Energy consumption 2012

Household energy consumption

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Energy consumption 2012 - Household energy consumption

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Edited by: Ingrid H. Magnussen

Authors: Birger Bergesen, Lisa Henden Groth, Benedicte Langseth, Ingrid H. Magnussen, Dag Spilde, Jun Elin Wiik Toutain

Contributors: Audun Fidje, Karen Byskov Lindberg, Lilly Næss

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Norwegian Water Resources and Energy Directorate
Middelthunsgate 29
Postboks 5091 Majorstua
0301 OSLO

Phone: 09575
Fax: 22 95 90 00
Internett: www.nve.no

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Preface

In this report, the Norwegian Water Resources and Energy Directorate (NVE) aims to provide a rounded picture of energy consumption in mainland Norway. The need for energy is crucial in decisions on whether to construct power plants and installations, for both the production and transmission of energy. The amount of energy we consume and where it comes from also determine the volume of greenhouse gases released by Norway.

This means that energy consumption and energy efficiency are important topics. We need to know how we consume energy in order to implement the right measures for reducing energy consumption and greenhouse gas emissions.

The focus in this report is on households. Over time, NVE has recorded a flattening out of energy consumption in the household sector, without being able to state with certainty why this is the case. This report provides more information about what determines the level of energy consumption in households.

In order to make the right decisions concerning measures directed at household energy consumption, it is important to have a reliable breakdown of end-use consumption in terms of space heating, hot water, and electricity-specific energy consumption. In this report, NVE discusses this end-use consumption, and summarises what, in our opinion, a reasonable breakdown should be.

This is NVE's second report on energy consumption. There will be regular editions, dealing with relevant issues within energy consumption. We hope that readers find this report both useful and informative.

Oslo, March 2013

Birger Bergesen
acting departmental director

Olav K. Isachsen
head of division

Contents

Glossary

Term	Explanation
Energy consumption	Consumption of all types of energy products (electricity, district heating, oil, gas etc.)
Electricity	Electrical power, electrical energy
Final energy consumption	Includes energy for lighting, appliances, hot water and space heating in houses and commercial buildings, for the manufacture of goods in industry and for domestic transport. Excludes energy consumed in the energy sector.
Gross energy consumption in mainland Norway	Total of final energy consumption and energy consumption in the energy sector.
Energy sector	Producers, distributors, retailers etc. of energy, oil, gas, district heating, electrical power etc.
Petroleum sector	Producers, distributors, retailers etc. of oil, gas and refined petroleum products.
Stationary energy consumption	Final energy consumption excluding energy consumed for transport.
Energy consumption in transport	Energy for motorised vehicles and means of transport
Transport	All types of passenger and goods transport, both private and commercial.
Energy-intensive industries	The metals, chemical products and pulp and paper industries.
Other industries	Non-energy-intensive industries.
General consumption	Energy/electricity consumption in households, service sectors, primary industries, building and construction and other manufacturing industries.
Temperature-corrected energy consumption	Actual energy consumption corrected to what it would have been under 'normal' year temperatures.
Smart metering (AMS)	Advanced metering and management system.
Energy intensity	A measure of the amount of energy used per unit. For example, energy consumption per person or energy consumption per area.
Radiant heat	Electromagnetic radiation, primarily light in the infrared region of the spectrum. When radiated heat hits an object, some of the energy in the radiation is absorbed. This causes

	the object to heat up.
Convected heat	The air around, for example, a stove heats up, expands and rises. The heated air displaces colder air. This causes movement in the air, spreading the heat.
Electricity-specific energy consumption	Comprises electricity for electrical appliances and lighting. Electrical appliances can only be run on electricity, and this energy consumption is therefore often referred to as electricity-specific energy consumption.
End-use consumption	How households' energy consumption breaks down by end-use in terms of space heating, hot water, and electricity-specific energy consumption.

Summary

After many years of strong growth, household energy consumption has grown more slowly in the last 20 years, and since 1995 it has almost levelled out at around 45 TWh. The exception was 2010 when, due to the cold weather, consumption was up to 50 TWh. The prime cause of the flattening out is a reduction in the rise in floor area per person and a fall in energy consumption per area. In addition, since the late 1980s, the climate has been noticeably milder, which has led to a reduced heating requirement for buildings.

This is one of the conclusions in this report. The report describes energy consumption in all sectors in mainland Norway up to 2011, with an emphasis on stationary energy consumption in general and household energy consumption specifically.

The report shows that the growth in living space per person has declined from 2.5 per cent per annum prior to 1990 to 1.0 per cent per annum thereafter. There may be a number of reasons for this, but urbanisation and a substantial increase in housing prices are probable contributory factors to the trend. Household energy consumption has fallen from approximately 210 kWh per square metre in the early 1990s to approximately 180 kWh per square metre today. The biggest cause of this fall is improvements to existing housing and better quality of new housing as a result of more stringent energy requirements in the new building regulations. There has also been a trend towards better heating systems.

A number of new studies indicate that the proportion of household energy consumption that is used for space heating is higher than previously thought. Whereas, in Energy Consumption Report 2011, it was estimated that 58 per cent of household energy consumption was for space heating, the new studies indicate that around 66 per cent of total household energy consumption is devoted to space heating. The new household end-use consumption breakdown presented in this report is approximately 66 per cent for space heating, approximately 12 per cent for water heating and approximately 22 per cent for electrical appliances and lighting.

This new end-use consumption breakdown represents an average for all Norwegian households. The size of the dwelling, its type, its geographical location, the size of the household and the behaviour of occupants are factors that may cause significant deviations from the average. In 2011, NVE surveyed the electricity-specific consumption of 2,000 Norwegian households. This showed that the number of people in the household is the most influential factor for electricity-specific consumption.

Outdoor temperature is an important factor for energy consumption in buildings. There has been a rise in the outdoor temperature in recent decades. NVE's calculations show that the higher outdoor temperature from the late 1980s to the present day has led to a total reduction in energy consumption in Norwegian households of 2-3 TWh/year. Most of the energy for heating is consumed in winter, which means that cold winters have very high energy consumption. Electricity is the most used energy product for space heating in Norway, and high electricity consumption at times of low outdoor temperatures is a challenge for the power grid. Low investments in the power grid in the last 20 years have produced a need for new investment and improvements in the central grid.

Following a number of years of flattening out, the stationary energy consumption in mainland Norway rose strongly in 2010. This was because 2010 was one of the coldest of the last one hundred years, causing high energy consumption for space heating in homes and commercial premises. 2011 on the other hand was mild, and less energy was consumed for heating. Stationary energy consumption peaked at 165 TWh in 2010, falling back to the long-term trend of just under 160 TWh in 2011. In the same period, energy for transport increased by 0.3 per cent.

Other factors that influence energy consumption are the choice of heating solution and consumer behaviour. In addition, in recent years the EU has influenced Norwegian households' energy consumption through the incorporation into the EEA Agreement of, for example, the Renewable Energy Directive, aimed at ensuring that the proportion of renewable energy increases, and the Energy Performance of Buildings and the Energy Labelling Directives, which both have the goal of reducing energy consumption.

1 Introduction

Norway is a country of substantial energy resources such as water, wind, oil and gas. A large proportion of stationary energy consumption is covered by hydroelectricity, while the majority of the oil and gas is exported to the EU which is Norway's most important trading partner. The EU needs to import large quantities of energy from countries outside of the Union and faces a scenario where, in 2030, 70 per cent of its energy requirement will need to be met by energy from non-EU countries. To a large extent, energy consumption will be linked to economic growth and it is anticipated that energy consumption will increase far into the future.

The increasing energy requirement can only be met to a limited extent by increased energy production. Land disturbance and atmospheric emissions resulting from the production and distribution of energy are problematical. Requirements for increased use of renewable energy mean that at times conflicting concerns for the environment, security of supply and value creation must be balanced. In order to stem and regulate this increasing energy requirement, there has been a keen focus on energy efficiency in the EU, and also in Norway (Energiutredningen, 2012), (Klimameldingen, 2012) and (Bygningsmeldingen, 2012).

In June 2012, the Council of Europe and the European Parliament agreed on an Energy Efficiency Directive to ensure that the member states save 20 per cent of the energy which the EU is set to consume in 2020. Such energy efficiency will also boost industry's competitiveness and safeguard employment[1]. This Directive was adopted by the EU in October 2012.

A number of studies have shown that there is great potential for making housing more energy-efficient (Enova, 2012). Knowledge about household energy consumption is important for understanding future energy consumption trends and for making sound decisions on measures directed at households. Household energy consumption has flattened out in recent years, but there has been uncertainty over the reasons for this, as discussed in NVE’s report on energy consumption from 2011 (Energibruksrapporten, 2011). NVE has a responsibility to facilitate reliable, efficient and environmentally-friendly energy supply and efficient energy consumption. In order to gain more knowledge about energy consumption in the household sector, NVE conducted two projects aimed at households in 2011 (Xrgia, 2011), (Vestlandsforskning, 2011). These projects are cited here and have yielded important information about the driving forces for household energy consumption.

