duration of the metering period and how the metering data will be analysed afterwards.

3.3.1 Methods for metering of end-use demand

There exists different methods for metering of end-use demand, and possible strengths and weakness for a selection of these are presented in Table 3.1.

Table 3.1 Evaluation of different methods for metering of end-use demand

Metering method	Strength	Weakness
Plug for *energy* metering[1]	• Simple technology. • Can be installed by the user.	• Require plug on the electrical appliances. • The size of the plug can limit the number of appliances to be metered on (if a socket is worked out for more than one appliance). • Can only meter energy consumption over a period.
Plug for *power* metering and with a central unit for storage of information[1]	• Time series with meter data. • Simple technology • Can be installed by user.	• Require plug on the electrical appliances. • The size of the plug can limit the number of appliances to be metered on (if a socket is worked out for more than one appliance).
Current clamp	• Inexpensive.	• The clamp needs access to a single wire (the wires to the appliance has to be split).
On/off-counters	• Can be used on electrical installations without plug. • Inexpensive.	• Can only be used on lamps with equal consumption every time it is turned on. (Not lamps with a dimmer). • One metering point per power switch is required.
Logger in fuse terminal box	• Only one metering equipment.	• Require space in the fuse terminal box. • Usually has to be installed by an electrician. • Only the consumption at single electrical wires is metered. Not end-use metering.
Non-intrusive[2]	• Only one metering equipment.	• Expensive. • Not commercial available.

[1] To be placed between socket on the wall and the plug of the electrical appliance.
[2] Non-intrusive metering method is one metering equipment that registers active and reactive power and transients for the whole building. Signatures of the different electrical appliances are used to detect the consumption for different appliances.

4 ANALYSING METER DATA

The USELOAD-software will be used for analysing meter data within the ElDeK project. With USELOAD it is possible to combine meter data with results from surveys. This makes it possible for segmentation of the meter data when analysing them, and analysing the end-use demand for different categories of building types, family size etc.

Since it is not realistic to measure the end-use demand at all the Norwegian customers, stratification is used to make the results valid for defined groups of customers.

The methods and tools for analysing meter data are presented in this chapter.

4.1 STRATIFICATION

In statistics, stratified sampling is a method of sampling from a population.

When sub-populations vary considerably, it is advantageous to sample each subpopulation (stratum) independently. Stratification is the process of grouping members of the population into relatively homogeneous subgroups before sampling. The strata should be mutually exclusive: every element in the population must be assigned to only one stratum. The strata should also be collectively exhaustive: no population element can be excluded. Then random or systematic sampling is applied within each stratum. This often improves the representativeness of the sample by reducing sampling error. It can produce a weighted mean that has less variability than the arithmetic mean of a simple random sample of the population.

Stratified sampling strategies:

1. ***Proportionate allocation*** uses a sampling fraction in each of the strata that is proportional to that of the total population. If the population consists of 60% in the male stratum and 40% in the female stratum, then the relative size of the two samples (three males, two females) should reflect this proportion.
2. ***Optimum allocation*** (or Disproportionate allocation) - Each stratum is proportionate to the standard deviation of the distribution of the variable. Larger samples are taken in the strata with the greatest variability to generate the least possible sampling variance.

A real-world example of using stratified sampling would be for a US political survey. If the respondents needed to reflect the diversity of the population of the United States, the researcher would specifically seek to include participants of various minority groups such as race or religion, based on their proportionality to the total population as mentioned above. A stratified survey could thus claim to be more representative of the US population than a survey of simple random sampling or systematic sampling.

Similarly, if population density varies greatly within a region, stratified sampling will ensure that estimates can be made with equal accuracy in different parts of the region, and that comparisons of sub-regions can be made with equal statistical power. For example, in Ontario a survey taken throughout the province might use a larger sampling fraction in the less populated north, since the disparity in population between north and south is so great that a sampling fraction based on the provincial sample as a whole might result in the collection of only a handful of data from the north.

Randomized stratification can also be used to improve population representativeness in a study.

