E F F L O C O M

Energy efficiency and load curve impacts of commercial development in competitive markets

EU/SAVE 132/2001

Phase 1 – Basis for Demand Response

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VTT	Partner 3	Finland
Energy Piano	Partner 4	Denmark
EDF	Partner 5	France
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*) Withdrawn from the project by 31 July 2003

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Summary

Load analysis related to demand response (load management) planning purposes has been performed. The analyses include total system as well as customer category hourly load profiles from six countries: Denmark, Finland, France, Norway, Sweden and UK (which throughout this report refers to England and Wales). For France and UK, customer category load profiles were unavailable.

Similarities and differences in the total load patterns are explained. Customer category load profiles have been used to produce hourly customer segmentations of the total load for most countries during the year 2001 (when most countries had deregulated the electricity market).

Mean day temperatures for each country have been used to perform temperature sensitivity analysis. The database that holds all collected data is available at the project web site: www.efflocom.com (password protected).

Load drivers as climate, season, day types (weekend/workday), price signals, hourly variation and building type (by customer) have been mapped to better quantify country specific potentials for load management and energy efficiency.

Investigation of the loads shows the following broad relationships:

- Temperature sensitivity
  All countries have quite high temperature sensitivities during spring and autumn, being the result of electric space heating. Some countries shows positive temperature sensitivities during summer – a result of cooling and air conditioning.
- Seasonal characteristics
  For all countries the consumption is higher during winter than the other seasons. This can be explained by use of electric space heating and use of lighting during cold and dark seasons. France and UK that have moderate temperatures during winter also show a much higher demand during colder seasons due to less restricted building codes, and fewer requirements for insulation standards of buildings.
- Day types
  All countries show a big difference in the day profiles for working days compared to weekends. This is natural since industry is partly shutting down activity during weekends.
- Hourly patterns during day
  All countries show reduction in the load during nights. All countries have two high activity periods during working days, one in the morning and one during evening. UK is special where the evening peak is much higher than the morning peak, the evening peak must be the result of domestic activity in this country - the use of TOU tariffs could be a reason for the high evening peak.

A large potential for demand response/load management is found for all countries:

- Reduction of peak load is possible for most countries due to the high activity of the domestic sector during the winter peaks. Automatic switching off of loads as water heaters and space heating would yield a more even peak load profile, and a lower peak.
- The load from the Industry sector represents the most interesting objects for demand response and power reserves
- The load duration curves for all countries show that 5 % peak load reduction could be achieved by concentrated demand response efforts in 20-75 hours.

- Countries that allow and promote space heating have low load factors – these countries could reduce the peak loads if the utilities and public authorities opposed space heating by promoting other sources for heating, and by promoting better insulation of buildings. (Building standards).

- Countries that make use of special tariffs as TOU tariffs show peak load profiles that are more even. Finland is a good example having the highest load factors of all countries investigated. In Finland customers mostly use central heating, and can accumulate heat during night at low prices. Denmark shows the greatest difference between night and day consumption during winter - Denmark has heavily promoted district heating and use of natural gas the later years, and customers can easier close down their electric consumption during nights.

Peak load reduction in one Nordic country gains the whole region.

- A study of the peak demand in the Nordic countries (Denmark, Finland, Norway and Sweden) shows a high degree of coincidence between the annual peaks of the individual countries. This means that the potential for demand response found by segmentation of the load curve for each country can be added in order to estimate the potential of load reduction in whole region.

1 Aims of EFFLOCOM Phase 1

Electricity demand varies from moment to moment, and the cost of meeting this demand can vary by time of day as well as season. In order to provide efficient and cost effective electricity supply it is required to understand the factors affecting this demand pattern. It is also necessary to acquire ability to influence the demand pattern to one that more closely matches the characteristics of the means of electricity production.

Electricity demand is the result of the customers needs and depend on season, type of day, time of day and other factors as the weather and country specific factors. Measurements of an individual user's electricity demand shows that some predictable patterns occur, but with a high level of variation.

Measurements of a larger population show that groups of customers tend to require similar and predictable load profiles. Wider analyses of other variables, for example climate and economic factors show the level of influence of these variables and enable a prediction of future demand to be made.

The load analysis includes load profiles from six countries: Denmark, Finland, France, Norway, Sweden and UK (which throughout this report refers to England and Wales). The requirements related to demand response (load management) planning purposes is focused.

Available load profiles are used in a load curve estimation model USELOAD for load analysis and segmentation into customer types, and types of end use. The USELOAD model is described in the Appendix.

Phase 1 includes the following results:

- Status of the national load curves for the six participating countries, revealing the potential for load management and energy efficiency in the countries. Due to strong electrical connections between the countries, the electricity market is (partly) international and all potentials for flexible demand are elements of the market. The differences in load patterns between countries depend on different customer mix and different customer behaviour.
- Weather and temperature influence. Customer behaviour depends on different climate, on different technical systems and on different ways of using these systems, or in a few words different "load drivers". Customer behaviour will be discussed in terms of category wise typical load profiles and their dependence on the load drivers.
- Daily load curve segmentation in relation to estimates of customer categories with possibilities for use of demand response offers.

Phase 1 form the strategic platform for the rest of EFFLOCOM including estimating the impacts of market opening, improved communications, use of advanced load control and energy efficiency measures.

2 Data requirements for demand response planning

In order to perform demand response analysis and planning a number of data are required. Table 2.1 lists the data that are available and used in the work for the six countries participating in phase 1 of EFFLOCOM.

	Denmark	Finland	France	Norway	Sweden	UK
Yearly system load curve	Yes	Yes	Yes	Yes	Yes	Yes
Yearly temperature per day	Yes	Yes	Yes	Yes	Yes	Yes
Main sector yearly load curves	Yes	Yes	No	Yes	Yes	No
Customer category yearly load curves	28 categories	7 categories	0	7 categories	48 categories	0
Yearly elec. sale per customer category	Yes	Yes	Yes (Data not available)	Yes	Yes	Yes (Data not available)
Yearly end use load curves	Domestic appliances	No	Yes (Data not available)	Load profiles of 10 end uses.	Street light, heating, refrigerators, freezers,	Yes (Data not available)

Table 2.1 Data requirements for demand response analysis and planning.

Denmark

- System load, System temperatures and sales statistics are available for several years.
- 28 Customer category curves are based on metering since 1991 in the Danish project 'Elforbrugspanel' including around 1200 metering points representing all types of customers.
- Main sector yearly load curves are based upon segmentation of the total load curve by USELOAD.
- All load recordings are with 15-minute integration period.
- End use data (in Denmark end use data are recorded for 100 households in 1999/2000). Data not available for this project.

Finland

- System load, System temperatures and sales statistics are available for several years
- Main sector yearly load curves are based upon segmentation of the total load curve by USELOAD and customer category wise typical load curves
- Customer category wise load curves are used by VTT to make customer segmentations for the peak days available for this project.
- End use data not available

France

- System load, System temperatures and sales statistics are available for several years
- Main sector yearly load curves are based upon segmentation of the total load curve by USELOAD and customer wise category typical load curves
- Customer category load profiles exist, but are not available for this project.
- End use load profiles exist, but are not available for this project.

Norway

- System load, System temperatures and sales statistics are available for several years
- Main sector yearly load curves are based upon segmentation of the total load curve by USELOAD and customer wise category typical load curves
- Customer category wise yearly load curves are based upon simulations of the annual load curve by USELOAD and customer wise category typical load curves
- Customer wise typical load curves are based on metering (60-minute integration period) during ca 1 year per customer and a sample of ca 20-3000 customers during the last 30 years. In Norway no panel exist, and metered load is collected through various project activity addressing special types of customers. This means that the load profiles for some customer groups are of low quality; e.g. heavy industry, social buildings, office buildings. For the residential sector the quality of the load profiles is good.
- End use load profiles exist, but have not been used for this project.

Sweden

- System load, System temperatures and sales statistics are available for several years
- Main sector yearly load curves are based upon segmentation of the total load curve by USELOAD and customer wise category typical load curves
- Customer category wise yearly load curves are based upon simulations of the annual load curve by USELOAD and customer wise category typical load curves
- Customer wise typical load curves are based on metering (15-minute integration period) during 1 year per customer and a sample of 500 customers during 1985-1987. This means that those curves are rather old.
- End use load profiles are estimated based on external conditions i.e. sunrise and sunset and temperature dependence, but these data have not been used.

UK

- System load, System temperatures and sales statistics are all available for several years
- Main sector yearly load curves are based upon segmentation of the total load curve by USELOAD and customer wise category typical load curves
- Customer load profiles exist, but are not available for this project.
- End use load curves exist, but are not available for this project.

3 Demand of energy and power in 6 European countries

3.1 Monthly consumption

Figure 1 shows the monthly variation during the year 2001. The figure shows that the variation is largest in Norway and Sweden followed by Finland and Denmark. France and UK seems to be very equal in the monthly variation.

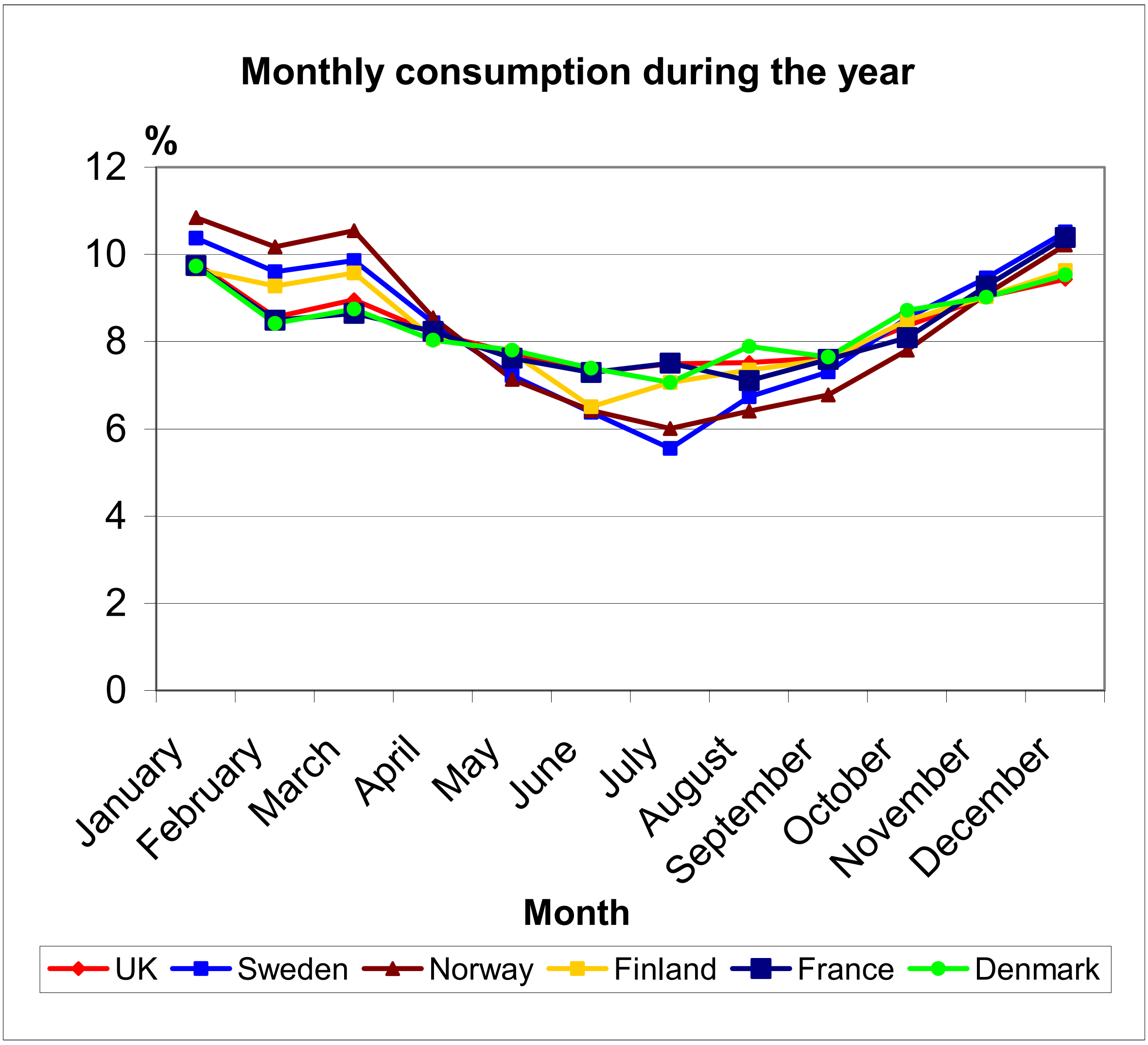

Figure 1 Total electricity consumption per month during the year 2001.

In winter, all six countries have lower temperatures and thus higher consumption. The temperature sensitivity is analysed in chapter 4. A larger difference in temperature between seasons, and a large difference of daily sun hours between winter and summer in Norway, Sweden and Finland explain the larger seasonal variation in the figure.

3.2 *Weekly Consumption*

Figure 2 shows a more detailed picture of the seasonal variation during a year.

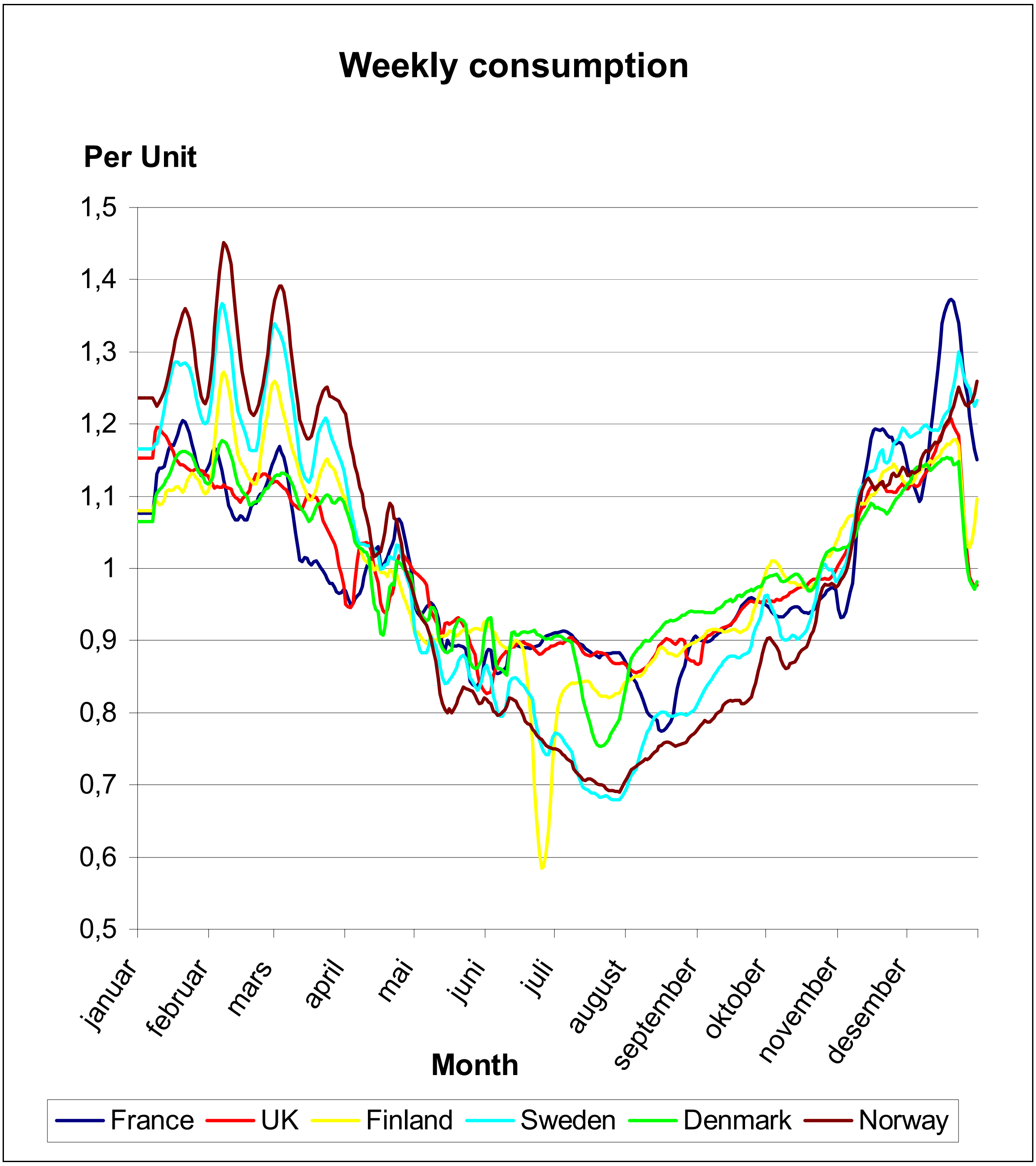

Figure 2 Weekly consumption calculated as a moving average per day based on the last 7 days.

Norway and Sweden have a very similar seasonal variation due to a similar dependency on outdoor temperature and the number of day hours although the outdoor temperature may be at a different level. Finland has a larger summer holiday break. The graphs of Denmark and Finland show a larger Christmas/new year holiday break of these countries.

UK has the smallest seasonal variation while France is rather sensitive to temperature variations (see also chapter 4) – in 2001 the coldest period in France was in December.

3.3 Daily consumption

Figure 3 shows the daily consumption in TWh/h which makes it clear that France is having the highest consumption of the six countries followed by UK. Norway and Sweden is at a very similar level although the population of Norway is half the size of Sweden. Smallest consumption is found in Finland and finally Denmark.

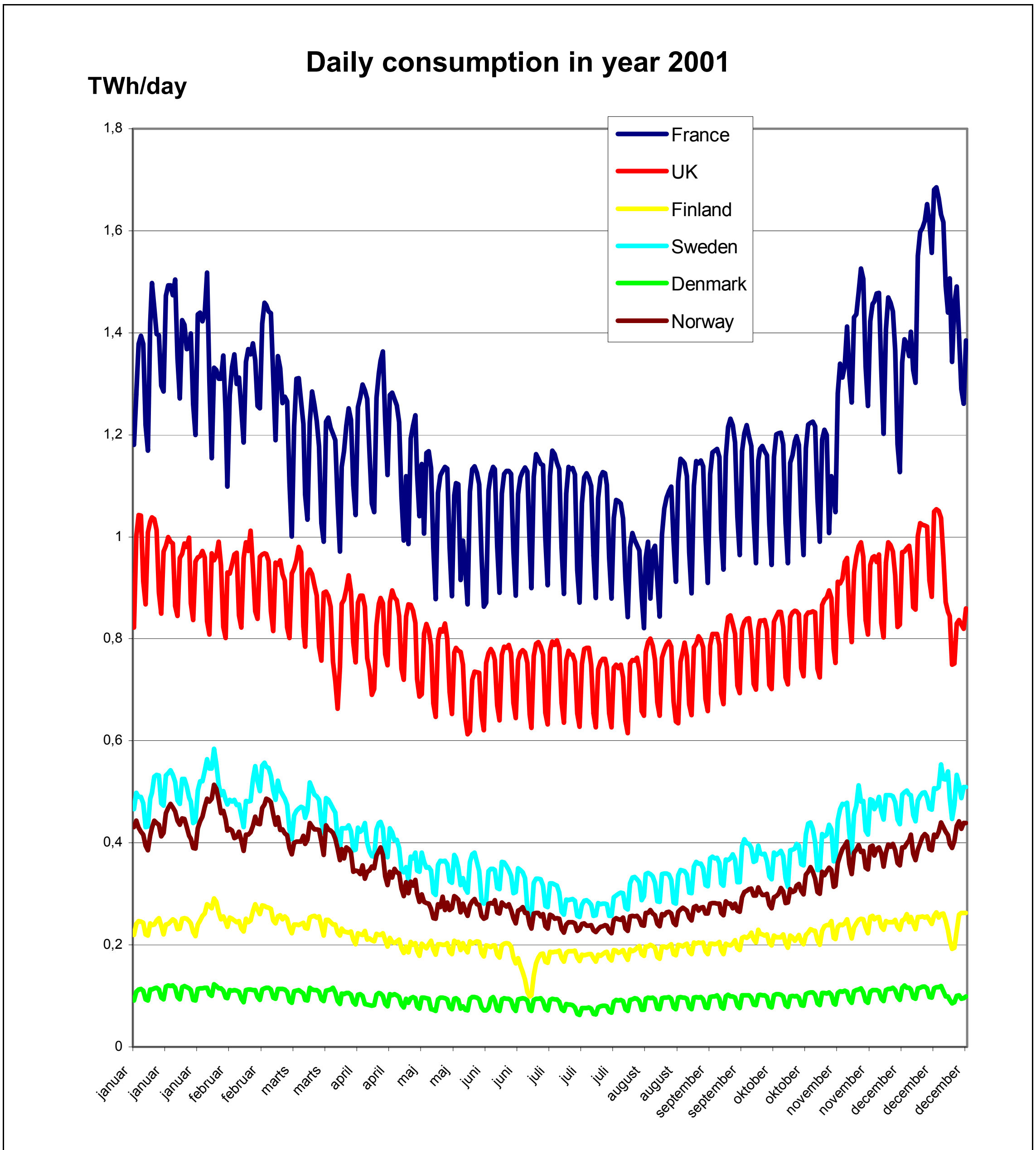

Figure 3 Daily consumption during year 2001.