From a climate perspective, it is necessary to replace fossil energy sources with renewable energy. More hydroelectricity and wind power are being developed in Norway. In order to secure sufficient electricity on demand for all consumers, there must be an equilibrium between production and demand, and adequate transmission capacity must be in place. For this reason, major investments in the Norwegian electricity grid are planned for the years ahead (Nettmeldingen, 2012).

Chapter 2 of the report maps out and summarises energy consumption in Norway in the various economic sectors for the period 1976 to 2011. Chapter 3 discusses household

[1] Non-paper of the services of the European Commission on Energy Efficiency Directive, April 2012

energy consumption, with a summary of what NVE considers to be a reasonable breakdown of end-use consumption. How household energy consumption is affected by decisions in the EU is described in Chapter 4, which deals with three different Directives which are incorporated into the EEA Agreement. Chapter 5 discusses the need for more power lines in the light of the trend in energy consumption.

2 Energy consumption in Norway

Final energy consumption in mainland Norway in 2011 was 214 TWh. In addition, the energy sector consumed 15 TWh. After a very cold year in 2010, 2011 was one of the mildest years in a century. This resulted in the energy consumption in commercial buildings and households being 10 per cent lower in 2011 than in the previous year.

2.1 Gross energy consumption in mainland Norway

Gross energy consumption in mainland Norway includes final energy consumption[2] and energy used for producing other energy products[3]. Final energy consumption is energy for lighting, appliances, hot water and space heating in houses and commercial buildings, for the manufacture of goods in industry and for domestic transport. Energy used for international sea and air travel and own-produced energy on the Norwegian Continental Shelf are not included.

In this context, energy consumption means gross consumption of all types of energy products converted to kWh. Energy products can be divided into seven main groups: electricity, district heating, heating oil, coal, gas, bioenergy and gasoline/diesel. The first six of these are mainly used in buildings and industrial processes, while gasoline and diesel are used as fuel for transport.

Total energy consumption in mainland Norway in 2011 was 229 TWh, a fall of 8 TWh from the previous year. The fall is due primarily to warmer weather, which reduced the need for energy for heating houses and commercial buildings. 2011 was one of the mildest years documented over the last century. For comparison, 2010 was the coldest year in Norway since 1985, causing record high energy consumption in this year.

The trend in energy consumption in mainland Norway is illustrated in Figure

Energy content

In order to compare energy products, they are all converted to kilowatt hours (kWh). Except for electricity and district heating, the energy content is calculated on the basis of the theoretical energy content of the energy product. The energy content of an energy product will vary, but Statistics Norway uses average values to convert to kWh. Below are Statistics Norway's conversion factors for the most used energy products. Electricity and district heating are sold in kWh and therefore do not need conversion factors.

Coal and coke	7,800 kWh/tonne
Natural gas	11,800 kWh/1,000 Sm3
Gasoline	12,200 kWh/tonne
Diesel and light fuel oil	12,200 kWh/tonne
Fuelwood	2,200 kWh/solid m^3

[2] Final energy consumption corresponds to domestic final energy consumption in Statistics Norway's Energy Balance.
[3] The energy sector in mainland Norway includes the production of electricity, the production of district heating, shoreside installations in the petroleum sector, the refineries, and oil and gas platforms that take power from onshore. Energy products consumed as raw materials for producing new energy products (conversion) are not included. See the Energy Balance.

2.1. The figure shows that energy for households and service sectors rose markedly from 2009 to 2010, and then fell back in 2011. The total energy consumption in these end-user groups was 87 TWh in 2010, falling to 79 TWh in 2011. In the period 2000 to 2009, average energy consumption in these two sectors was 77 TWh, of which approximately 45 TWh was in households and about 32 TWh in the service sectors.

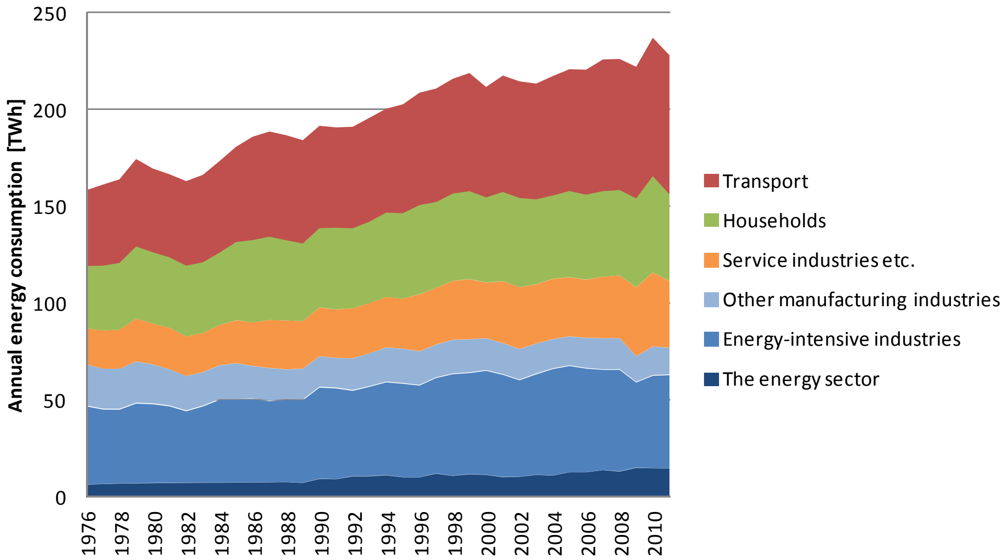

Figure 2.1 Energy consumption by sector in mainland Norway[4]. Source: (SSB, 2012)

Units

Energy can be measured in different units. The unit used in this report is kilowatt hours (kWh). Power is measured in watts (W) and energy in watt hours. Using one watt for one hour is consumption of one watt hour. Household consumption is typically measured in kilowatt hours (kWh), which is one thousand watt hours. When we analyse total energy consumption in Norway, it is more appropriate to use larger units, such as TWh.

Kilowatt hours	kWh	
Megawatt hours	MWh	thousand kWh
Gigawatt hours	GWh	million kWh
Terrawatt hours	TWh	billion kWh

An average household uses about 21,000 kWh of energy per year. Of this, some 16,000 kWh is electricity. For comparison, the largest energy-intensive companies use several TWh per year.

[4] Energy consumption in the service sectors here also includes energy consumption in buildings in the building and construction sector and commercial buildings in the primary industries.

2.2 Energy consumption in transport in mainland Norway

The sale of fuel for domestic transport rose by 0.3 per cent from 2010 to 2011. This includes both sales for households' private cars and commercial vehicles. Since 1976, energy for domestic transport has experienced annual growth of 1.8 per cent. After flattening out as a result of the financial crisis in 2008 and 2009, sales reached a new peak in 2010 and are now about 72 TWh per year. This trend is illustrated in Figure 2.2.

Figure 2.2 shows that gasoline and diesel are the dominant energy products for transport in mainland Norway. Some electricity is used for trains, trams and the metro, and some gas for ferries and buses. Electricity for road transport currently constitutes only a small proportion of total energy consumption for transport, but is expected to increase in the years ahead. In addition, as of 2005 more biofuel has been used as a blend with fossil fuels. This is shown by the green area in Figure 2.2. A 3.5 per cent blend of biofuel is now a legal requirement in vehicles used for road transport.