4.2 USELOAD

The objective of the USELOAD-software [39] is to model the electricity market consisting of various customer types. By simulating the behaviour of all customer types that are participating in the market, it is possible to estimate the total demand of electricity for each interval of a time period. The demand from each customer type is segmented into different end-uses that are modelled in a way similar to the customer types. The simulated market load is segmented into different customer types, or different end-uses.

USELOAD sports a user friendly interface, and stores data in an attached database. Various Windows screens are used to display information, and allow the user to start simulations, and edit input data. Result Graphs and formatted tables are automatically produced to allow for a wide spectre of interesting results. User friendly command buttons, radio buttons, combo boxes are used to ease the use of the tool.

4.2.1 Time step

In USELOAD the time step in use differs dependent on what is metered. The normal time step regarding “total” load of a household (the sum of all loads in the building) time series in USELOAD is one hour. The reason that one hour is selected for total load is that normally the DSO uses one hour as the time steps for AMR systems. The AMR data from DSO is the only source of total load metering data in Norway. The total load of a building consist of energy demand from a lot of different equipment, and it is not possible to figure out which equipment is in use during one hour – unless you have other data that tracks information on when a particular piece of equipment is in use. But the pattern of the total load still gives a lot of interesting information, as temperature dependency of the load, and how the load varies during the day, during the week, and from season to season.

For end-use metering a time step of less than one hour is selected. The reason for the better time step for end-use metering is that the researcher is in charge of the metering for end-use, and the cost of increased sampling of data is low, when the metering equipment is installed. Of course more granulated time-steps gives more data to take care of, and to analyse, but the cost of this extra procedures and work is quite low compared to the gains.

The gains of 1 minute time steps as used in Norway (REMODECE, chapter 2.1.1) is that it is possible to not only determine the energy demand of the metered equipment, but also the power demand example: It is possible to find the standby consumption[13]. By using certain rules when scanning the time series of one minute, standby periods can be found: The power consumption is not zero, and is less than 20 watts, and also is less than 10% of the full power use.

It is also possible to track the energy use of washing machines and dishwashers: Find the start of the "use": the equipment leaves the standby-mode – then determine when the equipment re-enters standby. By finding the energy demand per use of such appliances, it is possible to find the number of uses of the washing/dish washer machine of the week, which is crucial to remove serious errors of the analysis. In a project where the end-use demand for different electrical appliances were calculated (See chapter 2.1.2), Statistics Norway (SSB) [2] found that the normal energy demand of washing machines was 2026 kWh[14]. Based on meterings showing that washing machines uses ca 1 kWh per wash, SSB's value means that the normal use of washing machines is 5.5 times a day in average. In the REMODECE project it was determined that the normal use of washing machines is 209 kWh per year. The REMODECE values show that the washing machine is used ca 4 times a week in average. Information about the energy demand per use is necessary to make this conclusion.

4.2.2 Use of profiles

In USELOAD, the user can allocate all days of the year to certain day types. Each day type is connected to a load profile that defines the variation of load from hour to hour. The definition of the day types is described by the user and can define e.g. Mondays up to Fridays to be treated separately from Saturdays and Sundays (weekends). The program can also handle moveable holidays such as Easter.

Definition of types of seasons for all months over the year is also handled in the USELOAD-program. The season- and day- types describe which tariff period should be applied to the day in question. Typically a customer will respond according to the price signal from the tariff, and will have a separate load response for each tariff period or season. The seasons are defined by allocating each month to a user-defined set of seasons.

4.2.3 Methods for Modelling - Analysis of time series

Time series analysis in USELOAD can be divided into tree steps: The first step is to estimate expected values and standard deviations for each single customer during each season, day type and interval. The second step is to estimate the expected values and standard deviation for the sum (delivery) node, e.g. the node that delivers power to the selected customers. The third step is to estimate values for the equivalent single customer by dividing the expected demand for the sum

[13] Standby consumption = energy and power demand when the equipment is not in use, and "switched off"
[14] In the weighted selection presented in Figure 2.2 the electricity consumption for a washing machine was calculated to 1906 kWh/year. (Based on an ownership rate of 94%.)

node by the number of customers. The standard deviation for the equivalent single customer is found by dividing the standard deviation for the sum node by the square of the number of customers.