Figure 3 clearly shows a weekly variation through the year for all countries (Saturdays and Sundays at a lower level due to lower activity in the weekend). Evidence of periods with lower consumption as Christmas and summer vacation is clear for some countries. As mentioned above France is rather temperature sensitive and in 2001 the coldest days appeared in December along with the peak load.

4 Temperature sensitivity

4.1 Temperature sensitivity for seasons and day types

The percentage change in the total load has been calculated for a one-centigrade change in the average temperature. The temperature sensitivity has been calculated for weekdays ("Work" – not corrected for holydays) and weekend days during winter (December-February), summer (June – August) and spring + autumn (March- May / September-November).

Most of the values are negative meaning that the demand is growing when the temperature is falling.

"Winter working days" are the most important period since this is mainly the time when spot prices are high signalling a more stressed market. At this time, the highest sensitivity is found for France. Sweden and Norway have lower temperature sensitivities during winter.

Spring and autumn values are the highest for most countries compared to the values for winter and summer; space heating is used in most countries during this season.

The summer season shows the lowest sensitivity for all countries, this is natural since the space heating then is closed off during summer. Denmark has positive sensitivity during summer showing use of cooling and refrigeration during that season.

It is surprising to see that France and to some extent UK shows higher temperature sensitivities than Finland and Denmark for all seasons except summer. The low sensitivities of Denmark and Finland might be the result of heavily use of district heating and distributed natural gas for heating in these countries.

Values shown in italics have correlation coefficients less than 50% which indicates low significance of the temperature sensitivity. Low significance generally is connected to low sensitivity since other factors that influence on the consumption are relatively constant during the year. Temperature sensitivities that have low significance should be used with caution.

	Winter		Spring, autumn		Summer*		Average
	Work	Wend	Work	Wend	Work	Wend	
Norway	-0.97	-1.43	-2.63	-2.53	-0.80	-0.80	-1.53
Sweden	-1.14	-1.48	-2.25	-2.11	*-0.86*	-0.89	-1.46
France ***	-2.00	-2.54	-1.87	-2.00	*-0.04*	*0.20*	-1.38
Finland	*-0.37*	-0.73	-1.18	-1.17	*-0.47*	*-1.32*	-0.87
UK	*-0.08*	-0.66	-1.84	-1.59	*0.16*	*0.01*	-0.67
Denmark **	*-0.17*	-0.78	-0.95	-0.94	*-0.02*	*-0.12*	-0.50
Average after	-0.79	-1.27	-1.79	-1.72	*-0.34*	*-0.49*	-1.07

Table 4.1 Temperature sensitivity in percentage relative to the average yearly demand.

*) In general there are low correlation factors for summer, this indicates low significance of temperature sensitivities during summer.
**) In 2001 only 33% of the Danish consumption was included in the free market.
***) Development of the free market not yet matured.

Influence of day types

Weekends have the highest values of the winter season, for all countries; this can be explained by people being at home and needing more heating when it gets colder.

During summer some of the weekend values are more positive, possible showing more use of air conditioning during weekends. During spring and autumns the values for work and weekends are quite similar; the work days seems to have higher sensitivities, possibly showing use of space heating in the service and industry sectors.

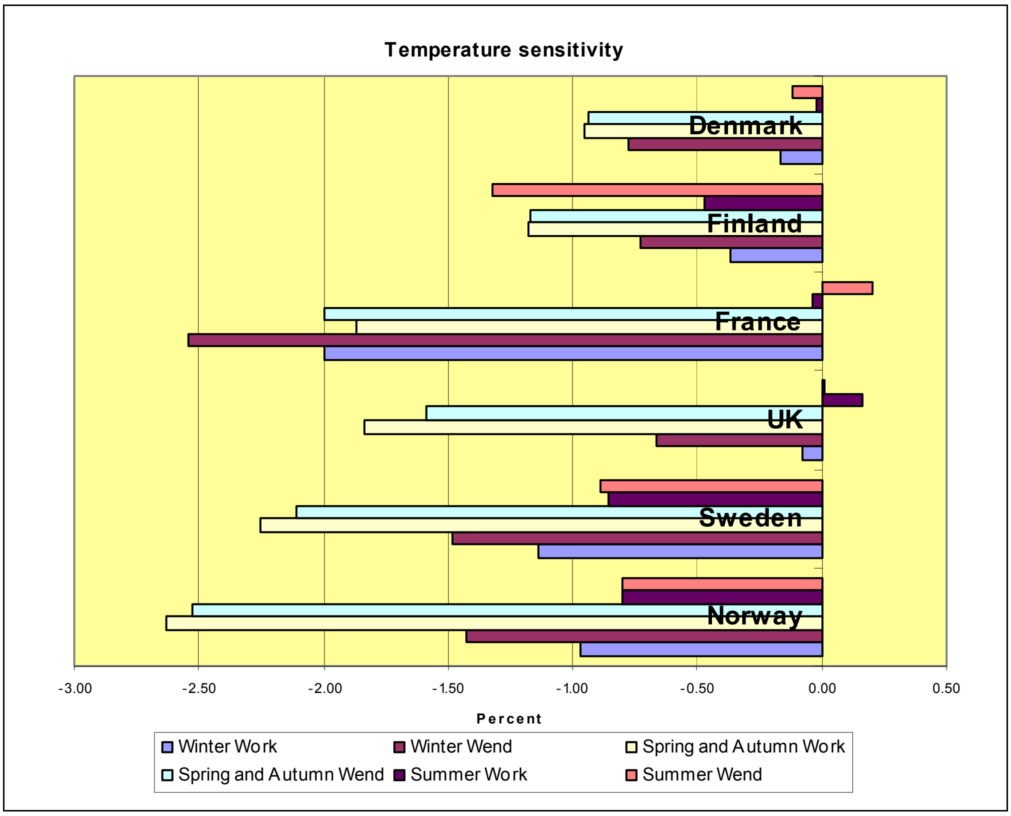

Figure 4 Temperature sensitivities for different seasons and day types.

Figure 5 and 6 gives examples of temperature sensitivity calculations for Norway and Denmark.

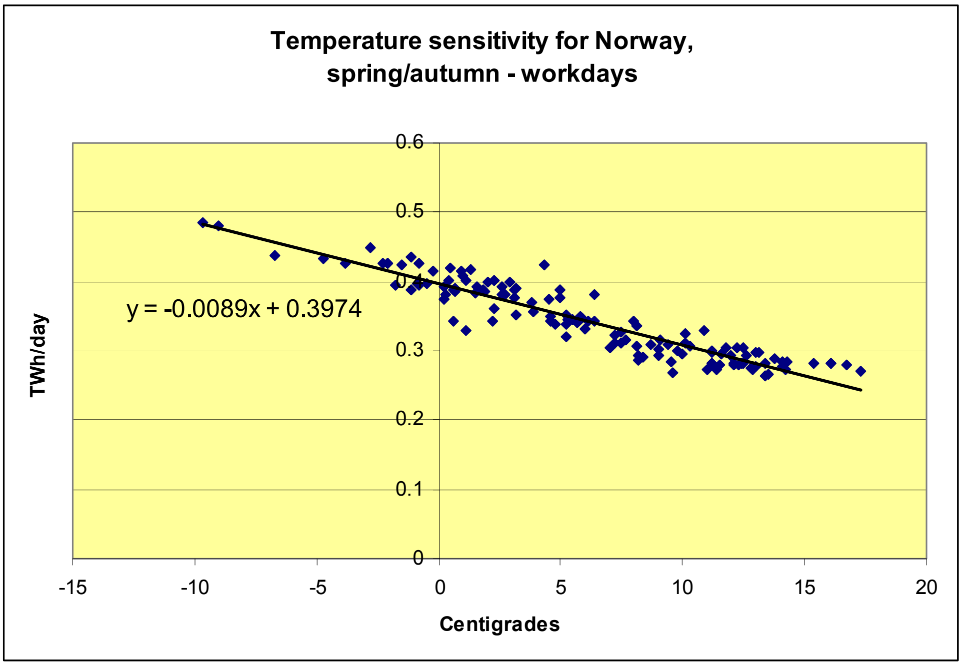

Figure 5 Temperature sensitivity calculation for Norway during spring/autumn (-0,009 TWh/day/Centigrade).

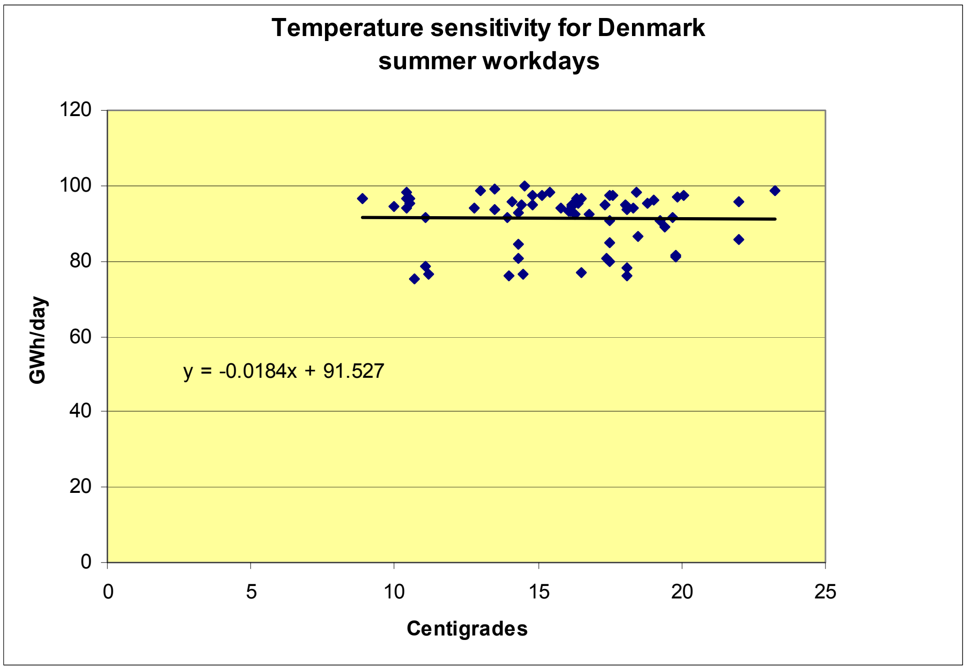

Figure 6 Temperature sensitivity calculations for Denmark during summer workdays (-0.02 GWh/day/Centigrade).

Figure 5 and 6 show how the temperature sensitivity is calculated in examples from Denmark and Norway. The actual calculations are performed with USELOAD, where system total load is stored per hour during the year, along with temperatures for each day for a typical geographical site of each country. USELOAD calculates how a pair of temperature and load correlates in a linear regression analysis for all data that belongs to a specific season and day type. The temperature sensitivities thus calculated are divided by the average day load for the whole year.

4.2 Climate statistics for all countries

Figure 7 shows the daily average temperature during year 2001 for the six countries.

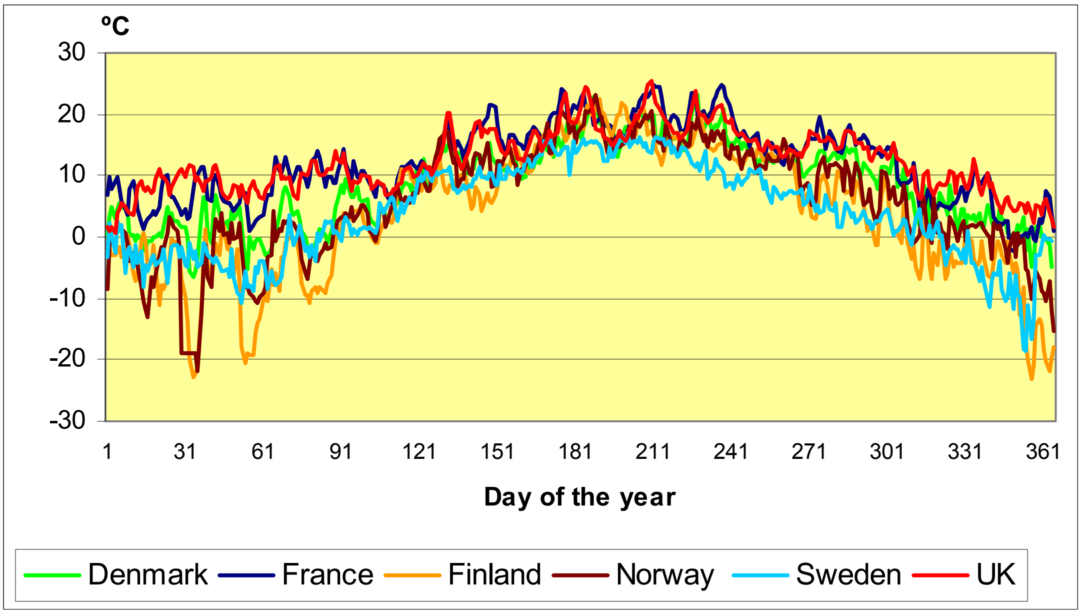

Figure 7 Temperatures in centigrade per day during 2001.

Table 4.2 shows the average temperature for summer and winter in the six countries (there is a little difference in methods used in the six countries for calculation of the average daily temperature). *For Finland and France the temperatures from four carefully selected geographical sites are averaged and used. For other countries temperature measurements for a dominant city is used*

	Summer	Winter
Sweden	10.2	-2.0
Norway	12.7	-0.62
Finland	12.1	-4.3
Denmark	13.4	3.7
France	16.5	8.0
UK	15.7	9.2

Table 4.2 Average temperatures during summer and winter for the year 2001 for characteristic sites in each country.

5 Daily Average System Load curves

Concerning the graphics in this chapter:

- Load curve is shown as per unit values in order to do comparison between the countries. The unit used for normalisation of the curve is the average load of the day.
- Summer is the period April - September
- Winter is the period October -March.

5.1 Winter average curves

Figure 8 shows the average daily load curve for winter working days.

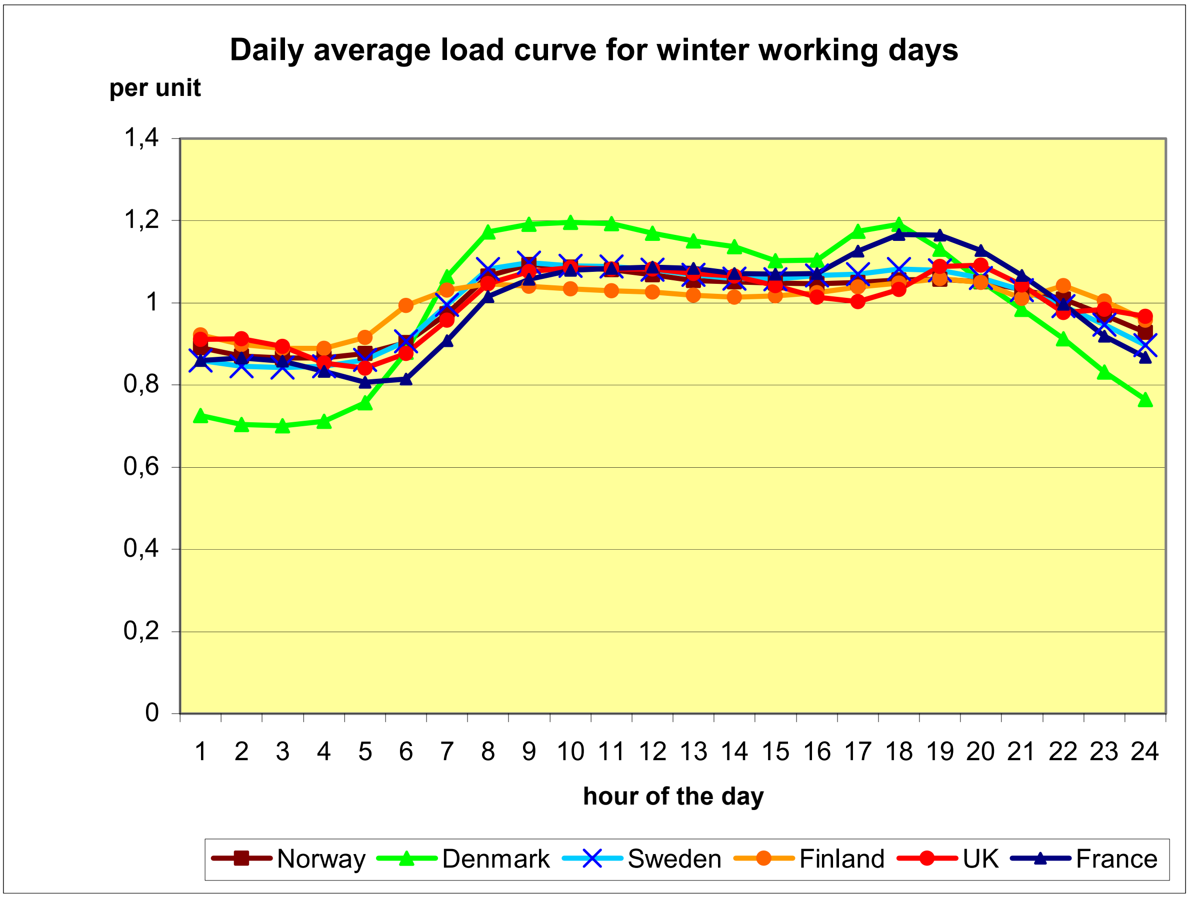

Figure 8 Daily average load curves for winter working days.

All countries show lower consumption during night hours. The average reduction during night hours from daily peak is around 25% except for Denmark with a reduction around 40%. Denmark has less heavy industry than the other countries, which results in reduced load during nights.

The peak hour is in the period 9-11, except for Finland where the peak is around 8 o'clock.

All countries show a second peak in the evening, almost as high as the morning peak. The second peak probably is caused by heating and lighting for residential customers. It can be seen that France and UK have late dinner, at 18-20 hours.

Figure 9 shows the average daily load curve for winter weekend days.