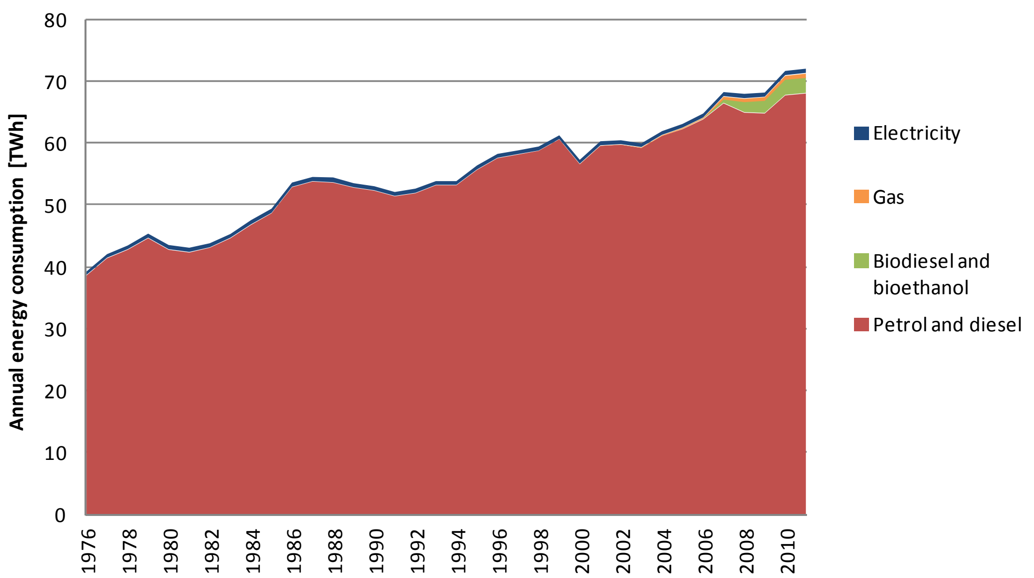

Figure 2.2 Energy for transport by energy product. Annual figures. Source: (SSB, 2012)

2.3 Stationary energy consumption in mainland Norway

Energy for buildings, industrial processes and the production of energy products (the energy sector) is called stationary energy consumption, as opposed to energy consumption in transport. The remainder of this report concentrates on stationary energy consumption in mainland Norway, with a primary focus on household energy consumption.

2.3.1 Energy efficiency leads to reduced energy consumption

After peaking at 165 TWh in 2010, stationary energy consumption in mainland Norway fell back to the long-term trend of just under 160 TWh in 2011. It has been at this level since 1998, with the exception of 2010. This is shown in Figure 2.3. Households account for around 30 per cent of total stationary energy consumption in mainland Norway, with annual consumption varying from 44 TWh to 50 TWh in recent years.

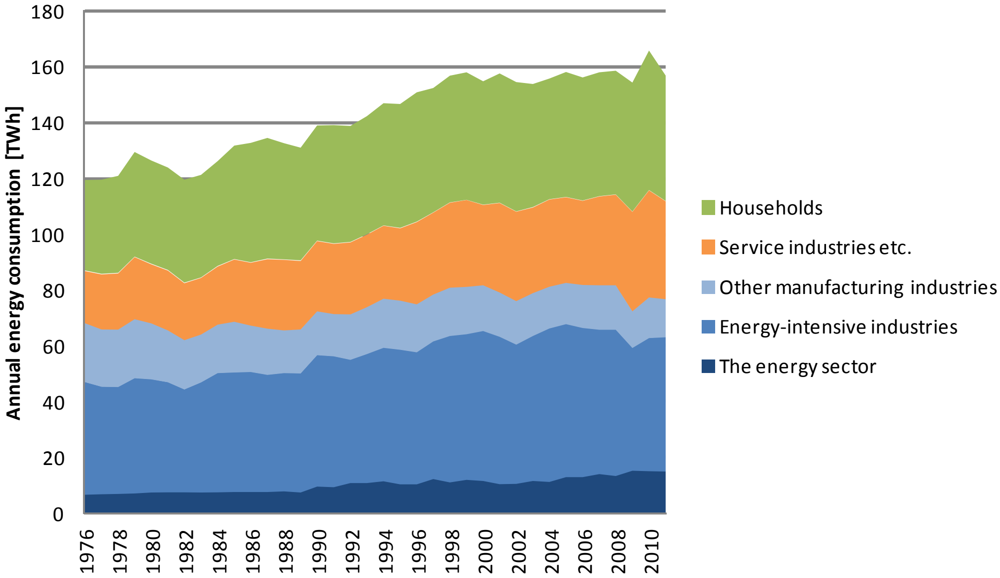

Figure 2.3 Stationary energy consumption in mainland Norway by sector. Source: NVE / (SSB, 2012)

One major reason for stationary energy consumption flattening out is better-designed buildings, energy-efficiency measures and better heating systems. A study carried out by the Vestlandsforskning research institute shows that household energy consumption per area was reduced by 14 per cent from 1990 to 2009. This is described in more detail in the chapter on household energy consumption. To date, there have been few studies of the overall effect of energy-efficiency measures in commercial buildings. Enova has however subsidised many energy-efficiency projects that have contributed to lower energy consumption in commercial buildings.

Building-focused measures are effective for as long as the building is standing, and energy-efficient heating appliances are effective for as long as they are operational. Measures employed in the building stock therefore yield reductions in energy consumption long after they are first implemented.

2.3.2 Consumption in electricity is flattening out

More than 70 per cent of stationary energy consumption in mainland Norway is covered by electricity. Energy-efficiency measures mentioned in the previous chapter have contributed to a flattening out of energy consumption since the late 1990s. In addition, a milder climate and a switch to other energy products have resulted in lower consumption of electricity for heating.

The closure of a number of energy-intensive-industry businesses has also been instrumental in the flattening out of energy consumption in mainland Norway. Energy consumption in industry has been reduced by several TWh in the last decade.

The only sector in mainland Norway experiencing a marked growth in electricity consumption is the petroleum sector. Here, consumption has risen from less than 1 TWh in 1995 to 6 TWh in 2011. This is due to the electrification of installations and platforms in the petroleum industry.

The trend in overall electricity consumption in mainland Norway is illustrated in Figure 2.4. Whereas there was annual growth in electricity consumption of 1.7 per cent from 1976 to 1998, there was only 0.1 per cent annual growth from 1998 to 2011. In 1998, net consumption of electricity in mainland Norway was 110.7 TWh, while in 2011 it was 112.3 TWh. Figure 2.4 shows that annual electricity consumption in mainland Norway has kept to a level of just over 110 TWh since the late 1990s, except for 2010 when it was up to 120 TWh due to the cold winter months in that year.

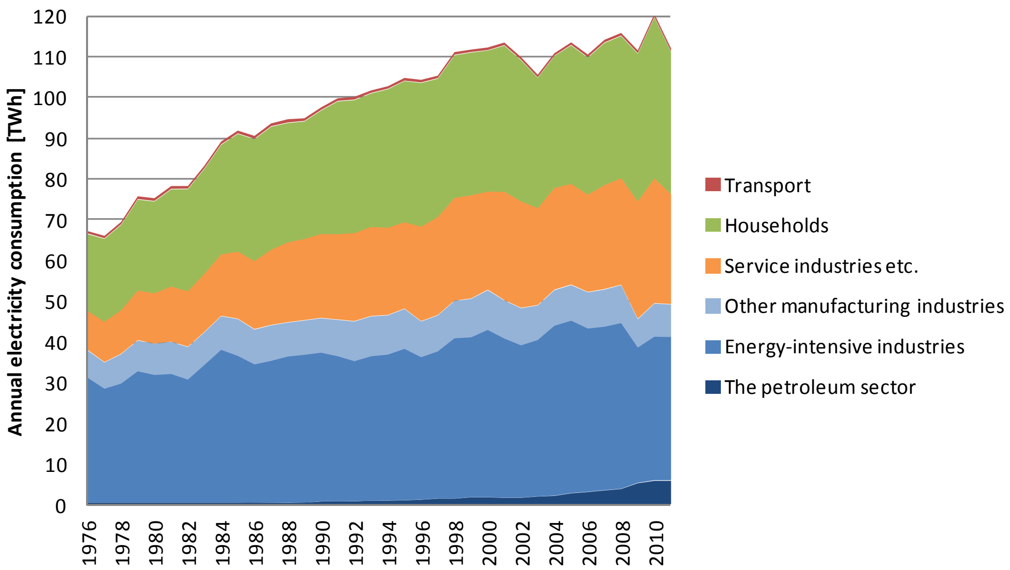

Figure 2.4 Electricity consumption in mainland Norway by sector. Source: NVE / (SSB, 2012)

2.3.3 Outdoor temperature remains highly significant for energy consumption in buildings

Although energy efficiency and improved heating systems have helped dampen growth in energy consumption in households and service sectors, energy consumption in these sectors remains highly influenced by outdoor temperatures. Two-thirds of households' energy consumption and around 40 per cent of energy consumption in commercial buildings is used for space heating and 2010 demonstrated that energy for heating spikes when outdoor temperatures fall.

The main cause of the large rise in energy consumption in 2010 and fall in 2011 was outdoor temperature variations. In 2010 there were two very cold periods within the same year. Both the first and the last months of 2010 were far colder than normal for the time of year. The first three months of 2011 were also colder than average. Conversely, the rest of the year was very mild in most of Norway.

The energy consumption recorded in the years 2010 and 2011 shows that the difference between a warm and a cold year can be up to 9 TWh for Norway's total building stock, i.e. houses and commercial buildings combined.

Figure 2.5 shows an overview of energy consumption in households and service sectors since 1976. It illustrates the powerful impact of a cold year on energy consumption in these end-user groups. Following a marked peak in 2010, energy consumption fell back to its long-term level of just under 80 TWh[5] in 2011.