This estimation is performed using a statistical method called convolution. The method used is based on the assumption that the loads of the customers are normally distributed and independent. The metered load from the selected single customers can come from different time periods and /or have different climate. Use the analyse parameters form to select the time period for which data should be used: All data or before or after a given date. You can also specify the level of quality of data to be used:

- No check
- Day demand > 0
- Every interval > 0
- Peak value less than a specified value

USELOAD will collect the load for each of the selected single customers or end-uses. Thereafter the program will perform a regression analysis on the data along with temperature data from the same time period. If temperature data are not available, the temperature will be assumed to be equal for each day. The regression analysis will yield expected and standard deviations for each single customer. These values will be combined by using standard statistical methods to give standard deviation and expected values for equivalent single customers – customer type profiles.

The resulting customer type profiles will be stored for each interval under each season type, day type and temperature band. The profiles will consist of expected values (B) [kW], temperature sensitivity (A) [kW/Centigrade] and standard deviation (S) [kW] per customer.

4.2.4 Combining survey data with metered data

From surveys it is possible to obtain information that should be combined with the results from the analysis of metered data.

Ownership

When end-use energy demand estimations are performed it is necessary to know the ownership of each equipment that should be a part of the analysis. Some appliances as “lighting” is owned by all households, in fact households in Norway in average have 33 light bulbs. Other appliances are owned by fewer households, as Microwave ovens – is on average owned by 10 % of the households. During analysis the energy demand of an appliance will be multiplied with the ownership level of the appliance for typical households in Norway – to find the average energy demand of this appliance. The average energy demand of Microwave ovens will then be quite low, since few people own such equipment.

Types of customers

The time series of energy demand of an appliance that is metered at some customer are used during the analysis. Dependent on the type of customer, the energy demand will be different: young people will use their PC in a different way than older people, although both strata might own PC's. Young people tend to use their PC more actively, and the PC's are more often switched on. So it is clear that the equipment should be metered at different customer types. In the REMODECE project the customers were divided into 3 strata: Retired person, Families with children, Single inhabitants. When the equipment was metered at a household, it was noted from which category or strata the household belonged to.

Survey

When doing surveys, the questionnaires must contain information that defines which type of household the person that answers the questions belongs to. The most interesting information to be found in surveys - learned from the REMODECE project – is the ownership of different types of equipment. In REMODECE it was also useful with answers regarding lighting: how many lamps are actually used (not only installed) in different types of rooms, and also how many hours the lights were switched on dependent on room type.

4.2.5 Stochastic modelling of customer load

Customers' energy demand is clearly stochastic values since it is rather impossible to exactly predict the load at all times. Instead the demand from customers is modelled as normally distributed values with a defined expected value and a standard deviation for a given interval over the day. The distribution will differ depending upon season, day-type and out-door temperature. Additionally, one can have separate definitions of customer demand for e.g. high-temperature and low temperature ranges. This method makes it possible to model customer types that have increased energy demand at low-temperature due to space heating, and also have air conditioning installations that generally start to work at high outdoor temperature levels.

USELOAD estimates the expected power demand for each time (60, 30 or 15 minutes) interval during a historical year of a given distribution grid. In addition to computing the demand, USELOAD estimates the distribution of the resistance losses of the grid. Resistance loss calculations are based on the assumption that resistance losses are proportionate to the square of the load.

The model simulates the behaviour of the customers, and consequently the grid that they are connected to, for each time interval over a historical year. Furthermore USELOAD computes annual coincident peak demand and peak demand responsibilities for each customer type that are served by the grid. The peak demand responsibility expresses the typical share of coincident peak demand measured at the customer site that will be a part of the peak demand measured at the feeding point of the network owner.