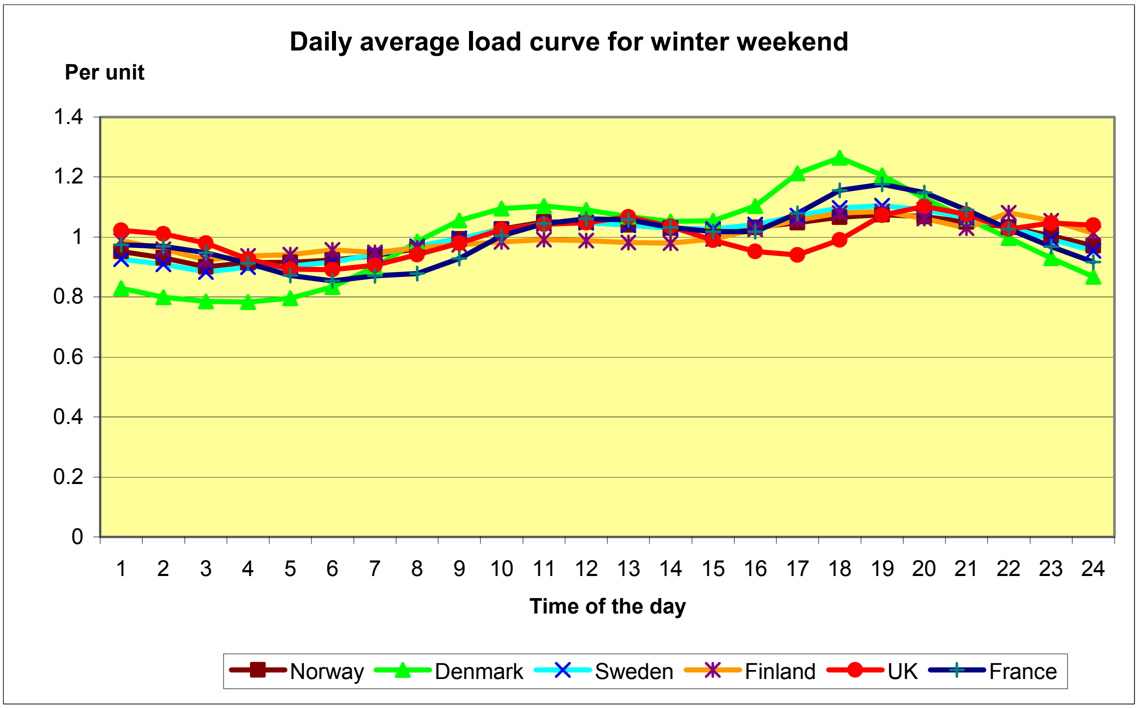

Figure 9 Daily average load curve for winter weekend days.

All countries show again lower consumption during night hours with a reduction during night hours from daily peak around 20%. Denmark has again a larger difference, this time around 35%.

The peak hour is in the evening period 18-21 with a second and much smaller peak around 11-12 hours - which is later compared to working days. The cause of the evening peak is use of heating and lighting in the residential sector.

In Norway, the heavy industry sector has an even load during workdays and weekends. Since the load from the public and service sectors is less during weekends, the Norwegian profile is less volatile during weekends than during working days.

In Finland the use of a Time Of Use (TOU) tariff is probably the reason for the high consumption during the hour interval 21-23, storage heating are switched on since a period of lower prices start in this intervals.

5.2 Summer average curves

Figure 10 and 11 shows the average daily load curve for summer working days respectively summer weekend days.

In general the demand of summer days are lower than during winter days, mainly due to more use of space heating and lighting during winter.

Also in summer, all countries have 20-30% lower consumption during night hours except for Denmark with almost 45% lower consumption

At working days in the summer the peak hour is around 11-12 hours while there is nearly no second peak in the evening.

At summer weekend days Denmark shows a relatively higher consumption during the evening peak while UK is having a lower consumption first in the evening and a higher consumption later in the evening.

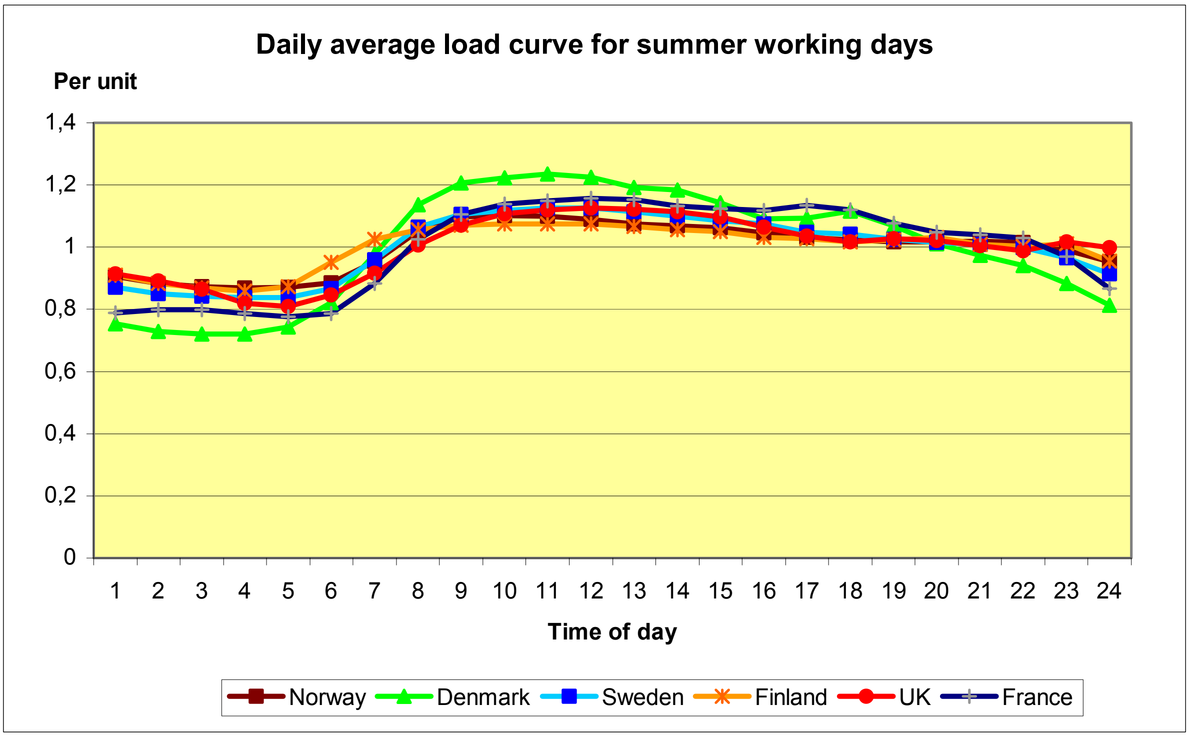

Figure 10 Daily average load curves for summer working days.

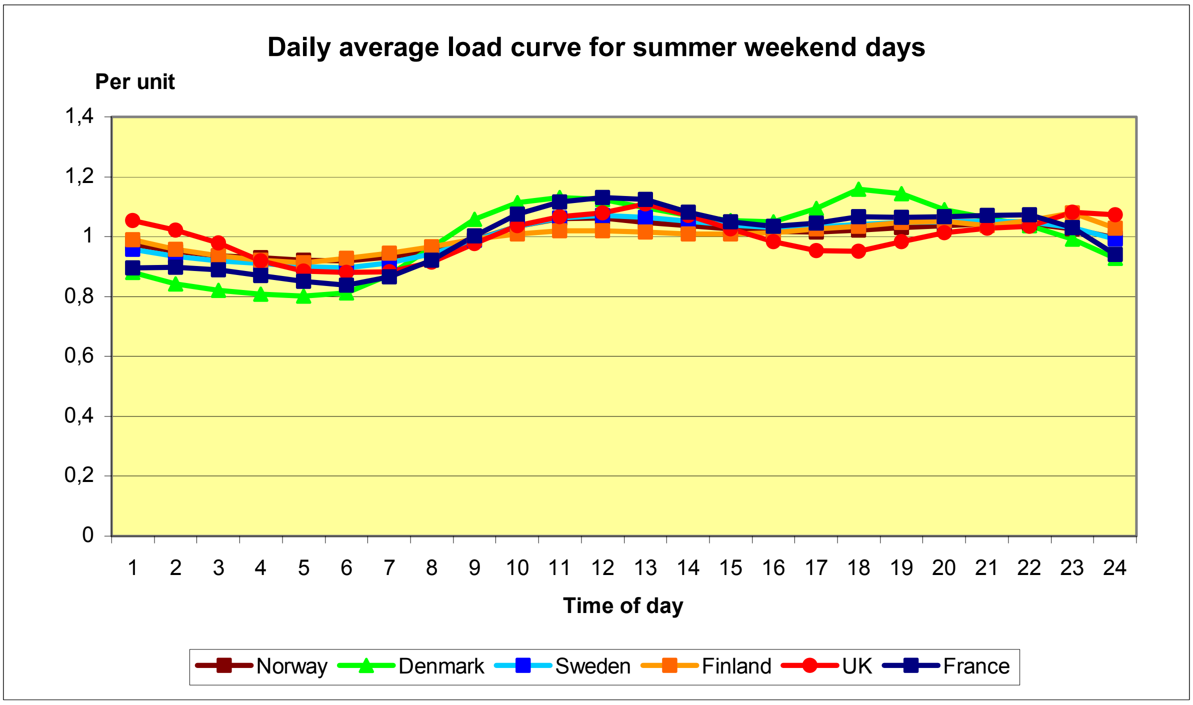

Figure 11 Daily average load curves for summer weekend days.

6 System peak Load

6.1 System peak load profiles for all countries

Figure 12 shows the peak day profile for 2001 in GWh/h to show and compare the size of the profiles for the different countries. In this figure, the daily variation of the profiles for the countries at a lower load level is hard to see, but this information will be available in figure 13 as well as later figures in the report.

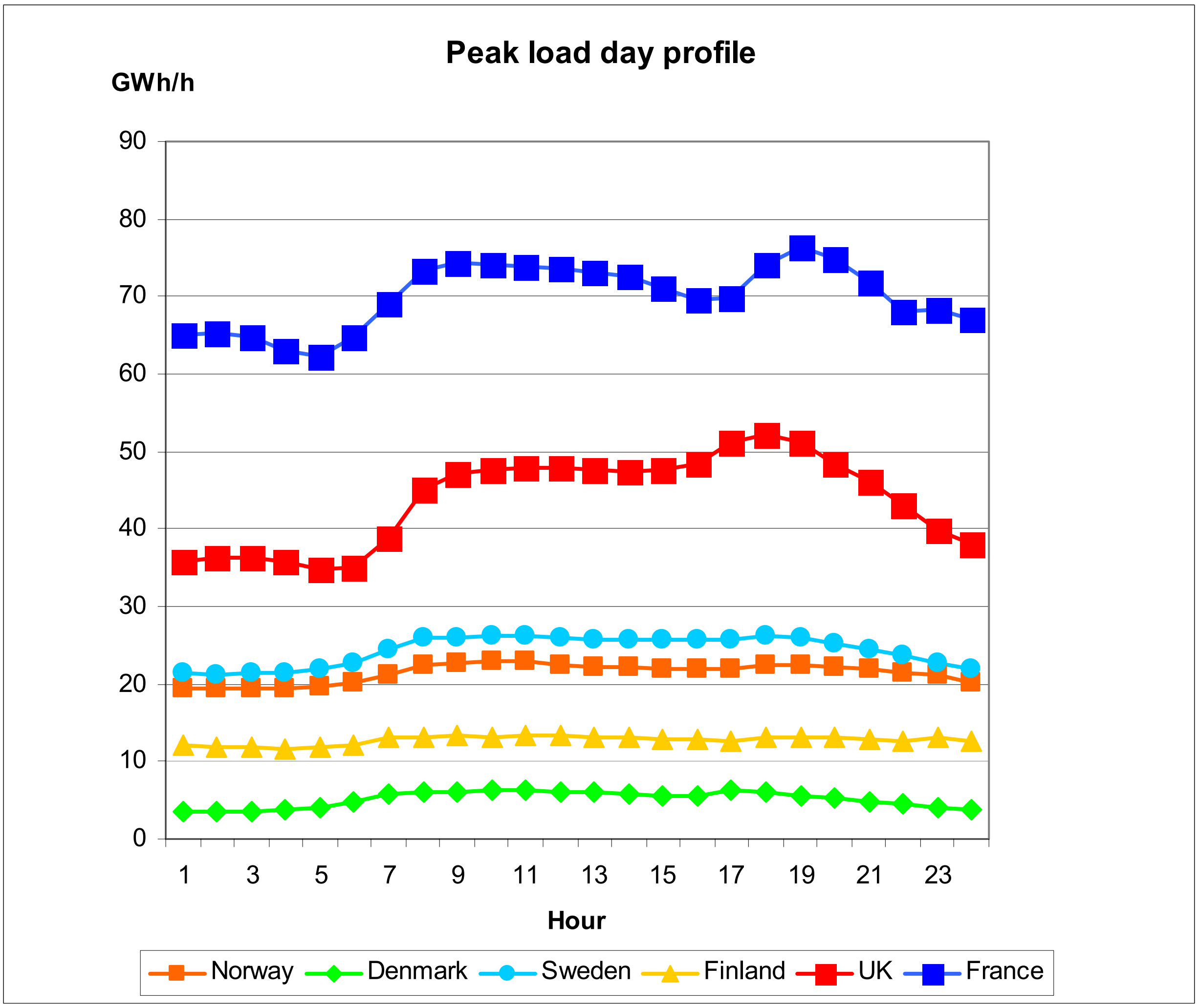

Figure 12 Peak day load profiles.

France has the highest demand followed by UK, Sweden, Norway, Finland and Denmark.

UK and France have their peaks during the evening: France 19 o'clock and UK at 18 o'clock.

Figure 13 is showing the daily peak curves as per unit profiles (normalisation by the average load of the day) making it possible to see differences in the profile between the countries.

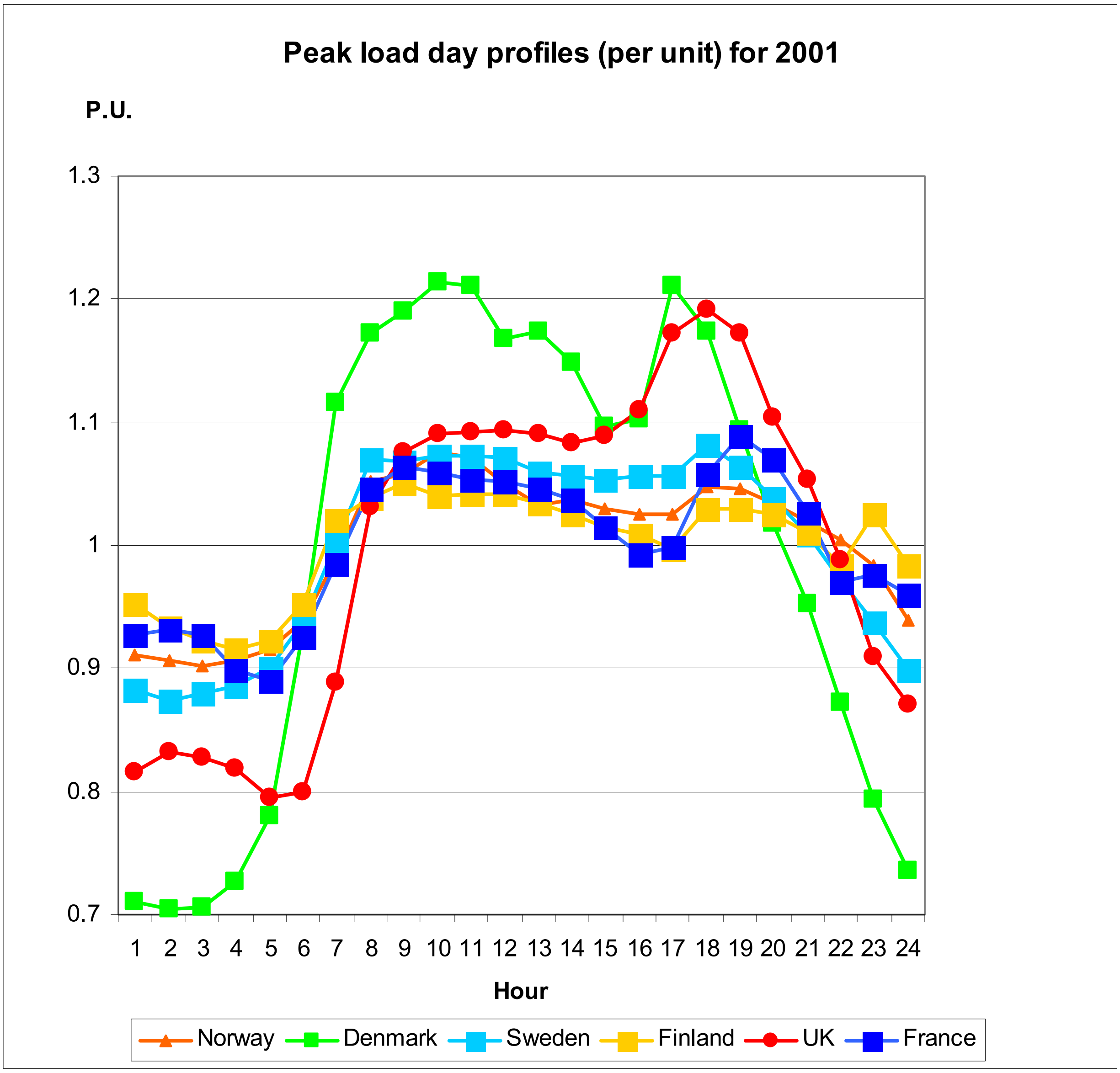

Figure 13 Peak day load profiles as per unit curves.

All countries show lower consumption during night hours. The average reduction during night hours from daily peak is between 10-20% for all countries except for Denmark and UK with a difference of around 40% for Denmark respectively 35% for UK. An explanation might be that Denmark has less heavy industry than the other countries so more load is closed down during night.

The peak hour is in the period 10-12. All countries show a second peak during the evening, almost as high as the midday peak caused by heating and lighting in the residential sector. France and UK have late dinner 18-20 which might cause the late max of these countries.

The Swedish peak of 2001 is a little special, because there was a lot of advertising in radio and TV during the day before asking consumers to reduce their consumption during the period before lunch, where the peak usually occurs. As a result of a peak reduction of 1000 MW (estimated) during the morning, the real peak occurred in the afternoon - which never had happened before.

6.2 Load Factors and duration curves

Table 6.1 shows the annual consumption, the maximum demand and the annual load factor. The load factor varies from 60% for Sweden to 69% for Finland.

$$\text{Load Factor} = \frac{\text{Annual Consumption x 100}}{\text{Peak Demand x Number of hours in a year}}$$

	Denmark	Finland	France	Norway	Sweden	UK
Annual Load (GWh)	**34.853**	**81.188**	**436.319**	**123.313**	**139.900**	**302.383**
Peak Demand (MW)	**6.223**	**13.360**	**76.298**	**23.054**	**26.323**	**52.079**
Load Factor (%)	**64**	**69**	**65**	**61**	**60**	**66**

Table 6.1 Load factors.

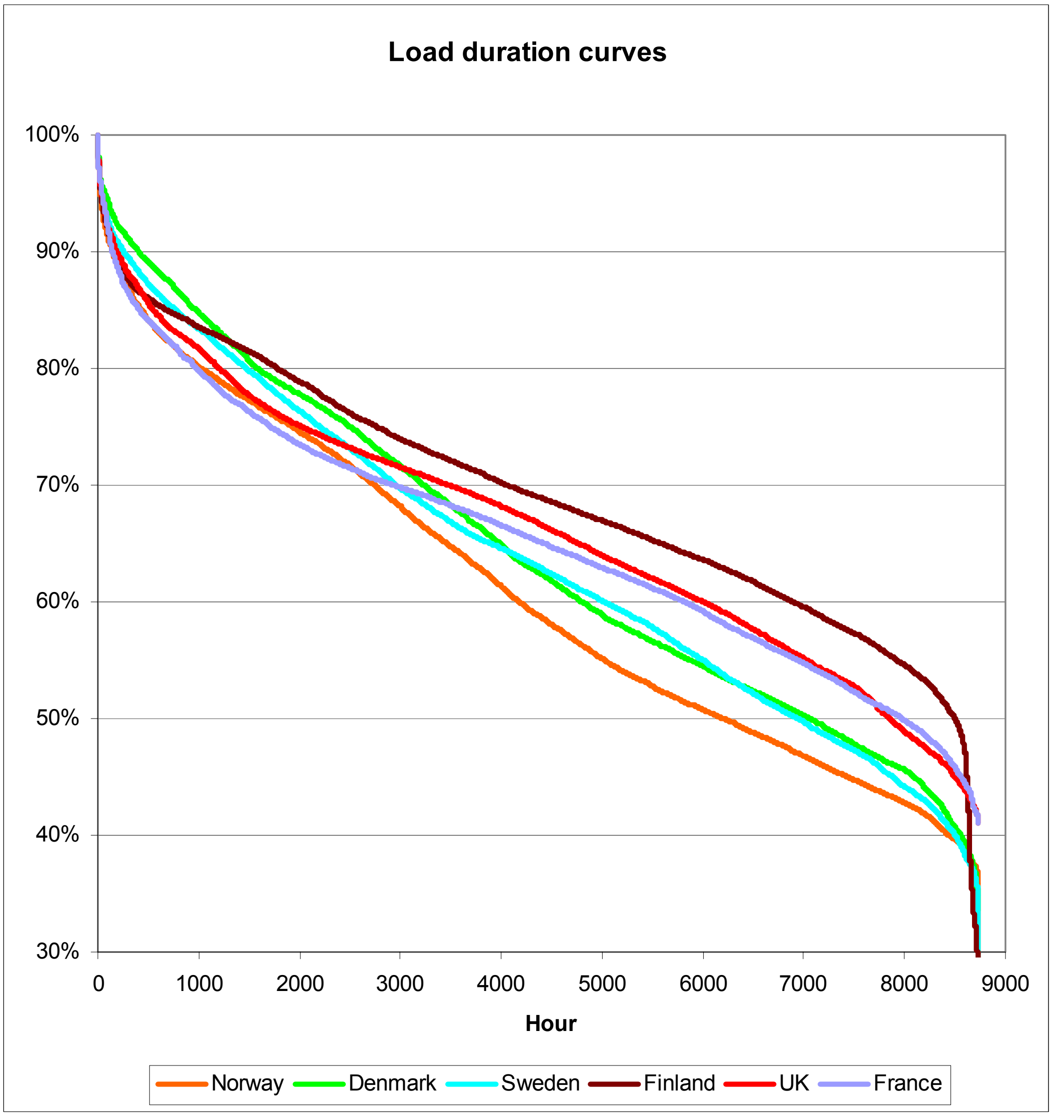

Figure 14 Load duration curves in percentage.