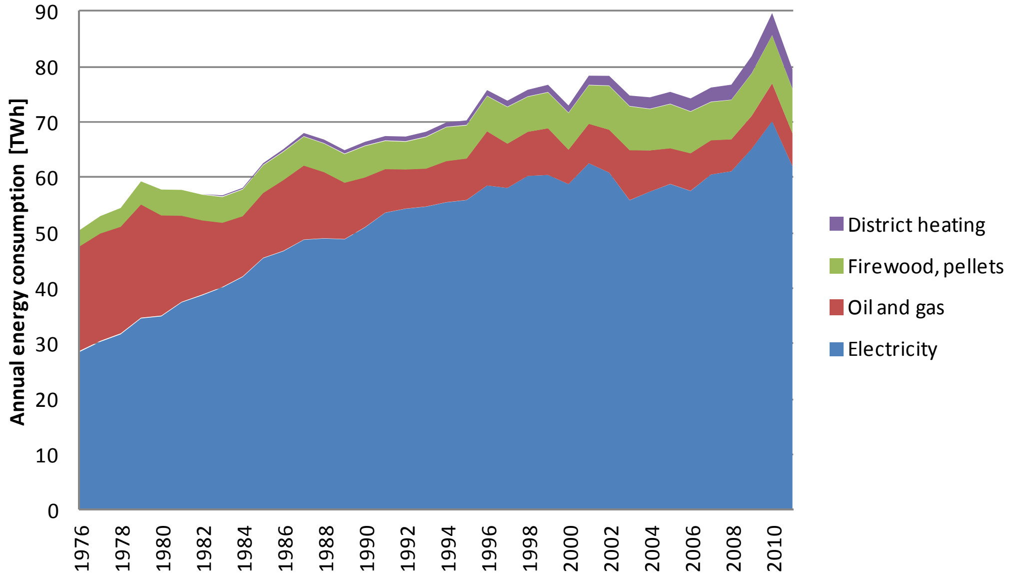

Figure 2.5 Energy consumption by energy product in households and service sectors. Source: NVE / (SSB, 2012)

Outdoor temperatures also affect the relative consumption of different types of energy products. Electricity is used for electrical appliances, lighting and heating in houses and commercial buildings, while other energy products such as heating oil, firewood, wood pellets and district heating are used only for heating. This means that the use of district heating, bioenergy, heating oil and paraffin in buildings is even more affected by outdoor temperatures than electricity is. From 2009 to 2010, while the consumption of electricity rose by 7 per cent, the consumption of bioenergy (firewood and wood pellets) and fossil fuels rose by 15 per cent and the consumption of district heating by a full 30 per cent. In 2011, sales of fuelwood, paraffin and heating oil dropped back again by 20 per cent.

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5 Does not include industrial buildings. Statistics Norway's industrial statistics show a decline in energy consumption in industrial buildings from 2010 to 2011.

The trend in the consumption of district heating, bioenergy, oil and gas in households and service sectors is illustrated in Figure 2.6. The figure shows that, while consumption of fossil fuels has fallen since the 1970s, consumption of firewood, wood pellets and district heating has risen. This is because many oil and gas-fired boilers have been replaced by bioenergy boilers or connected to the district heating network. Most district heating is used in commercial buildings in the service sectors, while most fuelwood is used in households.

Figure 2.6 also shows that consumption of heating oil, district heating and bioenergy rose strongly in the years 1996, 2002/2003 and 2010. This is because, in years with cold winters, more energy for heating is required and in some buildings electrical heating alone is insufficient.

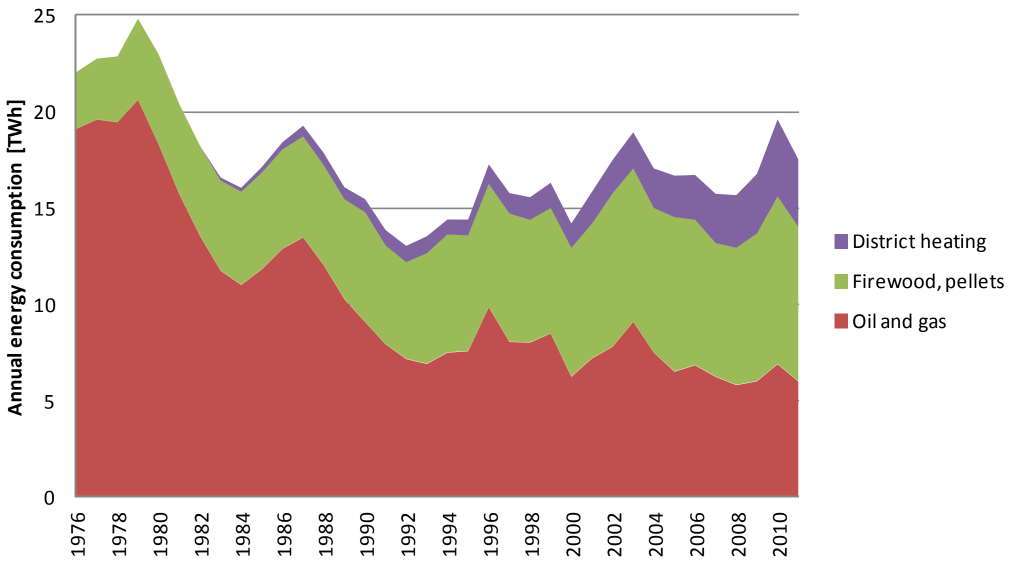

Figure 2.6 Use of district heating, oil and bioenergy in households and the service sectors. Source: NVE/ (SSB, 2012)

In addition to outdoor temperature, the price of the different energy products affects their individual consumption. When the price of electricity rises, some electricity will be replaced by fuelwood and heating oil. This was especially evident in the autumn of 2002 and spring of 2003 when the price of electricity rose strongly due to the dry autumn of 2002. High electricity prices in the winters of 2009/2010 and 2010/2011 produced the same outcome.

This shows that thermal energy products such as fuelwood, district heating and heating oil are very important for meeting heating requirements in cold winters, and they are important alternatives to electricity.

3 Household energy consumption

After many years of strong growth, since 1990 household energy consumption has risen more slowly. From 1995, it has almost flattened out. This is primarily due to a reduction in the increase in floor area per person and more efficient use of energy. New knowledge of how we consume energy in our households provides updated information about the end-use breakdown of energy consumption. New studies show, for instance, that the proportion of energy used for space heating is higher than previously thought.

In this context, a household is defined as one or more people living together in the same dwelling. There may be several households in the same dwelling, e.g. duplexes and blocks of flats.

This chapter examines important topics concerning households. It begins with a description of the historical growth and subsequent flattening out in energy consumption, and then explains why this happened. There follows a description of key drivers in energy consumption and how consumption is broken down within individual households. Heating solutions are then discussed more thoroughly and, by way of conclusion, a review is given of the behavioural aspects of energy consumption and potential measures for reducing energy consumption.

In 2011, NVE focused on increasing its knowledge of household energy consumption and accordingly initiated two additional studies. One of the studies was conducted by the Vestlandsforskning research institute, and examined reasons for the flattening out in overall energy consumption in the household sector in the last 15-20 years. (Vestlandsforskning, 2011). The other was conducted by Xrgia and TNS Gallup, and dealt with the electricity-specific share of household energy consumption (Xrgia, 2011).

3.1 Flattening out of household energy consumption

Figure 3.1 shows how annual final energy consumption[6] in households has nearly flattened out since the mid-1990s following vigorous increases up to the year 1990. Energy consumption in the last ten years has remained at around 44-46 TWh. 2010 was an exception, with energy consumption at around 50 TWh. This was a particularly cold year, with cold periods at both the start and the end of the year. Provisional figures indicate that energy consumption in 2011 fell back to the flattening trend.

There has been a gradual change in the mix of energy products in households. Figure 3.1 shows that since 1976 there has been an increase in the use of electricity and fuelwood, while oil consumption has fallen. This is due to a gradual phasing out of oil-fired boilers and paraffin stoves as a result of the 1970s oil crisis, higher oil prices and a gradual switch to electric heaters and heat pumps. In addition, wood burning has become increasingly more common and there has been a large increase in the number of clean-burning wood stoves in households.

[6] Final energy consumption means energy for lighting, appliances and heating.