5 METERING CRITERIA FOR THE ELDEK PROJECT

The metering criteria for the ElDeK project are specified in this chapter. The main focus here is on household customers, but the metering criteria may also be relevant for office buildings. The description below is focusing on the metering technology – and criteria for metering at household customers.

In the analysis of the meter data, the information will be segmented based on extra information regarding for example technological, physiological and demographical data. This extra data will be collected via questionnaires.

5.1 CHALLENGES

The following challenges are related to the measurements of the electricity consumption for end-use demands:

- The measurements should be performed at a **sufficient number** of metering objects from a **significant selection.**
- The metering period should be of a **sufficient length**.
- The metering objects should be based on a **random sample**.
- The electricity consumption should **not be affected** by the fact that metering is performed.

5.2 SELECTION OF HOUSEHOLD CUSTOMERS

The metering of end-use demand will be performed at household customers located in different geographical area in Norway. The **main criteria** that have to be fulfilled before metering can be started, is that *the customers accept to have the metering technology installed and that hourly metering of the total consumption is possible*.

Additional requirements for selecting household customers for participating in the project are that the metering should be performed at household customers with

- building types such as single family house, row house, semi-detached house or apartments.
- a yearly electricity consumption between 6 000 kWh and 40 000 kWh.
- a “normal” electricity consumption. (Customers without swimming pool and/or outdoor heater cable.)

5.3 METERING REQUIREMENTS

The ElDeK project will be founded on meter data, results and experiences from the REMODECE project. A lot of the measurements in the REMODECE project were performed during the winter. The ElDeK project will therefore try to spread the measurements more in time.

The following requirements are set for measurement of the consumption at household customers:

- The measurements should be **spread in time** (during a year).
- The measurements period should be **(2-)4 weeks** for each customer.
- The measurements should be performed at **5-10 electrical appliances** per households (dependent on metering technology available and electrical appliances with electrical plug).
- The measurement of end-use demand should be performed at **customers with possibility for hourly metering of their total electricity consumption**. The period for hourly metering of the consumption should be of at least 1 year.
- **Metering of end-use demand** will be performed with a time resolution of **1 minute**[15]. 1 minute metering interval is used to make it possible to analyse the consumption per use for the different electrical appliances, such as washing machine, electric cooker etc. The meter data for end-use demand is further aggregated to hourly values.

If possible, measurements can be performed several times at the same household, but this depends on accept from the customer.

Demographical and sociological data from the customers will be collected via questionnaires.

5.4 AVAILABLE METERING TECHNOLOGY

Metering technology provided in relation to the REMODECE project will be used in this project. Metering of end-use demand will be performed at customers that have installed technology for hourly metering[16] of their electricity consumption.

Available metering technology is:

- 124 Power Detective for metering of electricity consumption for appliances with an "ordinary" electric plug (Figure 5.1)
- 6 Power Detective for metering of electricity consumption at electric cooker (Figure 5.2)
- 16 centrals for collecting meter data

The metering technology available has not the possibility for remote reading. The meter data is stored on a memory chip located in the central. The duration of the metering period is therefore dependent on the storage capacity of the memory chip. The amount of data will increase, and the duration of metering period will decrease with an increasing metering frequency and increasing number of registration units. In a previous test the memory chip had a capacity to store registered values every 1. minutes for 2 metering points in a period of 12 months.

The registered data is stored in excel as ".csv"-files, with one file per day.

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[15] 1 minute time resolution is the same metering frequency as used in the Norwegian part of the REMODECE project.
[16] Higher time resolution can be considered used if installed AMR technology has the possibility for this.

Pictures of available metering technology are presented in Figure 5.1 and Figure 5.2.