Figure 14 do not show large differences between the six countries except for a higher level for Finland. The focus of figure 15 is the peak part only including the first 100 highest loads.

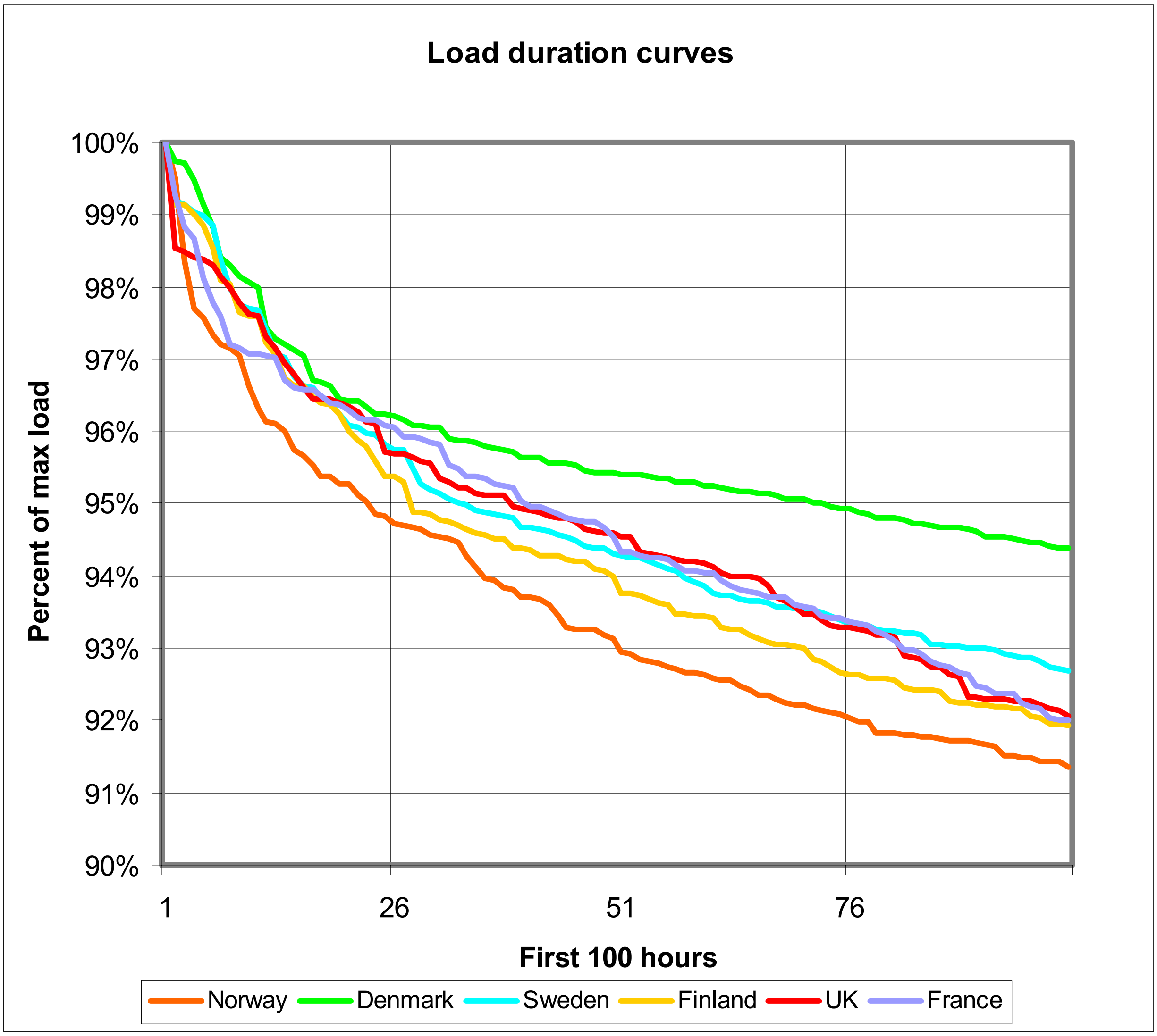

Figure 15 Load duration curves in percentage including only the first 100 hours.

Figure 15 shows that Norway needs peak reduction during 20 hours to reduce the peak nearly 5%, while Denmark need to reduce the demand during 75 hours to reach 5% peak reduction.

6.3 Annual energy consumption divided on the main customer sectors.

Figure 16 shows the division of the total national electricity consumption on the main customer sectors.

The figures is coming from EUROSTAT [1] Energy Monthly Statistics, Vol. 12, 2002, except for Norway, whose figures came from Eurelectric. UK figures refer to the whole of the UK and not just England and Wales.

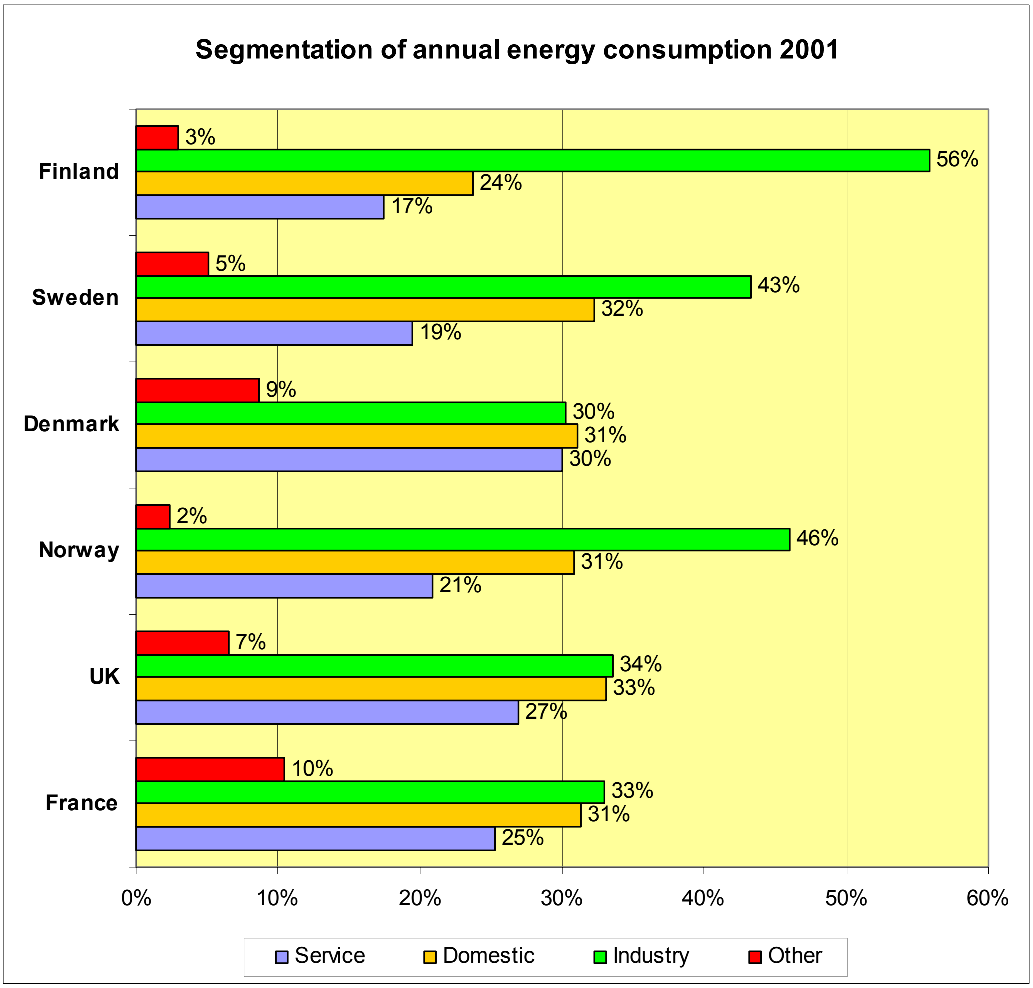

Figure 16 Segmentation of annual energy demand for different customer types year 2001.

The figure shows that Finland, Norway and Sweden have a large share of Industry, while Denmark, UK and France have a more equal share among the customer sectors.

Data are from year 2001, where all countries except France had deregulated the electricity market, although for some countries like Denmark still only a smaller part of the customers benefit from the deregulation.

6.4 Peak load and contribution from the main customer sectors

Table 6.2 shows the peak load and time in 2001 for the six countries. The peak time for Sweden is unusual due to a national request that day asking the customers to limit their load in the morning.

Country	Peak load 2001 [MWh/h]	Date of peak	Time of peak
France	76298	17 December 2001	18-19
UK	52079	17 December 2001	17-18 (equals 18-19 European central time)
Denmark	6228	5 February 2001	17-18
Norway	23054	5 February 2001	9-10
Finland	13360	5 February 2001	8-9 (equals 7-8 European central time)
Sweden	26323	5 February 2001	17-18 (normally 08-09)

Table 6.2 Peak loads in 2001.

Figure 17 shows the contribution to the peak load from the main customer sectors. Values for Finland, Sweden, Denmark and Norway are calculated by use of the software tool USELOAD, and are based on a large number of customer category curves (for Denmark e.g. 28 customer category curves) and the metered peak load curve. Values for France and UK values are supplied by EDF and EA.

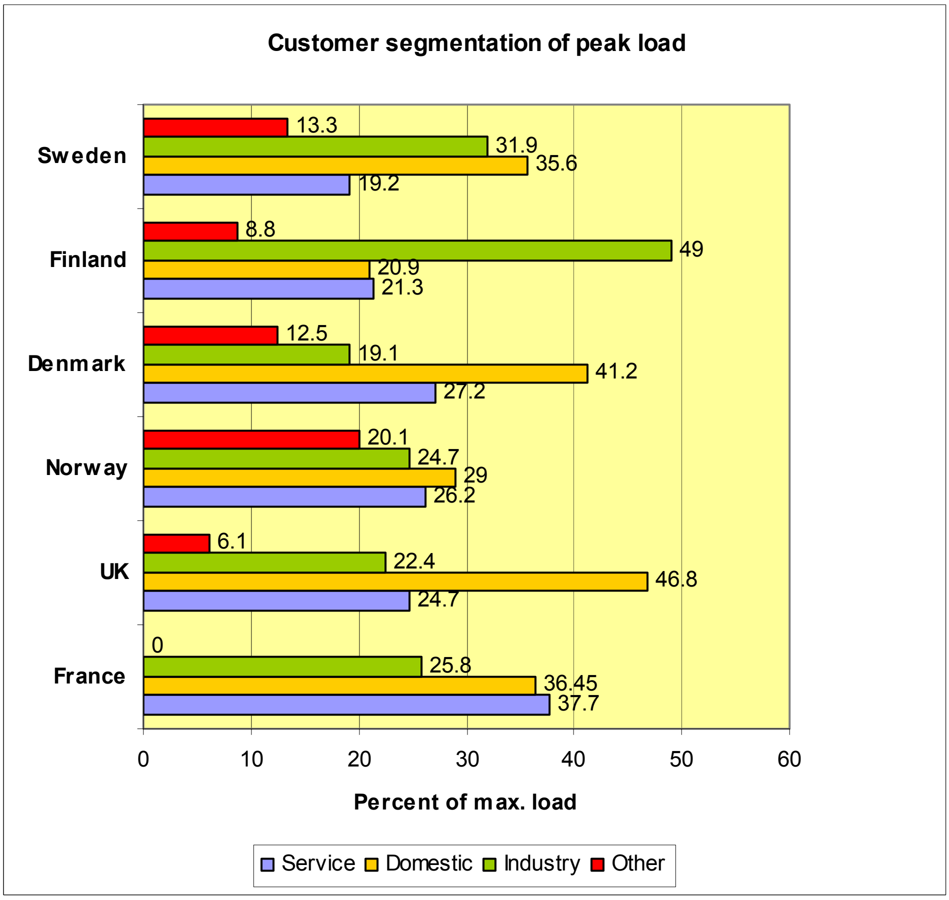

Figure 17 Contribution to the peak load in year 2001 from the main customer sectors.

Figure 17 shows that Finland has the greatest share of Industry load at the peak hour. Finland, and Norway have peak hours during the morning when domestic customers have a lower share. UK, France, Sweden and Denmark have an evening peak when the domestic customers have a higher share.

7 Demand response potential in Denmark

7.1 Peak load characteristics

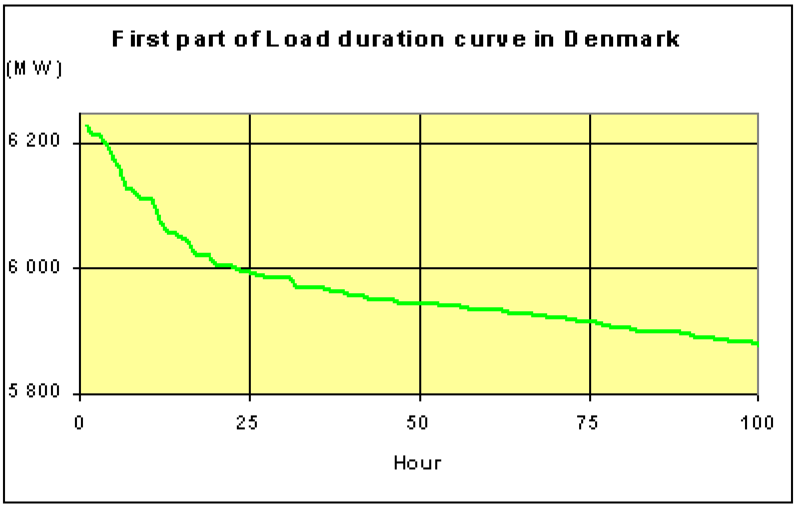

Figure 18 Load duration curves in MW including only the first 100 hours.

Figure 18 shows the Danish peak can be reduced:

- 200 MW by peak cutting during 20 hours per year
- 300 MW by peak cutting during 100 hours per year.

Figure 19 shows the daily load curves for the three largest peaks that occurred in 2001. These daily load shapes are very similar. The differences between day and night are as mentioned earlier very high compared to other countries.

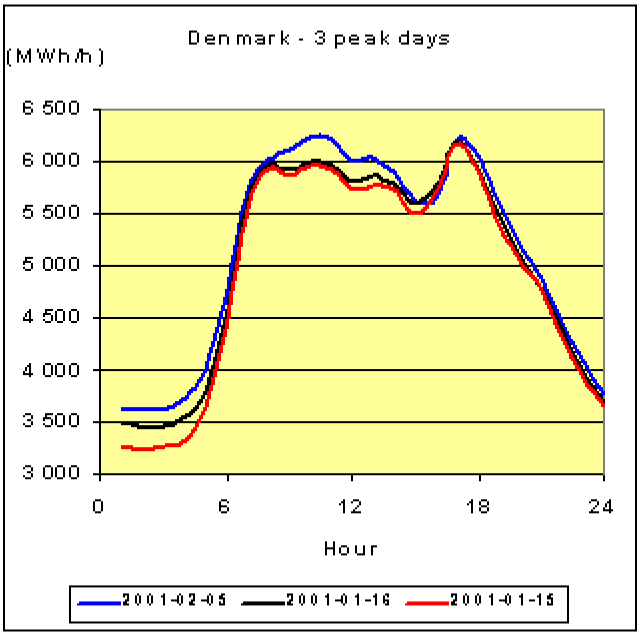

Figure 19 Three peak days in 2001 for Denmark.

7.2 Demand response potential

The potential for load reduction is estimated for the different sectors in Denmark using the following sources:

- A large investigation (10 reports) by DEFU performed in the period 1982-1986.
- An analysis at ELKRAFT System on flexible load within the industrial and commerce & service sector in 2001.
- Data from DE [2]: Dansk Energi Årlig statistik: Electricity sales per consumer categories

There is no experience on the:

- Payment expected by the customer for the peak power reduction
- Actual peak power reductions from customers flexible load

7.2.1 The domestic sector

7.2.1.1 Refrigerators and freezers

Switching all refrigerators and freezers off are estimated to give a load reduction around 200 MW. The duration of the reduction is limited by the time it takes before the temperature increases to an unacceptable level. After an hour the temperature increase will be 0.3-0.8 ^{0}C, which should be acceptable. The coincident load just after end of the reduction period is expected to be around the double of normal coincident load, because these appliances are expected to be running 50% of the time. This *payback* load thus has to be taken into consideration both at the national level as well for lines feeding domestic customers.

7.2.1.2 Washing machines

Switching off washing machines is estimated to give a reduction around 200 MW. The payback load will be higher since hot water has to be heated again and because the number people who want to wash will increase with the duration of the switching off.
It is not found possible to evaluate the size of the payback load.

7.2.1.3 Water heater

All homes with direct electric heating most probable have electric water heaters, but they are also used in some homes with other heating systems. The potential includes at least 100.000 homes and a flexible coincident load of 50 MW.

7.2.1.4 Direct electric heating

Around 100.000 homes have direct electric heating. 50% of these homes with a yearly consumption above 12.000 kWh are the most interesting in this respect. The potential depends on the outdoor temperature, the day type and the time of day. It also depends on the duration of the reduction, because higher payback load might have to be handled by switching off other groups of houses. The more groups that have to be switched off, the less the potential for load reduction. System peak hours often appear at rather cold days with a potential of at least 200 MW including 50.000 homes.

7.2.2 Agriculture

7.2.2.1 Watering

Watering is nearly only taking place in the second quarter of the year where the potential is estimated to be 60-120 MW.

7.2.2.2 Drying
Drying corn is nearly only taking place in the third quarter of the year where the potential is estimated to 10-20 MW.

7.2.2.3 Grinding mills
Grinding mills are typically used 1-2 times every day in less than an hour. The load of a mill is typically 10-15 kW. Assuming that only 10% of the mills are running at the same time and a number of 30.000 farms the potential is estimated to be 30-45 MW.

7.2.3 Industry

The potential includes three types of appliances:

- Plants and appliances possible to switch off without disturbing the production. This typically includes cooling and freezing rooms being turned off from one to several hours before the temperature increase sets a limit.
- Large plants where the tariff savings are higher than the extra costs by switching off and running at another time which might be overtime payment, destroyed material or cost because of a delay.
- Plants with a buffer where the most electricity consuming production can be stopped because of the buffer and the further manufacture can continue without interruption. This might be melting plants where the melted metal have to be kept fluid in owns for casting while the melting might be interrupted for some hours.

An older but rather detailed analysis have found that the number of industries which have a substantial interruptible load potential is around 240, where around 60% of the potential is concentrated at 20 industries. Depending on the payment for interruption and the yearly number of hours with interruption the potential is estimated to be 51-142 MW as shown in table 7.1.