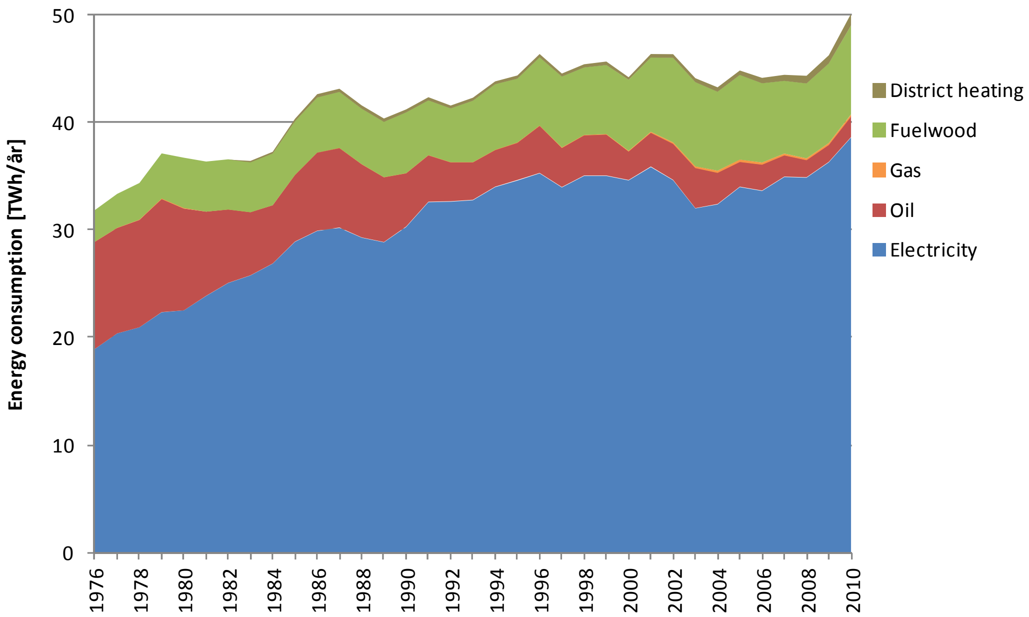

Figure 3.1 Household energy consumption, 1976 to 2010. (SSB, 2012)

Figure 3.2 explains why energy consumption in 2010 was especially high. The graph shows deviations from normal temperatures in Norway. In 2010, there were two cold periods, as opposed to the normal one. Both January-February and November-December were extremely cold, as shown by the two low points on the graph in 2010. Energy consumption was therefore much higher in this year than in the preceding ones. 2011 was a warm year, and energy consumption accordingly fell back to the previous trend.

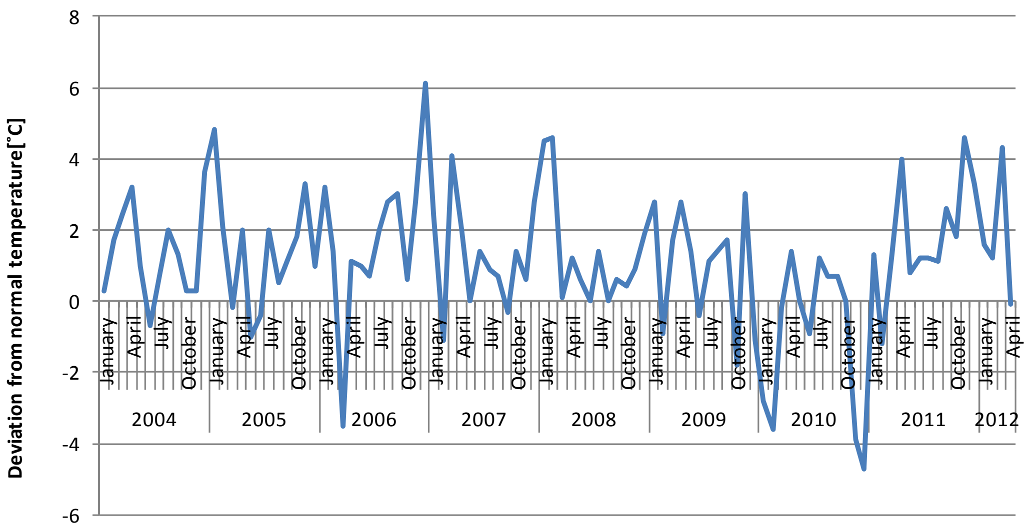

Figure 3.2 Deviations from normal temperatures, monthly figures. Norway. (MET, 2012)

3.2 What influences household energy consumption?

Household energy consumption is affected in both the short and long terms by a range of factors referred to as drivers of energy consumption. These drivers include changes in outdoor temperatures and the floor area our homes occupy. Population growth is also an important driver, as a determinant in the changes to floor area occupied.

The flattening out of household energy consumption in the last 20 years is shown in Figure 3.3, which depicts actual and temperature-corrected energy consumption. The annual growth in temperature-corrected energy consumption was only 0.15 per cent in the period from 1990 to the present day, whereas between 1976 and 1990 there was annual growth of more than 3 per cent in temperature-corrected energy consumption. As previously described, 2010 was a cold year, with several cold periods and therefore had high energy consumption. However, when corrected for the low temperatures, this year too fits into the relatively flat trend in the growth of energy consumption.

Temperature-corrected energy consumption

Temperature-corrected energy consumption means energy consumption adjusted for fluctuations in outdoor temperature.

Energy consumption for space heating and cooling is temperature-dependent, meaning that the energy requirement varies in line with the outdoor temperature. In cold years, for example, energy consumption will be higher than in years of normal temperature, and conversely lower in warm years.

When energy consumption is temperature-corrected, it is adjusted for these fluctuations in outdoor temperature. The result is energy consumption as it would have been, had the temperature in that year been normal.

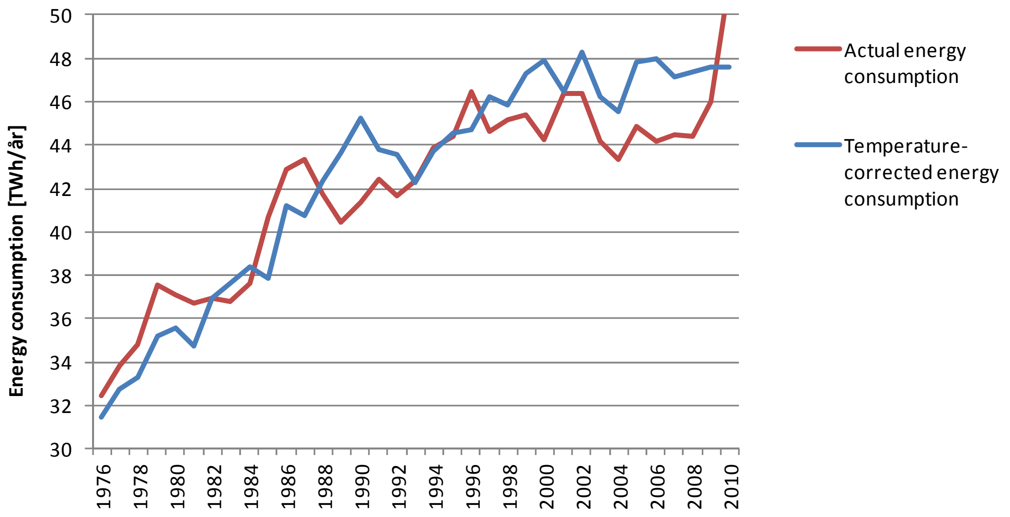

Figure 3.3 Trend in overall household energy consumption. (MET, 2012) (SSB, 2012)

An analysis commissioned by NVE shows that the flattening out in household energy consumption may have three main causes (Vestlandsforskning, 2011):

- Growth in floor area per person has been reduced in recent years. This has led to a reduced increase in energy consumption. Energy consumption is closely connected with floor area, and less growth in floor area per person results in less growth in energy consumption per person.
- The rise in energy consumption has also been dampened by the fact that energy-efficiency measures and better heating systems mean we consume less energy per square metre per year (kWh/m^2/year). The reduction in energy consumption per square metre comprises a number of factors, as described in chapter 3.2.2.
- Energy consumption has been reduced as a result of climate change, with higher outdoor temperatures. This has led to lower heating requirements and lower energy consumption per square metre. See the fact box about temperature-correction of energy consumption.

These three main causes are illustrated in Figure 3.4. The bottom line, in purple, shows actual energy consumption for 1992-2009. The effect of different factors is accumulated in the graph. The green dotted line shows what the approximate energy consumption would have been if we had had normal temperatures during the period. The red dotted line shows energy consumption if there also had been no efficiency improvements during the period. The top, blue, dotted line shows energy consumption if there also had been growth in occupied floor area per person as there was before 1990. The blue dotted line therefore shows the cumulative effect of the three main causes.

The gap between the lines illustrates the effect size of each cause. The figure shows that reduced growth in floor area is the factor that contributes most to the flattening out in energy consumption, since it is between the red and the blue lines that the gap is largest. How each of these three main causes affects consumption in households is described in more detail in the following subchapters.