Figure 5.1 Power Detective - plug for metering of end-use demand

Figure 5.2 Power Detective - plug for metering of end-use demand for an electric cooker

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APPENDIX 1

ABBREVIATIONS

AHU	Air Handling Units
AMR	Automatic Meter Reading
BM	Balancing Market
CDA	Conditional Demand Analysis
CRT	Cathode Ray Tube
DA	Day-Ahead market
DSM	Demand Side Management
DSO	Distribution System Operator
ElDeK	Electricity Demand Knowledge
ERÅD	EnergiRÅDgivning
ESD	Energy end-use efficiency and energy services Directive
ID	Intra Day market
KMB	Competence Building Project (In Norwegian: Kompetanseprosjekt Med Brukermedvirkning)
LCD	Liquid Crystal Display
MBDR	Market Based Demand Response
SCB	Statistics Sweden (In Swedish: Statistiska Centralbyrån. www.scb.se)
SSB	Statistics Norway (In Norwegian: Statistisk SentralByrå. www.ssb.no)
TSO	Transmission System Operator

APPENDIX 2

NORDIC PRE-STUDY – AVAILABILITY OF DATA IN NORDIC COUNTRIES

Source: [14]

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

The codes 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 colour 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

APPENDIX 3

EL-TERTIARY – MEASURING RECOMMENDATIONS

The project suggests focusing an audit on the data that can be acquired fast and accurately. The variable effects especially of use and operation should be evaluated in separate studies such as on the influence of motion sensors for lighting or the installation of pumps with frequency converters. Always do the documentation first and metering second. Good documentation of a system provides more information than imprecise metering. The metering strategy should always be applied, which provides the best quality, but also the best cost-efficiency in terms of time and cost spent on the metering procedure.

- Long-term metering for dynamic systems (e.g. cooling)
- Short-term metering for cyclic systems (e.g. lighting, ventilation)
- Spot-metering for continuous or on/off systems (e.g. office equipment)

Lighting systems
In many cases, metering lighting systems was impossible due to complicated electric circuits. Often the systems were mixed with office equipment and other consumers. Sometimes it helped to install the metering, turn all lights off and read out the electrical demand. Than all lights have been turned on and the demand has been read out again to derive the difference as power in operation. To meter the operation hours in some cases light detecting metering devices have been applied directly to lamps. Metering of about a week delivered good results.

Different appliances
The huge variety of different appliances like personal computers (PCs), laptops, printers, fax machines, coffee makers, electrical kettles and so on makes it impossible to measure the complete electricity consumption of all devices. Single devices though can usually be measured with plug-in meters. A metering period of one week including work- and weekdays is sufficient. Before a metering is implemented, the auditor should note the number and type of appliances and additional features to reduce their energy consumption, e.g. timers, sleeping mode, manual shut off etc. This can be combined with standard values for operation hours.

Cooling systems
The biggest challenge to evaluate cooling systems is to determine the actual use or supplied rooms and functions. Cooling is often supplied by central systems with chillers and then distributed to different uses e.g. chilled beams, ventilation systems for offices or forced-air cooling for server rooms. Therefore, the overall description of the systems is first priority. Since the consumption of cooling machines depends strongly on the weather conditions it is recommended to carry out a long term metering of cooling systems. If this is not possible, short term metering with different weather conditions (peak demand on hot, sunny and humid days / cloudy days with moderate or low temperatures) should be carried out.

Ventilation
The general assessment of ventilation systems also proved to be fairly simple describing the system and its parts. The main problem at ventilation systems is that it is difficult to find out information about the exact size of the supplied area and the actual volume rate. When the system is older and the plans are lost it is nearly impossible to get reliable information. However for air handling units (AHU) the actual operation is crucial for the performance. Therefore it is usually

necessary to carry out at least a short term metering. In most cases the systems work with constant power (at least regarding the accuracy desired in audits) or on discreet levels which can be turned on for metering. The metering of the sub-circuit on switchboards proved to be very convenient since it can be installed and subsequently allow the metering of different AHUs by turning them on and off or from one level to another and noting the differences in power.

Surveys

Two types of guidelines for gathering data using surveys were developed; one detailed (1 day) and a shorter one (1 hour). The results show that surveys are supplementary to metering approaches.

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