Customer category	***Number of industries***	***Potential in MW***
Pork/Bacon factories	40	0-10
Slaughtering and meat industry	20	2-4
Oil mills	1	4-5
Margarine factories	1	1
Dairies	40	10-20
Milk condensation	8	0-1
Fish meal/Flour factories	10	0-5
Fishing industries	30	0-3
Wood industries	5	2-4
Paper industries	5	2-3
Plastic industries	50	0
Cement industries	1	0-7
Tile works	20	0-4
Iron and metal works	1	30-65
Iron castings	10	0-10
Total	**242**	**51-142**

Table 7.1 Flexible load potential within the industrial sector (1986)

In 2001, ELKRAFT System produced an analysis on flexible load within the Danish industry. 10 industry companies within different customer categories were investigated including 2 large process industries, 5 medium size industries and 3 service companies.

For these ten companies it was calculated that an average of 17% (254 kW), (1-40%) of the maximum load could be interrupted in at least one hour.

Use of this potential requires investment in buffers, thermo storages and other necessary equipment. For most of the ten companies the investment were rather limited and it was a requirement that the payback period should maximum be three years and acceptable for the people who were affected by the interruption.

In table 7.2 the results are scaled up to a potential for East Denmark (around 33% and 50% of the total Danish industrial respectively commerce & service consumption). Some customer categories were not included by the ten industries in the investigation.

Customer category	***Consumption GWh/year***	***Potential East Denmark MW***	***Scaled up potential MW***
Food industry	518	13	56
Textile, cloth and leather industry	14	0	4
Wood industry	123	2	8
Paper and graphical industry	228	5	16
Chemical industry	1116	17	33
Stone, clay and glass industry	211	4	20
Iron and metal works + casting	528	26	42
Iron and metal industry	447	20	79
Retail, wholesale and hotels/restaurants	1507	54	134
Total	**4692**	**141**	**391**

Table 7.2 Flexible load potential within the commercial sectors in East Denmark (2001).

A simple scale up to the whole Denmark, gives a total potential around 390 MW of interruptible load. Reasons for estimation of a relatively larger potential in 2001 compared to an earlier investigation in 1986 are that new technology gives more flexibility:

- More dissemination of control of ventilation.
- HF compensation of fluorescent lighting giving some possibilities for control limited by the requirements for lighting quality.
- More than 100 natural gas turbines (electricity capacity 700 MW) and natural gas driven motors has been installed.

7.2.4 Commerce and service

A number of buildings within this sector have CTS (Central control and management) equipment e.g. municipalities, hospitals, schools, sport buildings, heating plants and banks. This equipment might be used for load management within the sector.

Depending on the payment for interruption and the yearly number of hours with interruption the potential an older analysis has found that the potential for interruptible load is 37-128 MW. Table 7.3 shows the potential for different customer categories.

Customer category	*Appliances*	*Potential in MW*
Retail	Cooling + Freezing	0-20
Wholesale	Cooling + Freezing	10-20
Service	Cooling + Freezing	0-15
Institutions for elderly people etc.	Cooling + Freezing + Washing	0-20
Hospitals	Electric water Heater + heating	0-10
Utilities (especially water plants)	Pumps + Motors	27-43
Total		**37-128**

Table 7.3 Flexible load potential within the commerce and service sector (1986).

The analysis above do not include:

- Regulation of ventilator loads because of small possibilities for regulation. This has changed in the years since and it might be interesting to investigate the dissemination of possibilities for regulation by CTS and other management.
- Lighting used for commercial reasons. Here is an extra potential especially within the retail category.

7.2.5 Total Danish potential for flexible load

The total potential for flexible load can't be found simply by summation of the potentials for the different sectors due to dependency on following factors:

1. Load variations due to time of year, week and day
2. Temperature
3. Duration of the interruption
4. Large payback loads for some loads which have to be handled
5. Payment (electricity price)
6. Dissemination of management/control equipment

The yearly peak load in Denmark is around 6.000 MW. The system responsible organisations could wish to have 10% flexible load being 600 MW.

Table 7.4 shows that there are different potentials to pay attention to in order to try to reach the goal of 10% flexible load.

Customer category	*Appliances*	*Period*	*MW*
2 million domestic customers	Refrigerator, freezer and washing	All year	400
100.000 domestic customers	Electric water heater	All year	50
50.000 domestic customers	Direct electric heating	Cold days	200
30.000 farms (agriculture)	Grinding mills	1-2 h/day	30-45
30.000 farms (agriculture)	Watering	2. Quarter	60-120
30.000 farms (agriculture)	Drying corn	3. Quarter	10-20
250 Industries	Many technologies	All year	200-300
5-10.000 Commerce & service	Many technologies	All year	100

Table 7.4 Total Danish demand response load potential.

7.3 Segmentation of the peak day

The segmentation of the metered peak load curve into different customer types is estimated based on models of each of the customer types along with an estimation of the network losses. A simulation of the country electricity demand for each hour during the year is performed with the USELOAD model. The total simulated demand for each hour is compared to the metered consumption, and all simulated values are stretched or lowered with a factor so that the total agrees with the metered value. To simulate the consumption of the different customer types for a particular hour; customer load profiles coming from the load research program 'Elforbrugspaneler' are used. The described method yields a segmentation that is not 100% correct, but is sufficient to give a broad picture of how different customers can influence the peak load.

Network losses are simulated assuming that losses in lines are proportionate to the square of the load, and that losses in transformers are constant during the year.

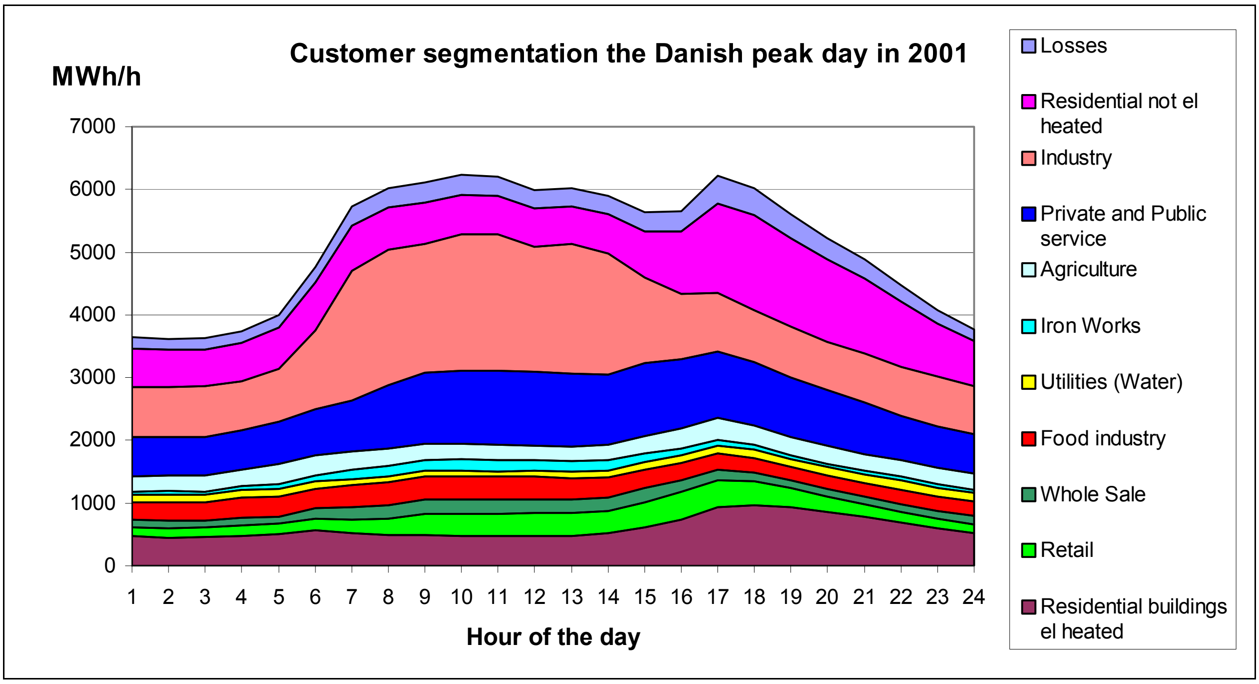

Figure 20 Customer segmentation of the peak load curve for Denmark.

Figure 20 shows that around 2000 MW of the peak 6.228 MW is coming from seven customer categories with a potential for demand response. Comments concerning the seven customer categories:

- Only a part of Agriculture (mainly grinding mills) has a potential all the year for demand response
- Iron works has a potential all the year except for summer holidays where some works close
- Utilities (mainly water plants) have a potential all year
- Only a part of Food industry (mainly ddairies) has a potential for demand response
- Whole sale has a potential all year
- Retail has a potential all year
- Residential electric heating has a potential mainly in the winter but the water heaters part is giving a potential all the year.

8 Demand response potential in Finland

8.1 Peak load characteristics

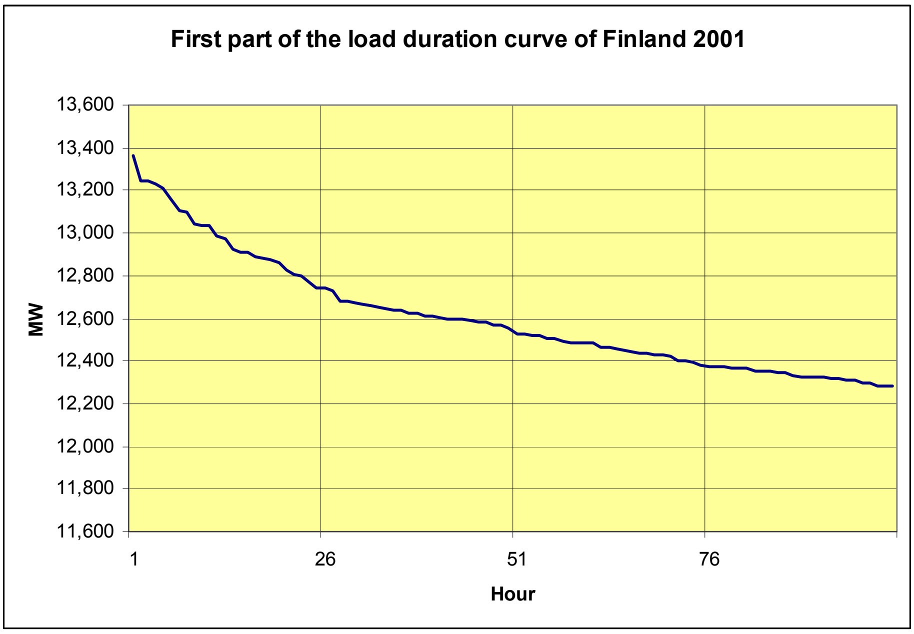

Figure 21 Load duration curves in MW including only the first 100 hours.

Figure 21 shows the Finish peak can be reduced:
- 650 MW by peak cutting during 25 hours per year.
- 900 MW by peak cutting during 50 hours per year.
- 1100 MW by peak cutting during 100 hours per year.

Figure 22 shows the daily load curves for the three largest peaks that occurred in 2001. These daily load shapes are quite similar. The differences between day and night are very high. All days have temperatures below –19 Centigrade.

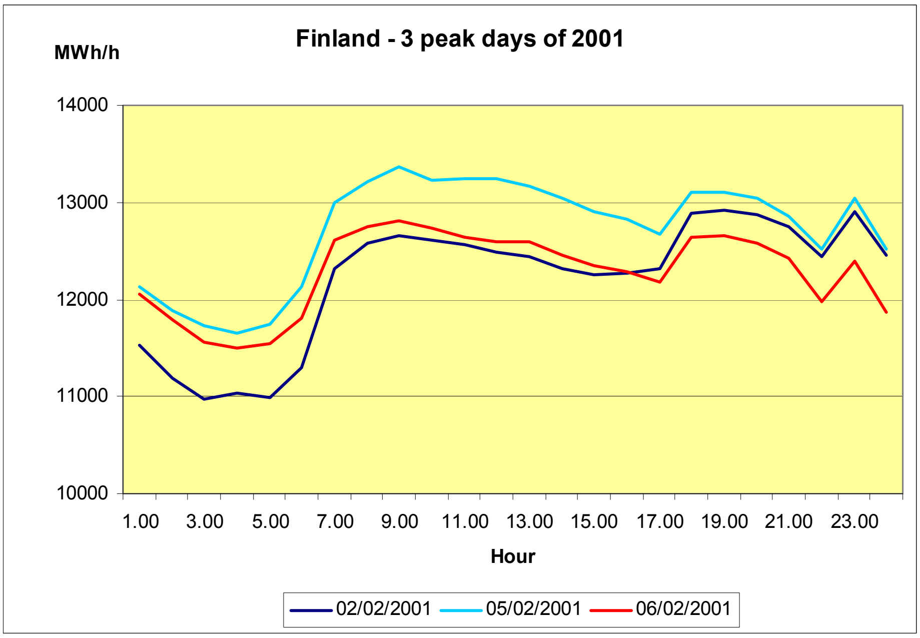

Figure 22 Three peak days in 2001 for Finland.

The peak levels are quite close to each other. The peak days: Monday (2001-02-05), Tuesday (2001-02-06) and Friday (2001-02-02).

8.2 Finnish Demand Response potential

Table 8.1 shows the Finnish potential for Demand Side Bidding (DSB) in Finland in 1999 calculated based on evaluations from 1982 and 1985 by interposition using annual energies and the hourly peak. DSB potential ref. "IEA DSM Agreement" [3].

Customer sector	Customers (*1000)	Energy TWh	Part of the hourly peak MW	Technical DSB-potential MW
Industry	30	42,4	6200	
Process industry	**unknown**	32,4	3600	1600 MW, max duration 1 h and warning time 2 h
Small/medium industry	30	10,0	2600	145 - 225 MW
Service	199	13,4	2500	120-285 + 60 MW road lighting
Public service	57	4,8	1200	
Commercial service	142	8,6	1400	
Agriculture	144	2,5	600	
Residential	2587	16,8	2800	
Electric heating	580	8,1	1100	600 – 1200 MW.
Other residential	2007	8,7	1700	
Losses	-	2,8	1000	
TOTAL	2960	77,8	~13360	About 2500 - 3300 MW.

Table 8.1 Annual electricity consumption and potential for DSB in 1999.

Figure 23 and 24 show the distribution of the customers respectively annual electricity use for 1999.

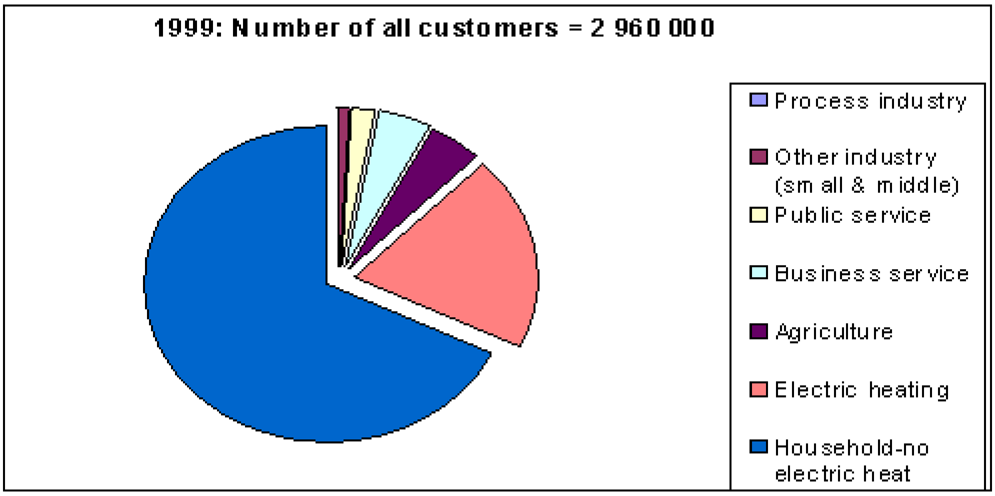

Figure 23 Finnish customers divided on sectors in 1999 where the population was 5 171 000 persons.

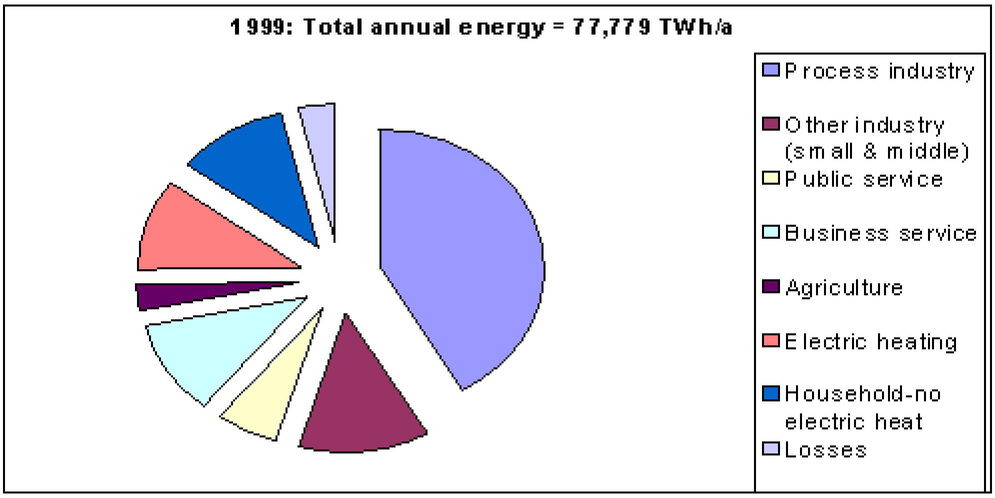

Figure 24 Electricity sales distributions for 1999 in Finland.

The process industry (or big industry) includes industry branches with average electricity consumption over 2 GWh/year at one operating site.

In 1983 the number of different industry types was 55 and the number of the operating sites was 691 that was about 9 % of the total number of all operating sites.

The process industry had around 42% share of the total Finnish electricity consumption in 1999.

Figure 25 shows the evaluated cumulative behaviour concerning the process industry DSB-potential depend on the warning time and the duration of the disconnection. The values for the year 1999 are interposed from the values of the year 1982 (by multiplying the older values with 1,81 that is an average value of the annual energy relation and hourly peak power relation from the years 1999 and 1982).

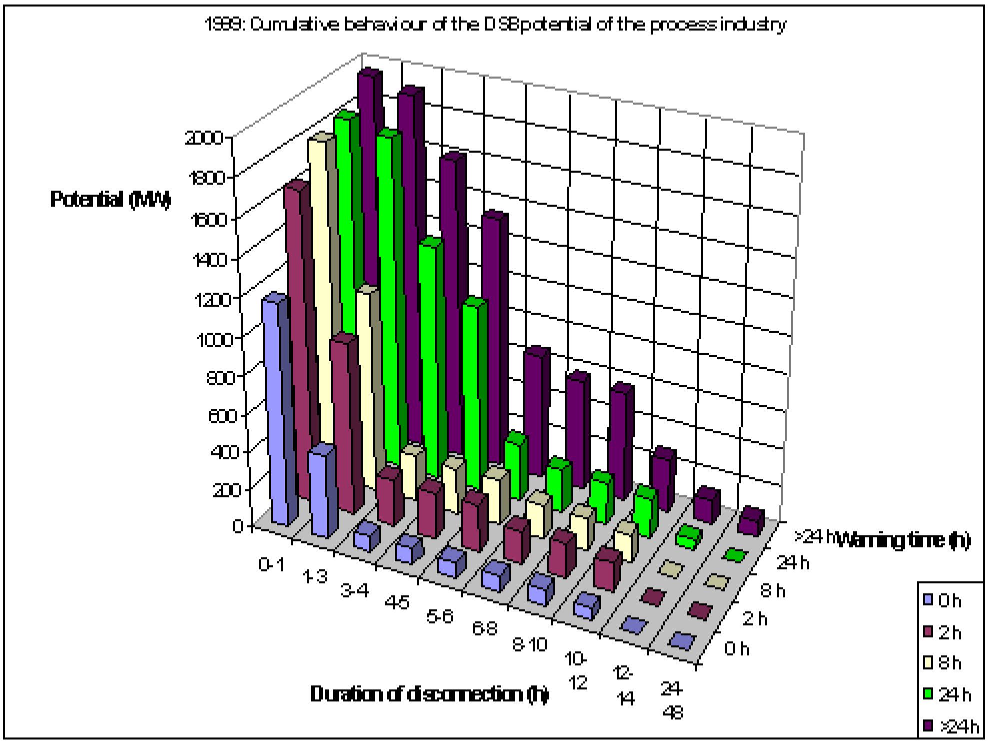

Figure 25 Cumulative behaviour of the DSB-potential of the process industry.