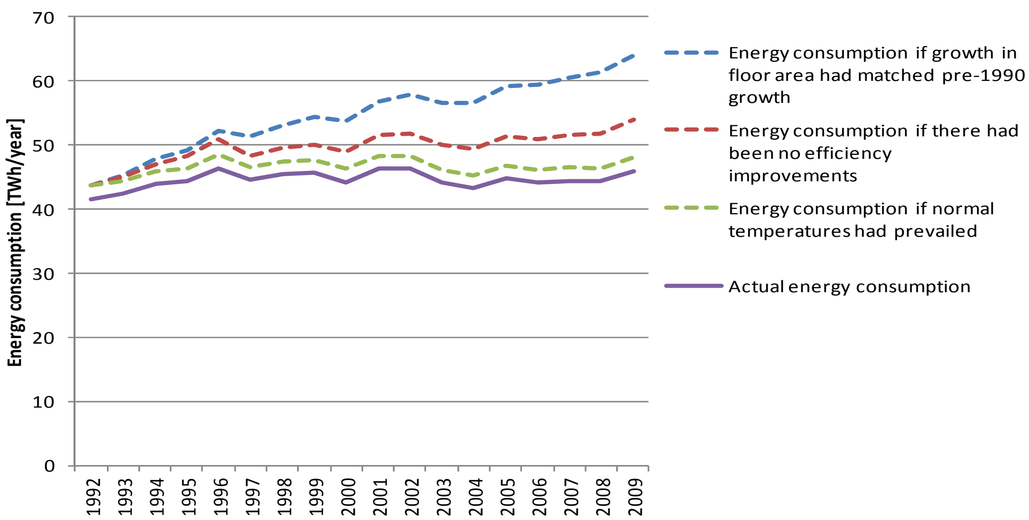

Figure 3.4 Illustration of factors that have contributed to a flattening out in household energy consumption.

3.2.1 Lower growth in floor area per person has a large effect on energy consumption

The population of Norway has grown more since 1990 than it did before. On this basis, we could expect to see a rise in occupied floor area and in energy consumption in the household sector, but some of the expected growth in energy consumption has been dampened by lower growth in floor area than previously.

Table 3.1 shows how growth in residential floor area per household and per person has declined since 1990, and especially since 2000. Note that it is *growth* in floor area that is declining, not total floor area. This reduced growth in floor area may have a variety of causes; relatively more flats are being built than detached houses and townhouses, increasing urbanisation is resulting in smaller residential units, there is strong demand for housing, and house prices have been rising strongly.

Table 3.1 Growth in residential floor area per person and per household, annual percentage growth. Source: Statistics Norway

	1973-1990	1980-1990	1990-2009
Growth in residential floor area per household	1.3 %		0.4 %
Growth in residential floor area per person		2.5 %	1.0 %

If the growth in floor area in the period 1990-2009 had continued as it was before 1990, residential floor area per household and per person would be considerably higher today. This in turn would have entailed distinctly higher total household energy consumption. In other words, reduced growth in floor area per person has significantly helped to dampen growth in household energy consumption.

3.2.2 Less energy per square metre reduces total energy consumption

In the early 1990s, energy consumption per square metre (m^2) in households averaged about 210 kWh/m^2. The corresponding figure today is about 180 kWh/m^2, a reduction of 14 per cent. If we had used as much energy per square meter in recent years as in the early 1990s, we would have considerably higher household energy consumption.

The decline in energy consumption per square metre has a number of causes, the most important of which are improvements in existing housing due to renovations, and a better quality of new building due to more stringent building regulations. There have also been improvements in technology, notably in water heating and the heating of houses. Oil stoves, paraffin stoves and old inefficient wood stoves have gradually been phased out and replaced with more efficient heating technologies such as electric heaters, new wood stoves and heat pumps.

The Vestlandsforskning research institute has five factors to account for the improvement seen in energy consumption per square metre (Vestlandsforskning, 2011).

Factors helping to suppress energy consumption per square metre:

Improvements to existing buildings: Norwegians are constantly upgrading their houses. This involves everything from changing kitchen fittings to replacing windows and improving insulation. Large amounts are spent each year on renovation, and figures from market analysis company Prognosesenteret show that around 19 per cent of these investments are spent on energy-related works, such as replacing windows and insulating walls. Their surveys also show that people do not primarily undertake these works for energy savings, but mainly because they are necessary or part of some other home improvement (Prognosesenteret, 2012).

Heat pumps: Heat pumps are making an important contribution to the fall in energy consumption. Calculations show that heat pumps contribute an annual reduction in energy consumption of between 1.8 and 2.9 TWh.

Better heating systems: A number of households have switched heating technology from oil-fired boilers and paraffin stoves to electric heaters and heat pumps. In addition, many old wood stoves have been replaced by more efficient wood stoves and heat pumps. This change in heating technology means that we are using energy for heating more efficiently and thereby reducing losses of energy for heating.

Introduction of TEK87 and TEK97[7] + demolition: New building regulations (TEK) contribute to reduced energy consumption per square metre. The regulations apply to the construction of new buildings and to comprehensive refurbishment of existing buildings. The more stringent requirements in TEK are especially important for new buildings, since they help ensure the buildings are constructed for reduced energy consumption. New buildings will stand for a long time, making it crucial that they consume as little energy as possible

Hot water: Use of new water tanks with better insulation and water-saving showers help reduce energy consumption for water heating in households.

Factors helping conversely to raise energy consumption per square metre:

Electrical equipment: Energy consumption for appliances and equipment is referred to as electricity-specific energy consumption, because such appliances can only be run on electricity and not, for example, on biofuels. The designation applies to all energy consumption for lighting, household appliances and entertainment devices such as TV/media. Households are acquiring increasingly more entertainment devices, at the same time as new devices are becoming more energy-efficient. We are therefore consuming somewhat more energy on this end-use than previously. For further discussion, see Chapter 3.3.2.

Shared consumption in housing blocks: New building regulations include requirements that entail new energy consumption. This applies to, for example, energy for operating lifts, ventilation systems and other shared functions needed in new housing blocks. In recent years, energy consumption for shared uses in housing blocks has increased.

[7] Norwegian building regulations 1987 and 1997

Uncertainties due to lack of data:

Indoor temperatures: Indoor temperature is one of the main determinants for the household's energy consumption. A few degrees' increase in indoor temperature will increase energy consumption considerably. Unfortunately, there is insufficient historical data on indoor temperature and it is not possible to say whether it has raised or lowered household energy consumption over time.

3.2.3 Higher outdoor temperatures lead to reduced energy consumption for heating

A change in the climate has been observed since the late 1980s. This is illustrated in Figure 3.5 where the line shows deviations from the normal temperature in Norway. The figure shows a rise in temperature at the end of the 1980s. Higher outdoor temperatures mean that households can reach their desired indoor temperature using less energy. NVE's calculations show that the higher outdoor temperatures from the late 1980s to the present day have led to a total reduction in household energy consumption in Norway of 2-3 TWh/year.

> **Normal temperature**
>
> Normal temperature refers to an average temperature calculated for a 30-year period. The normal temperature referred to here is based on the years 1961-1990.

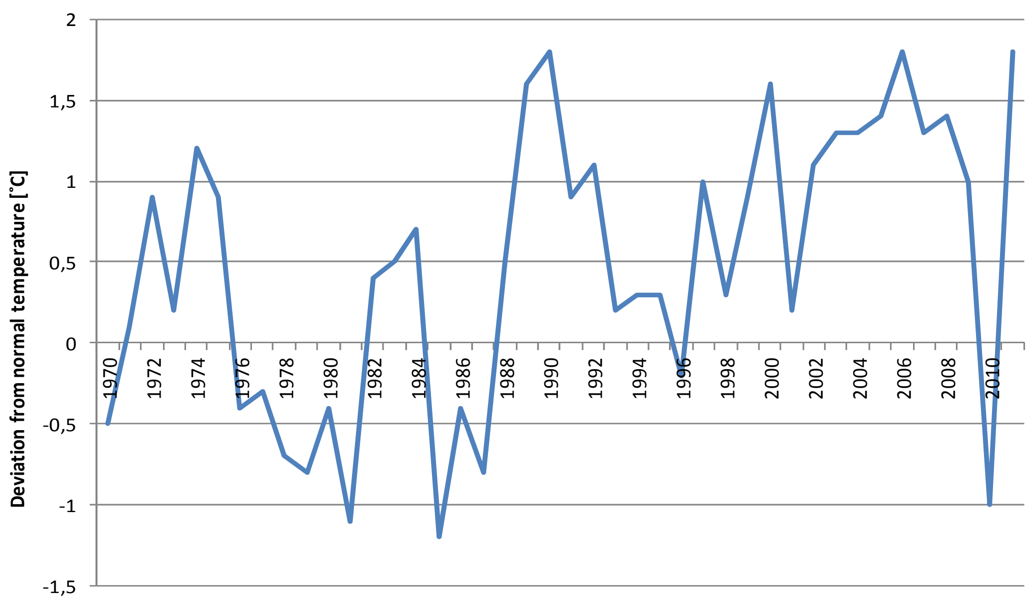

Figure 3.5 Deviations from normal temperatures, annual figures. Norway. (MET, 2012)

3.3 What do households use energy for?

Households use energy for three main purposes: heating rooms in the home (space heating), heating water and electricity-specific energy consumption (electrical appliances and lighting). Space heating can be provided by various energy products and technologies, including wood stoves, heat pumps, electric heaters, oil-fired boilers and pellet stoves. Hot water can be obtained from electric water heaters, district heating, heat pumps, solar heating, biofuel boilers and so forth. Electricity-specific consumption comprises electricity for electrical appliances and lighting. Electrical appliances can only be run on electricity, and this energy consumption is therefore often referred to as electricity-specific energy consumption. Electrical appliances include white and brown goods, computer equipment and entertainment devices, lighting and other appliances.