8.3 Segmentation of the peak day

Load curves for the customer categories were applied into the tool USELOAD where losses were evaluated to be 7 %. Figure 26 and 27 shows a segmentation of the peak day and the peak week. The distribution of the peak power is also presented in table 8.1.

Based on potential demand response from 1982 and 1985 the evaluated DSB-potential in 1999 was around 2500 – 3300 MW. At that time were no attractive offers or charges for the minor electricity markets, the main purpose was that the transmission and distribution system could operate properly and a probable second hand profit was the money saved by cutting the peak power.

The new market situation with bid and request may have changed the incentives to larger demand response potential. From this aspect demand response potential may rather be at the upper limit 3300 MW than the lower value of 2500 MW.

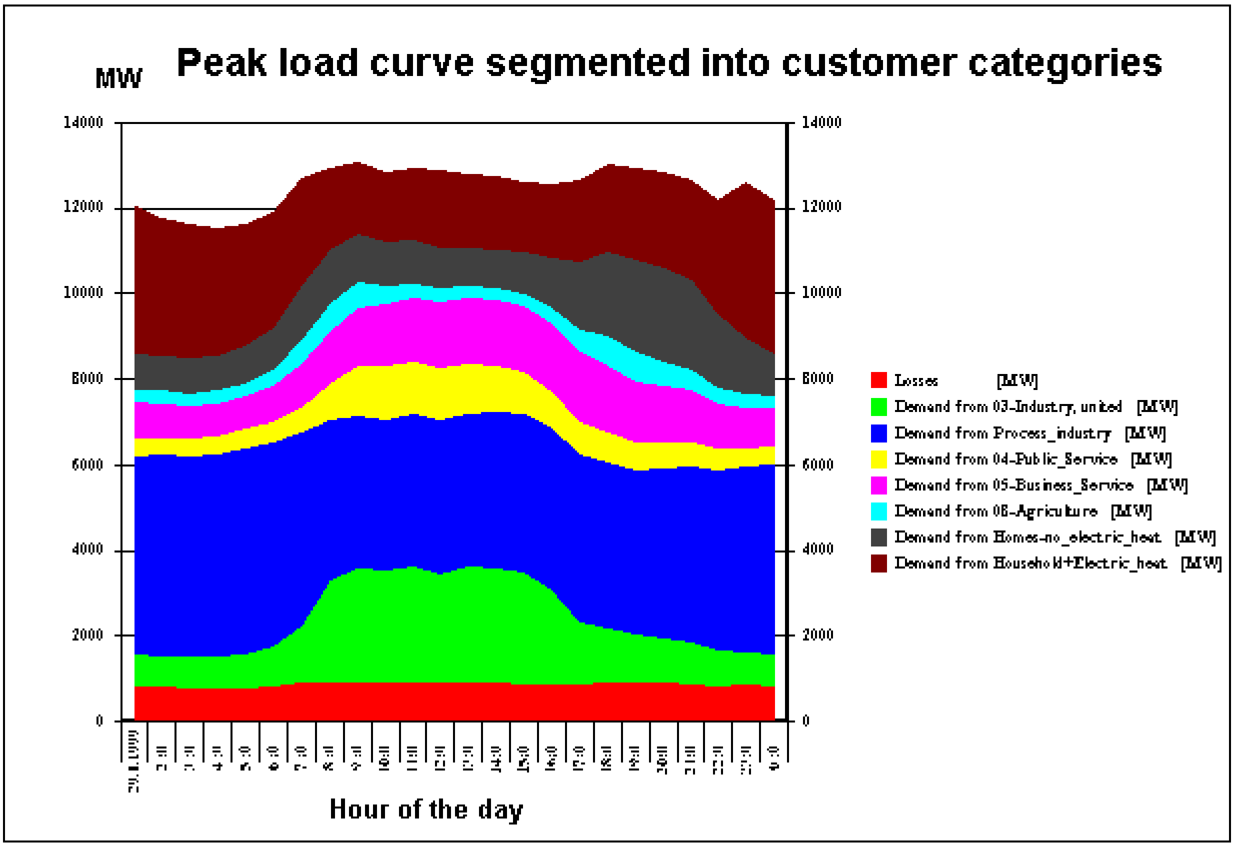

Figure 26 Finnish peak daily load curve of 29.01.1999 segmented into customer categories.

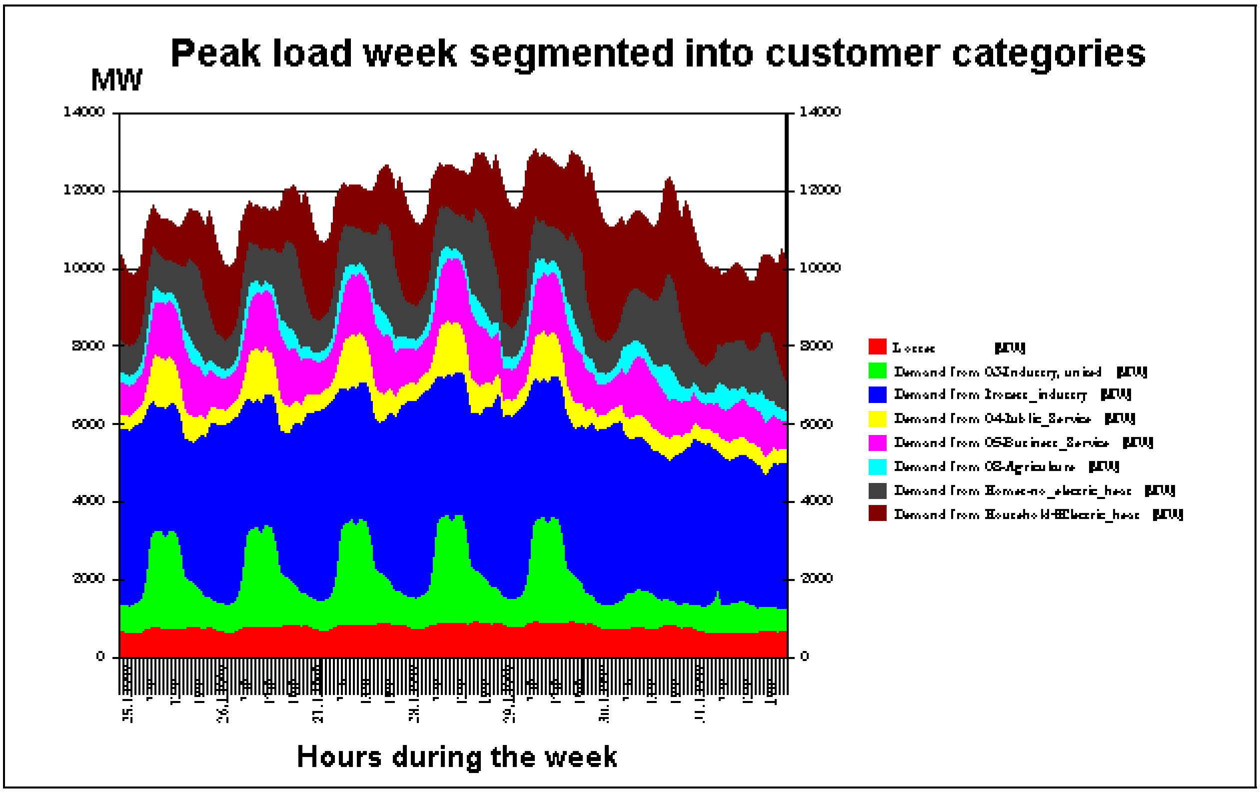

Figure 27 Finnish peak load week curve 25-31.01.1999 segmented into customer categories.

9 Demand response potential in Norway

9.1 Peak load characteristics

Data from [4] (SSB) is used for evaluation of the Norwegian market, along with data from Nord Pool, and data gathered from project activity (hourly meter readings).
Figure 28 shows the Norwegian peak can be reduced with 1300 MW by peak cutting during 25 hours per year and by 2000 MW by increasing the annual number of hours to 100.

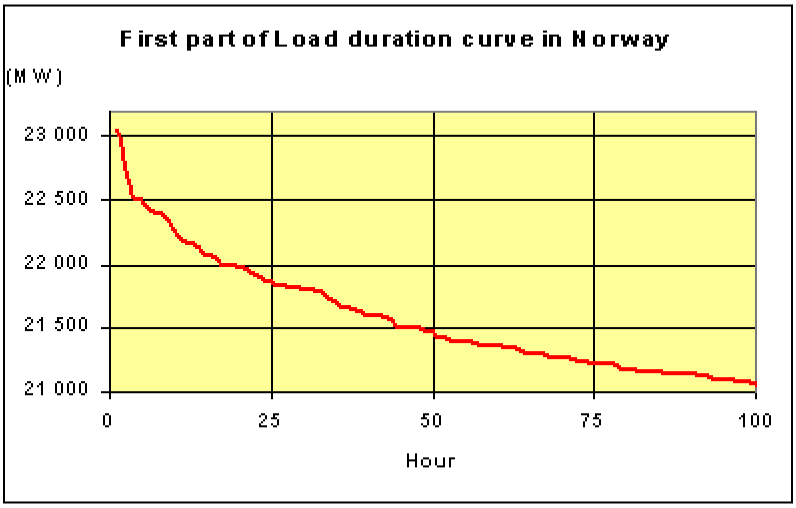

Figure 28 Load duration curves in MW including only the first 100 hours.

Figure 29 shows the daily load shapes during the three peak days have the same characteristics with morning peak. The levels differs rather much.

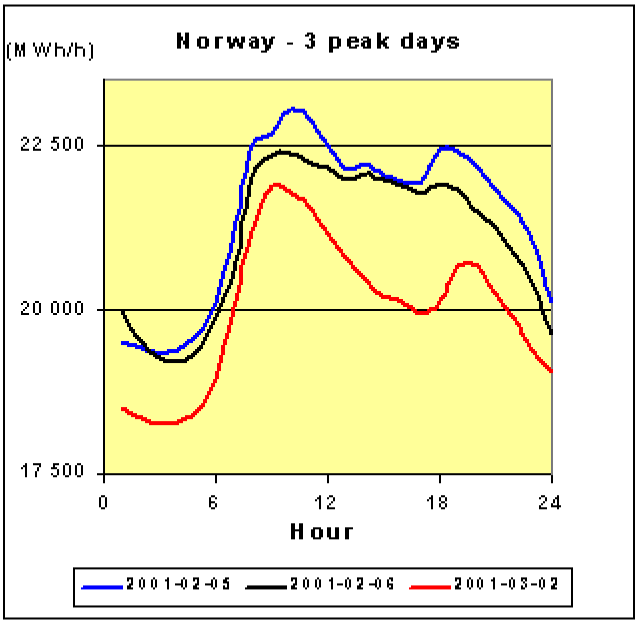

Figure 29 Three peak days in 2001 for Norway.

9.2 Potential for Demand Response

9.2.1 Potential load reduction for different customer groups

Table 9.1 show that the potential is estimated to be 15-30% of the peak demand.

Sector	Customers [Number]	Sites [Number]	Energy [TWh]	Load (coincident) [MW]	DSB Potential [MW]
Household	1 840 000	1 840 000	35.5	6670	1900-4000 depending on duration and outdoor temperature
Service	80 000	≈ 80 000	21.4	6030	
Industry	12 000	> 12 000	45.3	5680	> 3000
Power Intensive	13	30	-	-	1300 – 3000
Pulp and paper	-	-	-	-	500
Rest	110 000	-	9.4	1770	-
Network losses	-	-	11.2	2950	-
Total	≈ 2 000 000	-	122.8	23000	≈ 3000 - 7000

Table 9.1 DSB potential in Norway.

The power intensive industry is an important target group for DSB in Norway since it only include few decision makers (30 com.) and use more than 60% of the industrial consumption.

A questionnaire towards the power intensive industry showed that the power intensive industry has a potential to contribute, with a substantial amount of power reserves, for critical situations on the electricity power markets in Norway. The maximum market potential for the power industry revealed in the survey is 1240 MW for one-season system services. This is about 40% of the technical potential 3000 MW for these customers. The total market potential for DSB (in table 9-2) is thus between 3000 and 5200 MW.

The survey also showed that economical incentives are important. The higher the availability and activation payments, then the higher the reported potentials for demand reductions. Guaranteed payments also seem to give higher reductions than non-guaranteed payments.

For more exact estimation of the short and long term potential market potential for DSB, further analysis is necessary among other large customers as well as residential and other customers groups with yearly consumption below 100 000 kWh in relation to:

- Size of compensation (different kind of economical incentive)
- Maximum duration and frequency of disconnection
- Possible comfort reduction
- Comprehension of the need for load reduction and the solutions of the problem
- Need of information from the utility
- A decision basis
- Necessary infrastructure to perform demand response operation.

9.3 Peak load segmentation

The segmentation of the metered peak load curve into different customer types is estimated based on models of each of the customer types along with an estimation of the network losses. A simulation of the country electricity demand for each hour during the year is performed with the USELOAD model. The total simulated demand for each hour is compared to the metered consumption, and all simulated values are stretched or lowered with a factor so that the total agrees with the metered value. To simulate the consumption of the different customer types for a particular hour; customer load profiles are used. The customer load profiles are results of load research activity in each country.

Network losses are simulated assuming that losses in lines are proportionate to the square of the load, and that losses in transformers are constant during the year.

The described method yields a segmentation that is not 100% correct, but is sufficient to give a broad picture of how different customers contribute to the coincident load.

Figure 32 shows a segmentation of the peak day for Norway.

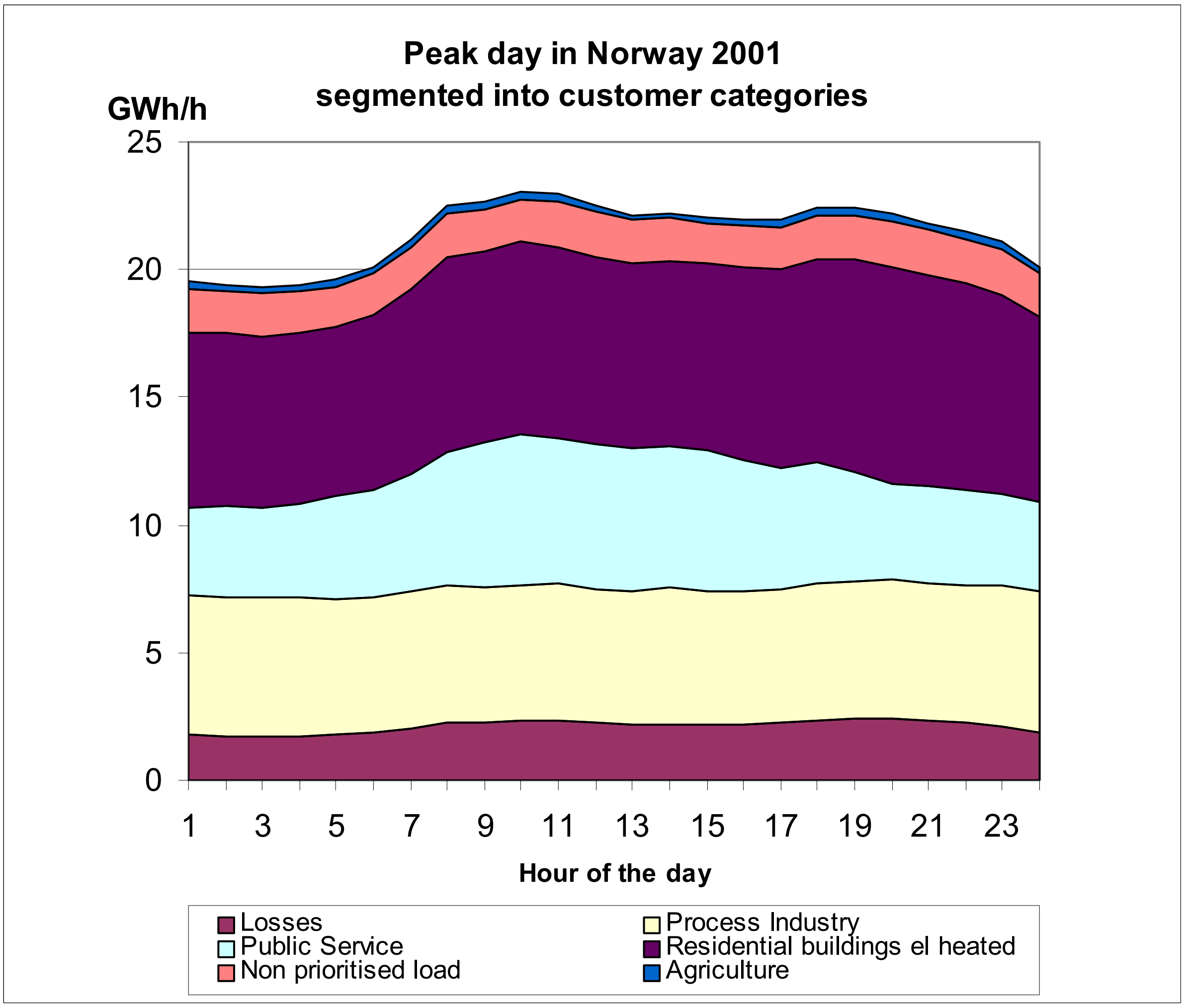

Figure 32 Norwegian daily peak load curve segmented into customer categories.

Figure 33 shows a segmentation of the yearly load curve for Norway.

From figure 33 can be seen that the industrial load is constant over the year while residential and commercial sectors have seasonal variations mainly due to heating and lightning. Non-prioritised load (el. boilers) also show a greater demand during winter as well as agriculture.

The difference in load between seasons most certainly is a result of space heating, which has a high penetration in Norway.

Network losses clearly follow the total consumption, with a lower demand during summer and a peak during wintertime.

It is easy to see that the public sector has the biggest difference between day and night demands, but also the domestic sector has a higher demand during daytime. Industry has a flat consumption during the day, and the 'flatness' continues all through the year. Agriculture seems to be less important at the peak day of Norway.