Focus on the potential for efficiencies in energy consumption in homes has increased. Knowledge about how energy consumption in homes breaks down into different end-uses is important for framing appropriate instruments that relate to household energy consumption. Especially important is the difference between the end-uses that can only be covered by electricity and heating end-uses that can be met by electricity as well as other energy products such a district heating, fuelwood, ambient heating and oil products.

3.3.1 Energy for different purposes in households

The most common high-level classification by purpose is into space and water heating on the one hand and electricity-specific usage on the other, referred to as a breakdown by end-use consumption. The following compares estimated end-use consumption, based on results from major Nordic projects aimed at providing an accurate depiction of how end-use consumption breaks down.

Energy consumption in Norwegian households is about 21,000 kWh/year (SSB, 2011). Of this, it is estimated that around 4,500 kWh/year is electricity-specific, of which 1,000 kWh is lighting. Water heating uses about 2,600 kWh/year and the remaining 13,900 kWh is used for space heating. On these assumptions, household end-use energy consumption breaks down as shown in Figure 3.6.

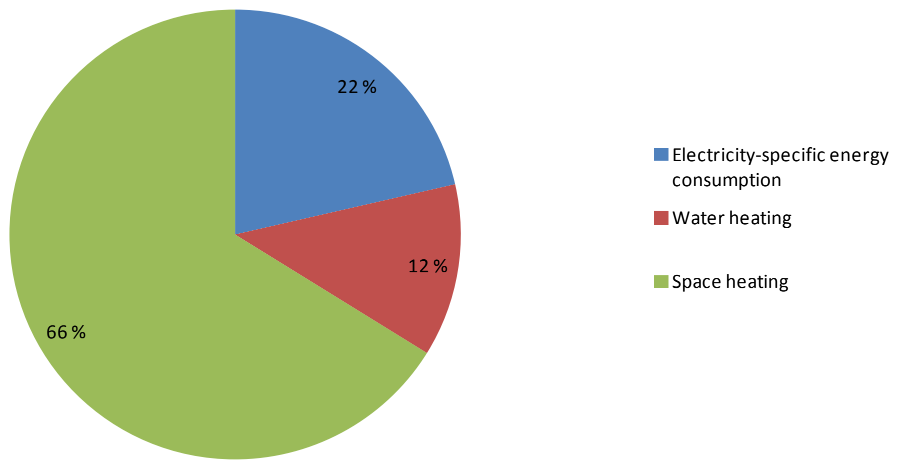

Figure 3.6 Breakdown of end-use energy consumption in households.

The figures in the chart are based on an assessment of studies from Norway and other Nordic countries. These studies are described in more detail in the sections below.

Results from different Nordic studies

Studies or measurements of electricity-specific consumption have been carried out in several Nordic countries. The results from these surveys indicate that electricity-specific consumption per household is about 4,500 kWh/year. This includes appliances, lighting and electricity for operating technical equipment. An overview of the results from some of the studies is shown in Figure 3.8 and expanded upon in Chapter 3.3.2. Here, we examine the projects that mapped electricity-specific consumption and describe how they help provide a picture of end-use consumption.

In 2011, NVE commissioned a project to survey **the use of electricity for electricity-specific end-uses in households** (Xrgia, 2011). The study found that the average electricity consumption on appliances in households was about 4,000 kWh/year. The study included most appliances, but did not include all electricity consumption on fans and pumps. Electricity for lighting was included, but it is reasonable to assume that this was underreported. We therefore assume that the actual figure for electricity consumption is more than 4,000 kWh/year. The study is examined more closely in 3.3.2. Energy use for hot water was not included in this study.

SINTEF Energi is chairing a research project called **ElDeK**[8] (SINTEF), which is metering electricity consumption in households. The results from this study are provisional and limited primarily to detached houses with electric heating. Their provisional figures show that about 2,000 kWh is used for lighting and about 3,600 kWh for electricity-specific consumption. Electricity consumption for electricity-specific end-uses therefore comes to about 5,600 kWh/year. The study also shows that about 2,300 kWh is used for water heating. Total electricity consumption in these houses was metered at about 24,000 kWh/year. Other energy products come in addition to electricity, but these were not measured. Total energy consumption in these houses may therefore be higher than 24,000 kWh/year.

The sample for this study is not representative of all housing in Norway, since the metering was of energy consumption in detached houses, i.e. the *largest* type of housing. They therefore have higher energy consumption than the average of houses in Norway. Electricity-specific consumption at 5,600 kWh comes to around 24 per cent of 24,000 kWh/year. The percentage would be lower if the total energy consumption figure were increased by including other energy products. Since the figures from **ElDeK** apply to larger houses, it may be assumed that electricity-specific energy consumption for an average house is somewhat lower than 5,600 kWh/year.

Surveys of energy consumption in Norwegian households were published in 2009 by the **REMODECE** (SINTEF, 2009) project, which metered appliances in one hundred households. The results were weighted relative to the composition of households in Norway, and they show that the average consumption by appliances was about 2,500 kWh/year and by lighting was about 1,000 kWh/year, making a total of 3,500 kWh/year.

[8] ElDeK is an abbreviation for Electricity Demand Knowledge

The average household in Norway in 2006 used about 21,500 kWh/year. (SSB, 2011). This makes the electricity-specific proportion of energy consumption about 16 per cent.

The project also metered water heating to about 3,000 kWh/year in the houses that had electric water heaters. About 85 per cent of households have water heaters and energy consumption per average household in their study was therefore about 2,500 kWh/year. Households without water heaters may be assumed to be in housing blocks with shared hot water supplies for both heating and hot tap water, which also consume energy. According to these figures therefore, average energy consumption per household on water heating is likely to be between 2,500 and 3,000 kWh/year.

Vestlandsforskning has conducted a survey of household energy consumption (Vestlandsforskning, 2011). On the basis of earlier studies (SINTEF, 2009) (Zimmermann, 2009), (Kofod, 2005), (IT Energy, 2008), they calculate electricity consumption on appliances in Norwegian households to be 3,800-4,300 kWh/year. Of this, about 950-1,450 kWh/year is used for lighting, about 1,550 kWh/year for household appliances, and about 1,300 kWh/year for electronics and small appliances. For an average household consuming about 21,000 kWh/year in 2009, electricity-specific consumption therefore makes up about 18-20 per cent of the total.

In addition, Vestlandsforskning calculated that shared functions such as fans and pumps constitute on average about 500 kWh/year per household. They also made a calculation of energy consumption for water heating based on figures from Høiax and OSO Hotwater, and an assessment of changes in showering and washing habits. They arrived at a figure for water heating of about 2,900 kWh/year.

In 2006 in **Finland** a survey was conducted to meter households' electricity consumption on appliances (Rouhiainen, 2009). The project found electricity-specific consumption to be about 4,200 kWh/year. Consumption for household appliances came to about 2,700 kWh/year, and about 1,000 kWh/year was used for lighting. In addition, some electricity use was recorded for saunas, car heaters, underfloor electrical heating and fans and pumps. The metering survey did not state total energy consumption per household, but, according to another source (Odyssée), Finnish households' energy consumption in 2006 was about 24,000 kWh/year. Electricity-specific consumption then seems to be about 18 per cent of total energy consumption.

Another Finnish survey, conducted in 2011 (Statistics Finland, 2011), shows that total household energy consumption is about 61 TWh[9], of which about 10 TWh is electricity-specific, about 44 TWh for space heating and about 7.2 TWh for water heating. These figures put the electricity-specific share at about 16 per cent, space heating at about 72 per cent and water heating at about 12 per cent.