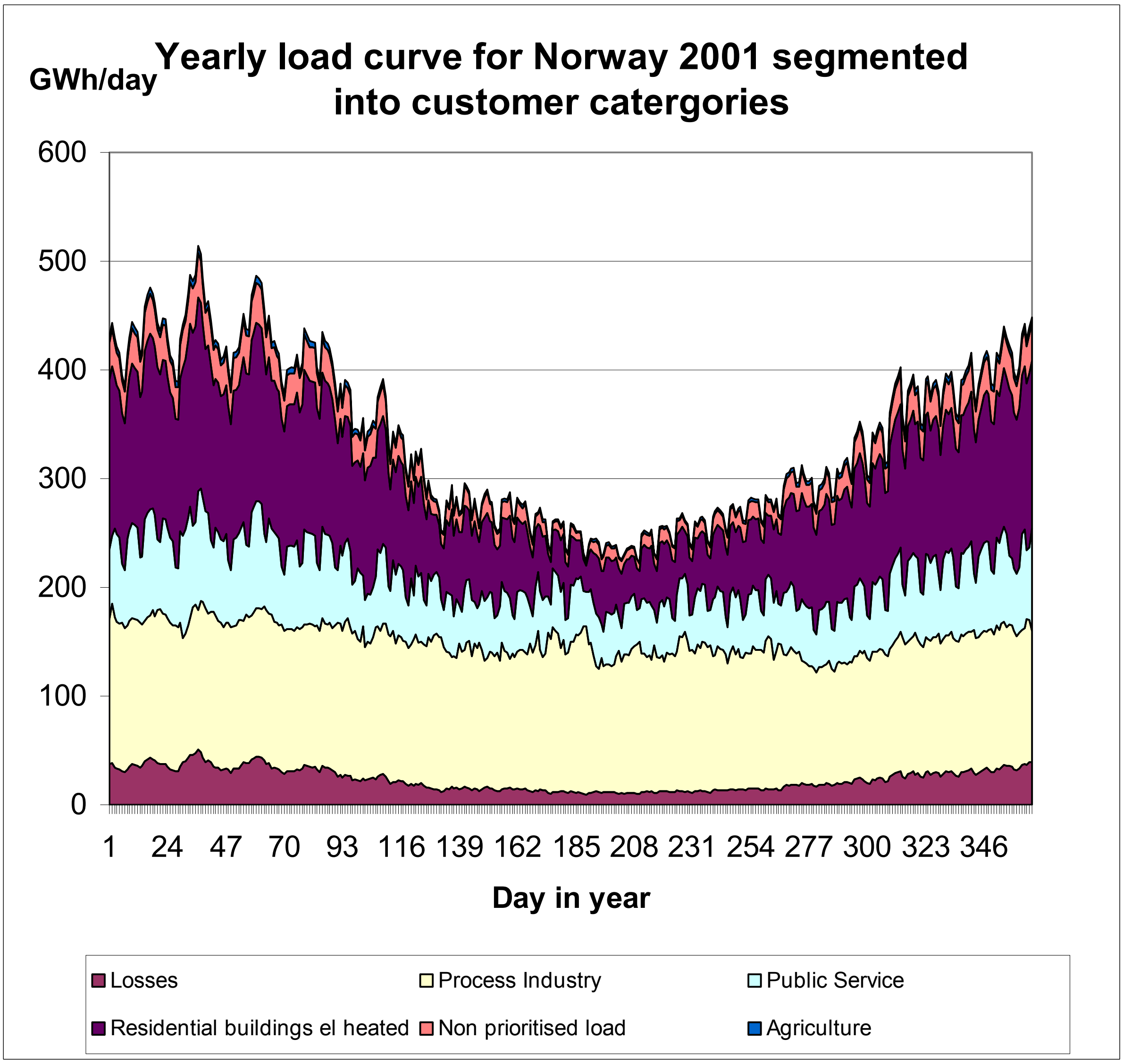

Figure 33 Norwegian yearly load curve segmented into customer categories.

10 Demand response potential in Sweden

Data from SCB [5] is used for evaluating Swedish customer load, along with data supplied from SYCON.

10.1 Peak load characteristics

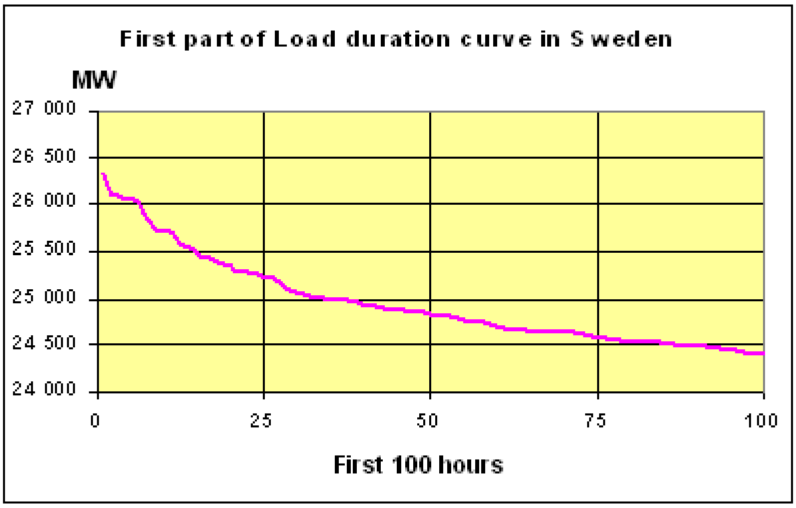

Figure 34 Load duration curve for Sweden including the first 100 hours with highest demand.

The Swedish peak can be reduced:

- 1000 MW by peak cutting during 25 hours per year.
- 2000 MW by peak cutting during 100 hours per year.

Figure 35 shows the daily load shapes during the three peak days are similar, taking into consideration what's earlier mentioned about the fifth of February 2001. The evening peak occurs one hour earlier in December than in February, which probably depends on that the daylight disappears earlier in December than in February. The levels differs around 500 MW between second and fifth of February, but should have been 1000 MW more if the authorities hadn't advertised in TV and other media about need for load reduction.

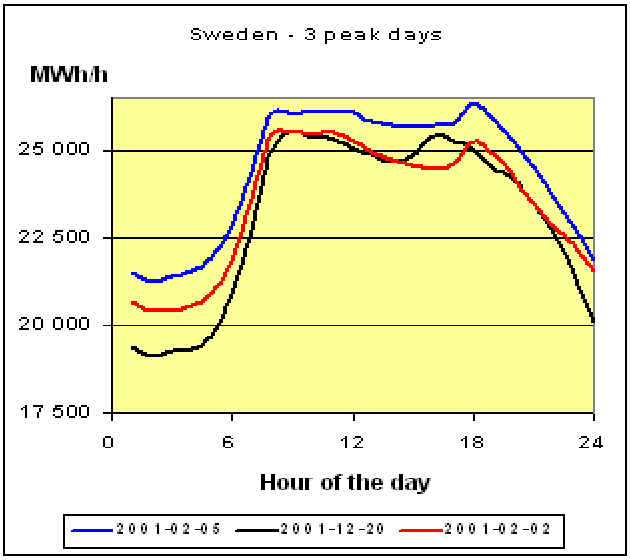

Figure 35 Three peak days in 2001 for Sweden.

10.2 Segmentation of the Peak day load curve

Figure 36 shows a segmentation of the peak day for Sweden.

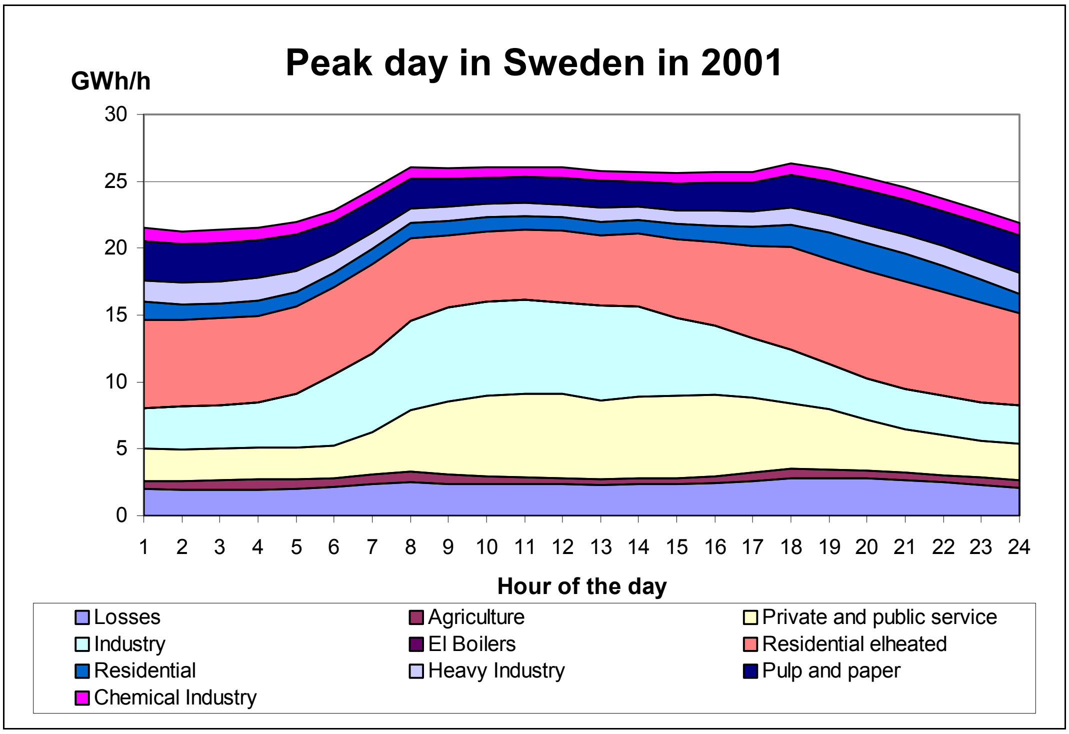

Figure 36 Swedish daily peak load curve segmented into customer categories.

11 Demand response potential in France

11.1 Peak load characteristics

Figure 37 shows the French load duration curve for the 100 hours with highest demand.

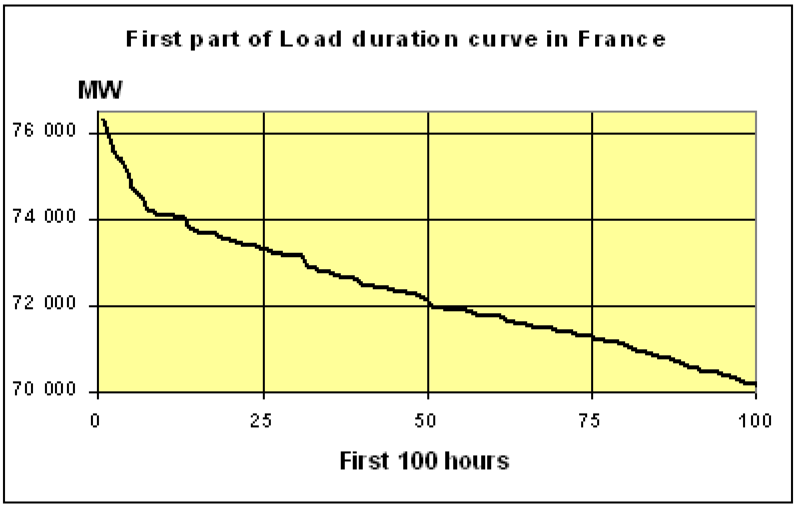

Figure 37 Load duration curve for France including the first 100 hours.

The French peak can be reduced:

- 2800 MW by peak cutting during 25 hours per year.
- 6000 MW by peak cutting during 100 hours per year.

Figure 38 shows the daily load shapes during the three peak days are similar and the levels are also very close to each other. If the peak is cut only 1 hour per day during the peak days a reduction of 1400 MW ought to be achieved.

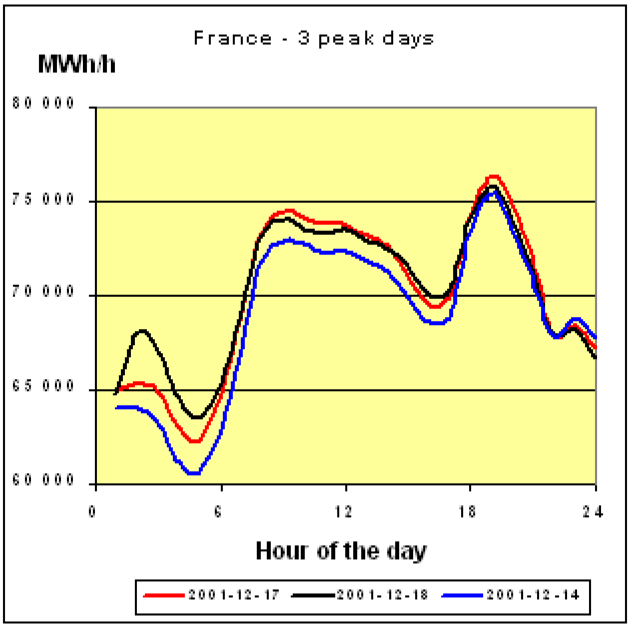

Figure 38 Three peak days in 2001 for France.

11.2 Segmentation of the French daily load curve

Figure 39 shows a segmentation of a French daily load curve into customer sectors.

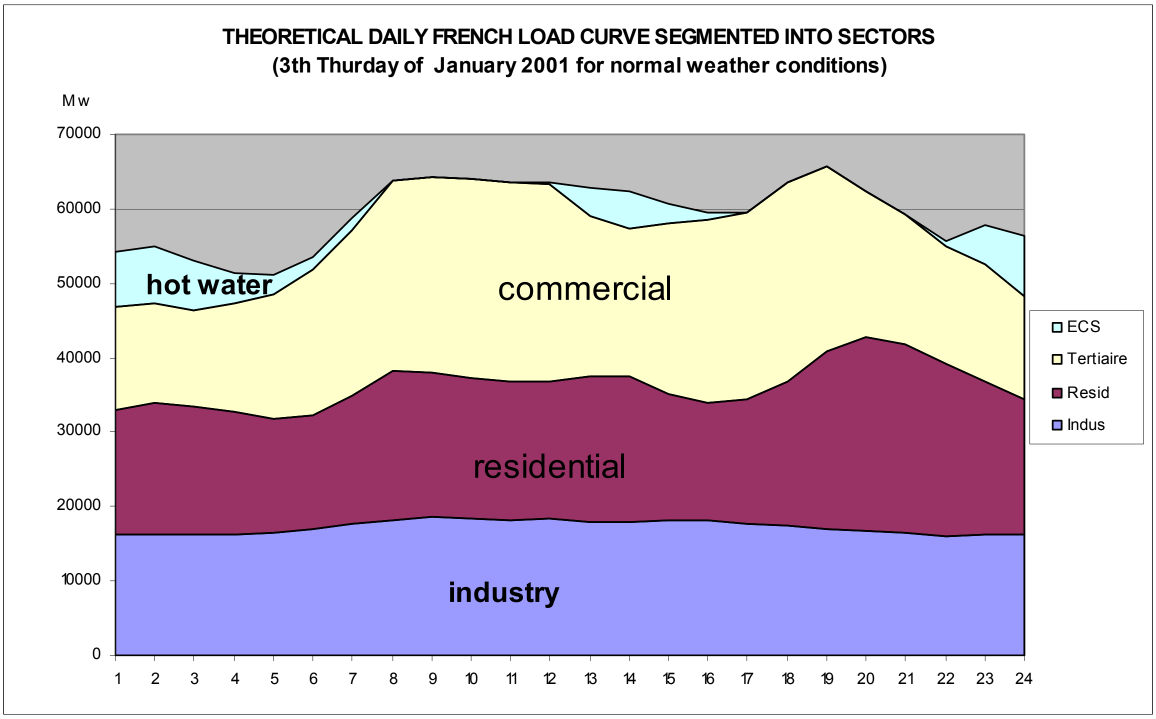

Figure 39 Segmentation of a daily load curve into customer sectors.

12 Demand response potential in UK

12.1 Peak load characteristics

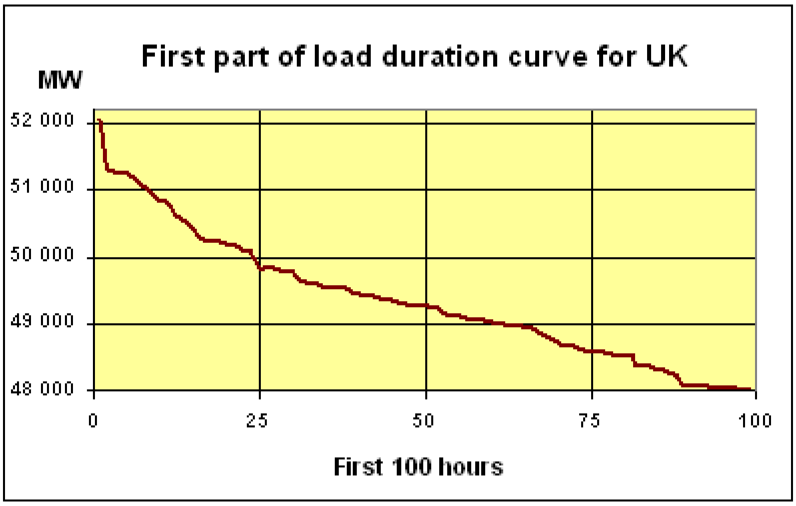

Figure 40 Load duration curve for UK including the first 100 hours.

The UK peak can be reduced:

- 2000 MW by peak cutting during 25 hours per year.
- 4000 MW by peak cutting during 100 hours per year.

Figure 41 shows the daily load shapes during the three peak days are similar and the levels are also very close to each other. If the peak is cut 3 hours per day during the peak days a reduction of 3500 MW ought to be achieved.

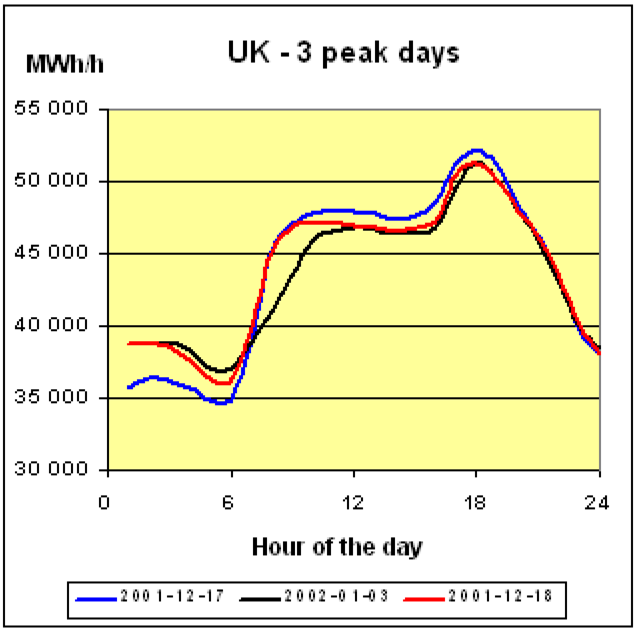

Figure 41 Three peak days in 2001 for UK.

13 Load coincidence in Nordic market

The Nordic countries are relatively small compared to France and UK. However in the Nordic countries there is a common power exchange, Nord Pool, which creates a common electricity market of the same size as the French or UK market.

The Nord Pool market contains several acting generators of different sizes. No one of the actor controls more than 20% of the generation. The objectives of Nord Pool are power trading and power trading services. The Real time balancing is a business for the TSO's not involving Nord Pool.

This common Nord Pool market makes it interesting to analyse the total demand of the Nordic countries. Figure 42 shows the first 100 hours of the total load duration curve for Nord Pool compared to the sum of the individual load duration curves for the Nordic participants.

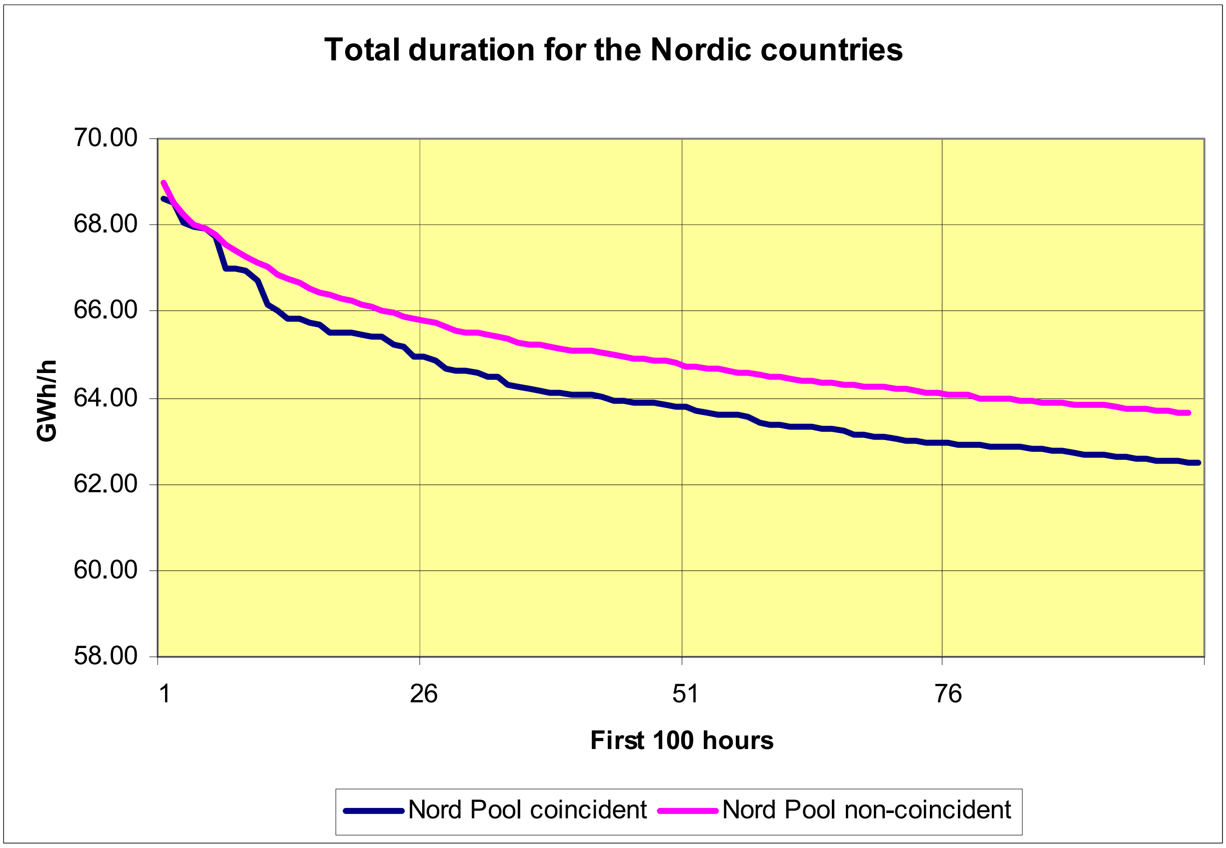

Figure 42 Load duration curve for Nord Pool including the first 100 hours.

The peak load of the Nordic countries can be reduced:

- 3500 MW by peak cutting during 25 hours per year.
- 6200 MW by peak cutting during 100 hours per year.

Figure 42 shows a difference between sum of the national peaks and the peaks of the summation of the load curves for the Nordic market:

- Nearly 0.5% for the 5 highest loads
- 1.0% around 25th highest load
- 1.8% around the 100th highest load

The actual values for the yearly peak are shown in table 13.1. The coincidence might even have been higher than 99,5% since the peak of Sweden often is coincident with the Danish and Norwegian.

Peak per country				
Norway	Sweden	Denmark	Finland	Total
(GW)	(GW)	(GW)	(GW)	(GW)
23,054	26,323	6,229	13360	68,966
Coincident peak demand (5/2/2003 9-10o'clock)				
Norway	Sweden	Denmark	Finland	Total
(GW)	(GW)	(GW)	(GW)	(GW)
23,054	26,095	6,229	13,242	68,624
Coincidence factor 99.5%				

Table 13.1 Coincidence between yearly peaks in the Nordic countries.

As showed above the consumption in the Nordic countries have a high degree of coincidence. Therefore the results from segmentation of the single countries duration curves will in very high degree be similar to the results achieved from analysis of the total Nordic load duration curve. Below you will find the segmented load duration curves from Norway, Sweden and Denmark for the 100 hours of highest demand in 2001.

These segmented load duration curves show:

- The losses vary depending on the variation in demand in different customer segments because those segments are connected to different voltage levels.
- The demand from the residential sector and the industry seems to be complementary, which means that the total is rather smooth, while the segmented demands are irregular.

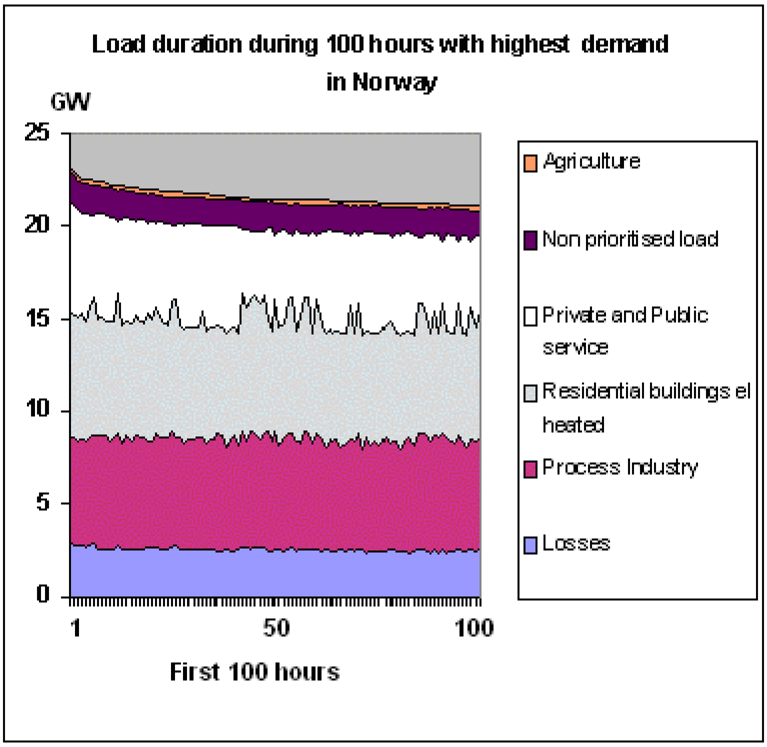

Figure 43 Duration curve for Norway segmented into customer categories.

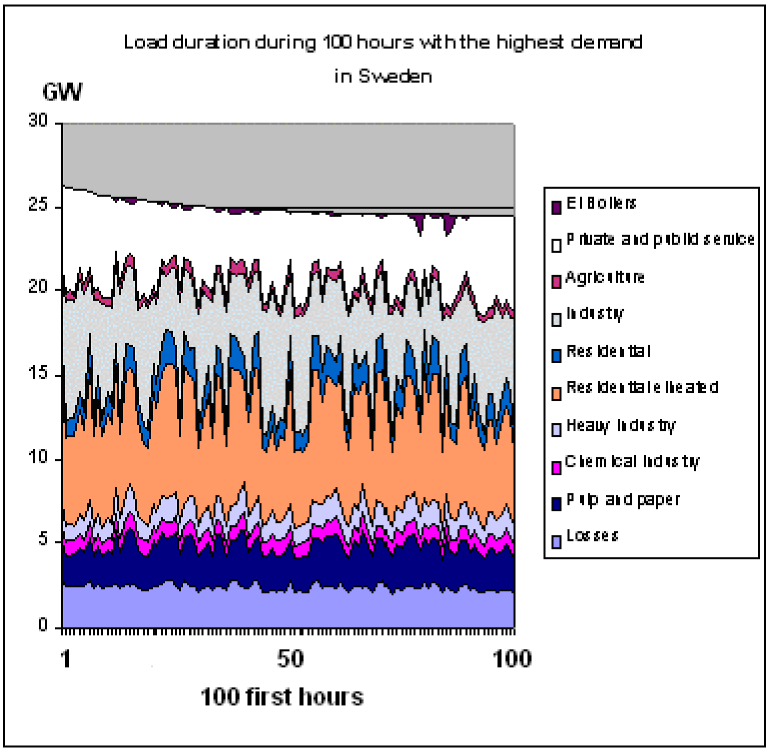

Figure 44 Duration curve for Sweden segmented into customer categories.

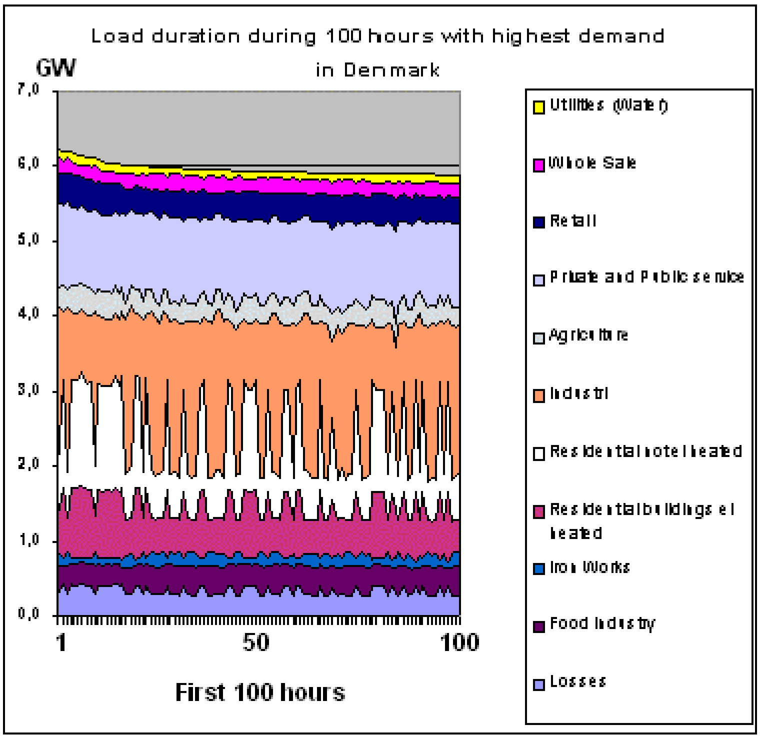

Figure 45 Duration curve for Denmark segmented into customer categories.

14 Load drivers and demand response

14.1 General Load drivers

14.1.1 General

Load drivers as climate, season, day types (weekend/workday), hourly variation, tariffs and customer type have been mapped to better quantify country specific potentials for demand response (load management) and energy efficiency.

The main load driver is the human need and behaviour; which in turn depend on external conditions as time of day, day of the week, season and weather and on random incidents. In this study:

- Time of day has been handled by use of daily load curves with hourly loads.
- Day of the week by dividing the week into weekdays and weekends.
- Seasons by dividing the year into summer and winter, (and spring + autumn when calculating temperature sensitivity)
- Weather sensitivity by analysis of the sensitivity for variations in the outdoor temperature for different seasons.

14.1.2 Time of day

A study of load profiles from the peak days of 2001, reveals that during winter working days the average reduction during night hours from the daily peak is around 25% for most countries. Denmark has a higher reduction of 40% during night. Finland has higher night consumption due to use of TOU tariff with low prices in the night.

The reduction during night is generally caused by reduction of human activity – less use of space heating and lighting during night. Some branches of industry as bakeries and newspaper printing works shows higher activity during nights, but this is quite irregular. Heavy industry often has a flat load during the day, with equal load for all hours during the day and night.

The peak hour for most countries happens in the working hours of 10-12, but many of the countries have a second peak later in the afternoon just before dinnertime almost as high (higher for some countries) as the morning hours. This second peak is due to domestic activity as lighting, heating and cooking.

14.1.3 Seasons

Load profiles are also heavily influenced by annual seasons; the load during winter clearly is much higher than during summer for all countries in the project. This is mostly the result of electric space heating and a lower temperature during winter, but also due to reduction of sun hours during winter, resulting in use more of electric lighting.

Countries that have prioritised district heating on the account of electric space heating clearly show less variation during the year, than the other countries.

14.1.4 Temperature

Temperature is a very important factor of the load profile during cold periods for all countries. In cold periods customers use electric space heating, resulting in negative temperature sensitivities. Even France and UK have high temperature sensitivities, though these countries lie quite far south, and have moderate temperatures all through the year. A reason might be that buildings in UK and France are built under other building codes than Nordic countries, and are less good insulated, needing heating even at moderate winter temperatures. In cold periods domestic customers without direct electric heating, hook up small heaters even though the prices might be high.

In countries like Norway and Sweden temperature sensitivity is highest during spring and autumn. During particularly cold winter days customers are likely to use other energy sources as oil and wood so that the need for electric space heating is somewhat reduced.

In Denmark and Finland most domestic customers use district heating or distributed natural gas heating (Denmark) instead of electric space heating, so these countries have quite low temperature sensitivities.

During summer some customers use air condition, and for some countries this can be seen as positive temperature sensitivity – with higher load at higher temperature.

14.2 Influence from authorities and utilities

14.2.1 Power prices

Power prices seems to have low influence on the load, at least when the prices are low. In most countries customers treat electricity as a necessity resulting in low price elasticity. Also in periods of high prices customers do not regard electricity as luxury good that easily can be reduced. It also is difficult for the customer to reduce the demand manually; automatic reduction of consumption monitored by high prices would lead to higher response.

During the winter 2002 - 2003 Norway has seen a greater customer interest in power prices, caused by a general price increase due to low inflow to the hydropower system. Since the high price period during last winter domestic customers are now more interested in obtaining fixed price contracts for 1-3 years, than using the normal variable price contracts. Customers are also taking interest in initiatives as installing heat pumps, and doing other general energy conservation measures as a result of the power price increase.

14.2.2 Time of use tariffs

In Sweden time of use (TOU) tariffs have mostly been eliminated – Swedish customers want low and predictable prices rather than complicated TOU tariffs. Prices therefore tend to be flat during the day, and the customers gets little incentive for load shifting from day to night.

In Finland TOU tariffs are used, and may be a reason why the peak load profile is more even distributed than for the other countries. TOU tariffs are in Finland applied for low voltage customers, and to power tariffs (low and high voltage customers).

TOU tariffs are in use in UK, which can clearly be spotted on the day profiles as high consumption during evenings.

The TEMPO tariff of France might be considered a TOU tariff, (although an advanced version), and the use of the tariff is reported to give significant reduction to the peak load.

TOU tariffs are of significant interest in ongoing test projects (e.g. Efflocom pilot 6).

14.2.3 *Influence of media*

Media can have a strong influence on the electricity demand. In an example from Sweden 2001, the peak load happened on Monday February 5. The demand had been extreme high since Friday February 2, and the distribution system could collapse if the situation got worse. Information was spread in national media that customers should reduce the consumption during daytime. On Monday the temperature got even lower, but the consumption was reduced from the predicted load as a result of the media influence. The actual peak was delayed from the normal 10 o'clock to 18 o'clock, since the reduction only happened during working hours.

14.2.4 *Use of other energy carriers*

Denmark and Finland are examples of how use of district heating results in a flatter load curve during the year. In Denmark the public authorities have placed restrictions on use of electric space heating, this has resulted in a very low temperature sensitivity of the electricity demand. Use of district heating leads to a more predictable load pattern during the different seasons of the year; example: the tree peak days of Denmark in 2001 are almost equal. The experience of Finland is much the same - use of district heating has resulted in low temperature sensitivities, and the highest load factor of the countries inspected.

14.2.5 *Interruptible load*

In Nordic countries electrical boilers with oil backup are a significant customer type. This type of consumption has the ability to be substituted from electricity to oil when needed, and this characteristic is actively being used in Sweden, where most electrical boilers are out of use during the coldest period of the year. In Sweden the peak load therefore is reduced with 2-3% by switching off the interruptible load.

In Norway there is little use of the potential to reduce load of the electric boilers during cold periods, although the customers show some response when power prices are high. In February 2001 there was an approximate reduction of 50% of the load from el. boilers due to high prices. Still the load from el. boilers had a share of ca 3% during peak hours.

15 Conclusion

The contents of this report comprise the basic analyses of load curves in the EFFLCOM project.

The analyses are based on data from six countries: Denmark, Finland, France, Norway, Sweden and UK, with focus on the following aspects:

- Yearly system load and peak load characteristics
- Costumer segmentation of the total load
- Temperature sensitivity analyses and discussion of other load drivers
- Potential for demand response

The main findings are:

- All countries have quite high temperature sensitivities during spring and autumn.
- For all countries (included France and UK) the consumption is higher during winter than the other seasons.
- All countries show a big difference in the day profiles for working days compared to weekends.
- All countries show reduction in the load during nights. Countries offering Time Of Use (TOU) tariffs with lower prices during night have a flatter profile (less reduction during night). Denmark shows the greatest difference between night and day consumption during winter.
- All countries have two high activity periods during working days, one in the morning and one during evening. UK is special where the evening peak is much higher than the morning peak.
- Reduction of peak load is possible for most countries due to the high activity of the domestic sector during the winter peaks.
- The load from the Industry sector represents the most interesting objects for demand response and power reserves
- The load duration curves for all countries show that 5 % peak load reduction could be achieved by concentrated demand response efforts in 20-75 hours.
- A study of the peak demand in the Nordic countries (Denmark, Finland, Norway and Sweden) shows a high degree of coincidence between the annual peaks of the individual countries. This means that the potential for demand response found by segmentation of the load curve for each country can be added in order to estimate the potential of load reduction in whole region.

Appendix

Description of the USELOAD model

USELOAD is a tool with incorporated database that enables analyses of metered time series of customer loads and end-uses. The program is based upon load curves and end-use load curves from national load research projects and applies statistical methods, climatic dependencies and the diversification in the load among different individual customers. The tool can be used for estimation of e.g. the coincident peak demand in a network with selected confidence, and for simulation of hourly (15/30/60 minutes intervals) demand under selected climate for a network supplying different customer groups. Simulations can be made for up to 100 climatic years in one run.

USELOAD has an integrated metered time series database where individual time series for different customers can be stored and analysed. Metrics as peak load day profiles, temperature sensitivities and seasonal load curves can be estimated and displayed. USELOAD also shows duration graphs, power/temperature and energy/temperature graphs. USELOAD can import data from many different formats: PVE, txt, exp, excel etc. It is also easy to export data from the program into selected format, and supports Windows copy paste.

USELOAD can analyse data based on metered load from single customers stored in the separate database, and construct customer wise load profiles that contains temperature sensitivities, and standard deviations used for estimation of coincident peak load. End-use profiles can also be constructed - based on end-use time series. End-use data will be connected to the customer type where the end-use is metered.

SINTEF Energy Research has developed USELOAD, in cooperation with Electricité de France, Sycon, VTT Energy, Electricity Association and Energy piano.

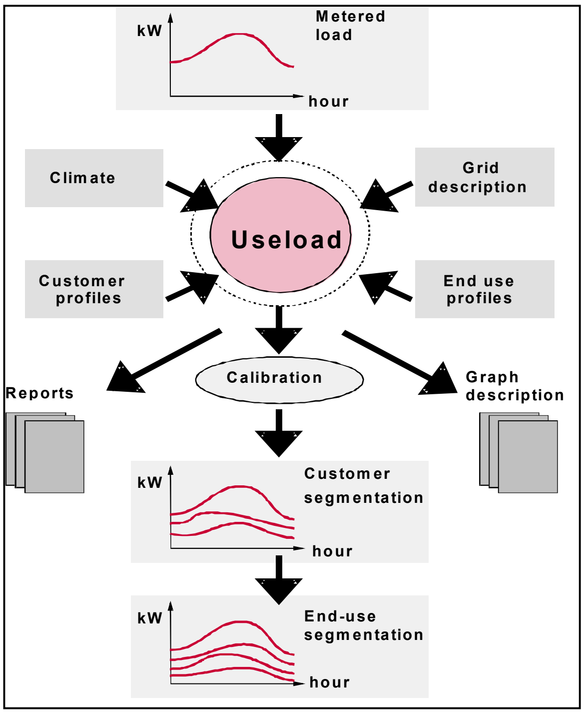

Figure A1 Structure of the USELOAD model.

The overall objective of USELOAD is to model different customer classes and end-use types and to segment continuously metered load into different customer classes and end-use types.
Another important issue for development of USELOAD is to support collecting and storing of end-use and customer profiles, and to support the exchange of such material between different users.

Application fields for the model includes:

- Forecasting of load curves
- Filtering climate, time of day and season influence
- Profitability appraisals
- Load profile estimations for customer types and end-use types
- DSM/energy efficiency evaluations
- Development of alternative scenarios within a strategic assessment framework

The results from the different analyses that can be carried out by using the new tool, makes useful material for following in depth analyses:

- Analyse of continuous (60/30/15 minutes intervals) metered end-use demand in different distribution network areas.
- Estimation of consequences in power and energy demand when introducing new effective equipment as e.g. efficient lighting in residential areas.
- Evaluation of different kinds of remote power control/management.
- Support of system load projections with end-use metering
- Analyse of the influence of implementing energy efficient and flexible solutions.
- In detail end-use and customer segmenting of distribution networks when annual customer class demand are known.
- Temperature correction of power and energy demand between different climatic years.
- Evaluation of marginal/continuous hourly network resistance losses based on known annual total losses for a network.

Considering the above-mentioned possibilities for modelling and network assessments, the model gives benefits for the different market actors:

NETWORK OPERATOR:	Network planning, energy planning, designing of new tariffs, establishing of the optimal customer segment suiting the utility.
Power supplier:	Market analysis, development of new energy services and new products
System operator:	Analyses of demand-side reserves and services
Authorities:	Performing DSM-analyses. Development of instruments directed against the demand side, augmenting the confidence of re-purchasing power.

A more detailed description of the USELOAD model is found on the EFFLOCOM project web site: *www.efflocom.com*

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