In Denmark, an analytical model called **ELMODEL-bolig** has been developed. As the basis for this model, data from metering and surveys of the energy consumption of individual household appliances is collated in a report (IT Energy, 2008). The Danish figures show annual energy consumption of about 2,700 kWh/year for appliances, not including lighting. This project also revealed that energy consumption for water heaters was between 1,900 and 2,700 kWh/year, depending on the age of the appliance. The

[9] Excluding holiday homes

project did not come up with a figure for total energy consumption per household, but, according to another source (Odyssée), Danish households' energy consumption in 2006 was about 21,500 kWh/year. Electricity-specific consumption seems with that to be between 21 and 25 per cent of total energy consumption.

The Swedish Energy Agency has undertaken the most comprehensive measurement we are aware of. In 2006-2007, they metered energy consumption in 200 one-family houses, including detached houses, townhouses and terraced houses, and 200 flats (multi-dwelling units). The results show that electricity-specific consumption is 5,100 kWh/year for one-family houses and 3,000 kW/year for flats (Bennich). For an average household, electricity-specific consumption is about 4,100 kWh/year. The project did not come up with a figure for total energy consumption per household, but, according to another source (Odyssée), Swedish households' energy consumption in 2006-2007 was about 21,200 kWh/year. This indicates that electricity-specific consumption constitutes about 19 per cent of total energy consumption.

Sweden also conducts regular surveys of household energy consumption. Table 3.2 show national average figures for Sweden. The two right-hand columns specify the percentage shares of electricity-specific energy consumption and thermal energy consumption (space heating and hot water). The table shows that Swedish electricity-specific consumption in one-family houses and in flats is respectively about 24 per cent and 20 per cent of the annual supplied energy amount (Energimyndigheten, 2007).

Table 3.2 Breakdown of electricity-specific and thermal energy consumption in Sweden. Source: The Swedish Energy Agency[10]

Dwelling type	Energy consumption/year [kWh/year]	Electricity-specific [kWh/year]	Heating [kWh/year]	Share electricity-specific	Share heating
One-family houses	26,200	6,300	18,600	24 %	76 %
Flats	14,200	2,800	11,500	20 %	80 %

A comparison of Swedish and Norwegian statistics shows that average household energy consumption is much the same in the two countries. Figures from Statistics Norway also show that energy consumption per person in Swedish and Norwegian households is almost identical, at nearly 10,000 kWh/person. The breakdown into one-family houses and flats is different, in that Norway has a larger proportion of one-family houses. The breakdown between electricity and other energy products is also different in the two countries. Considerably less electricity is used for heating in Sweden than in Norway

Nothing indicates that there are substantial differences in end-use consumption between Sweden and Norway. Swedish households may consume more for heating since they have more diverse use of energy products and heating systems that are less efficient than the direct use of electricity, such as district heating. Electricity-specific consumption however is not assumed to be correspondingly different. There may be somewhat greater use of electricity for lighting in Norway in winter, and somewhat different ownership of

[10] Figures for one-family houses are from 2010 and for flats from 2006.

electrical appliances and different behaviours may play a certain role. But these factors are assumed not to constitute major differences.

Summary of end-use consumption:

It is not possible to provide an exact conclusion as to the breakdown of end-use consumption. Different methods yield different results and it is impossible to define the correct end-use breakdown with certainty in the absence of comprehensive measurements. The surveys referred to above used different methods, with different strengths and weaknesses. The results from these projects vary somewhat, but the general indication is that electricity-specific energy consumption in Norwegian households is around 4,500 kWh/year per household, of which around 1,000 kWh/year is used for lighting.

Electricity-specific energy consumption is generally better documented than energy consumption for heating, since the former only includes the metering and calculation of *electricity*. This makes it easier to estimate the amount of energy used for electricity-specific consumption than for heating.

It is uncertain whether the breakdown of end-use consumption in flats and one-family houses is the same. Flats may have a smaller share of energy consumption for space heating than one-family houses, but they also generally have less equipment than one-family houses. Since energy consumption both for heating and for electricity-specific end-uses is smaller in flats than in one-family houses, we have no basis for assuming that the end-use breakdown is significantly different between the two dwelling types.

On the basis of the studies, it is realistic to estimate that electricity-specific household energy consumption is approx 4,500 kWh/year, of which about 1,000 kWh/year is used for lighting. The studies also show that water heating accounts for about 2,600 kWh/year. The remainder of household energy consumption is with that used for space heating. Total energy consumption in the average home from 1993 to 2009 is between 23,000 and 21,000 kWh/year (SSB, 2011). This figure is derived from Norway's energy products balance and the number of households in Norway, and may contain uncertainties, but we assume it is correct. If we assume energy consumption of 21,000 kWh/year, as in recent years, space heating accounts for about 13,900 kWh/year. The end-use breakdown is then 22 per cent electricity-specific consumption, 12 per cent water heating and 66 per cent space heating. End-use consumption is dynamic and the breakdown may change over time as the building stock, technology and usage patterns change.

3.3.2 Electricity-specific consumption in households

As mentioned at the beginning of Chapter 3.3, electricity-specific consumption is the part of energy consumption that can only be covered by electricity, i.e. energy consumption for electrical appliances and lighting. Electrical appliances include everything from refrigerators and washing machines to hairdryers, TVs and so forth.

As previously mentioned, NVE commissioned a project to survey electricity-specific consumption in Norwegian households in 2011 (Xrgia, 2011). More than 2,000 households were questioned about the types of appliances they own and their usage patterns for them. This information was linked with data on how much electricity the appliances need, so that electricity-specific consumption in different types of household could be calculated.

Figure 3.7 is a graph of the total electricity-specific consumption of all the 2,049 households that completed the questionnaire. The green line indicates the average electricity-specific consumption, which in this study is about 4,000 kWh/year.

The figure shows that there is a wide spread in the amount of electricity that households use for electricity-specific end-uses. Some use as little as 1,000 kWh/year, while others use almost 14,000 kWh/year. Characteristics of the household, such as the number of persons and the size of the dwelling, are determinative for how much electricity each household uses. This is discussed later in this chapter.

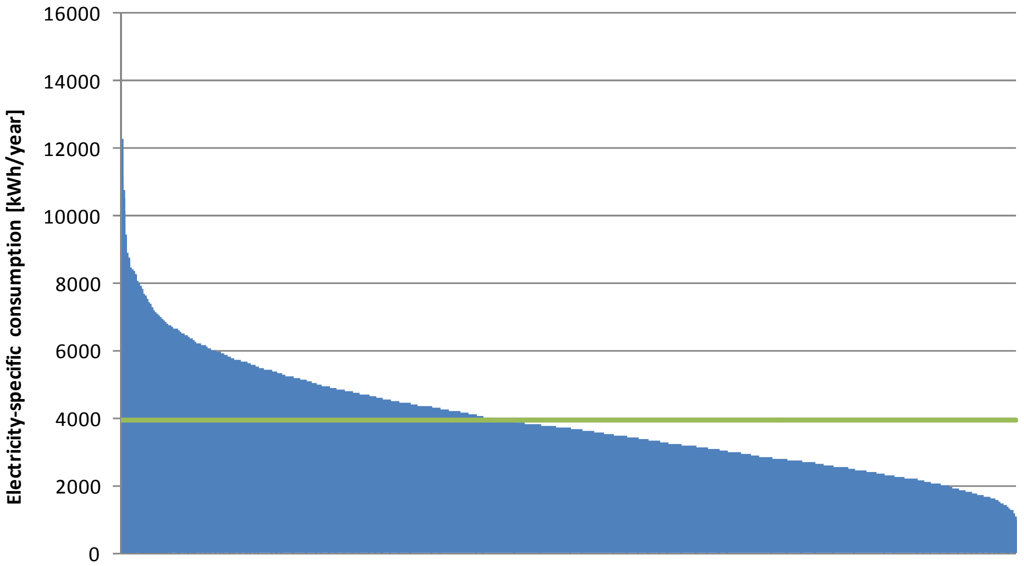

Figure 3.7 Total electricity-specific energy consumption for all respondents (Xrgia, 2011)

Electricity-specific consumption is easy to reduce. By making sure to purchase energy-efficient appliances and remembering to turn them off completely rather than leaving them on standby, their energy requirements can be reduced considerably. Find out more about energy-efficiency measures in chapter 3.6.

In order to examine electricity-specific consumption more closely, NVE compared the results from Xrgia's survey with those from surveys performed previously in the Nordic countries (Grinden & Feilberg, 2009), (Zimmermann, 2009), (Rouhiainen, 2009), (IT Energy, 2008) and (SINTEF Energiforskning, 2010). These surveys are also discussed in Chapter 3.3.1. In Figure 3.8, the results of Xrgia's survey are compared with the results from the other surveys, and shown to be on a par with them.

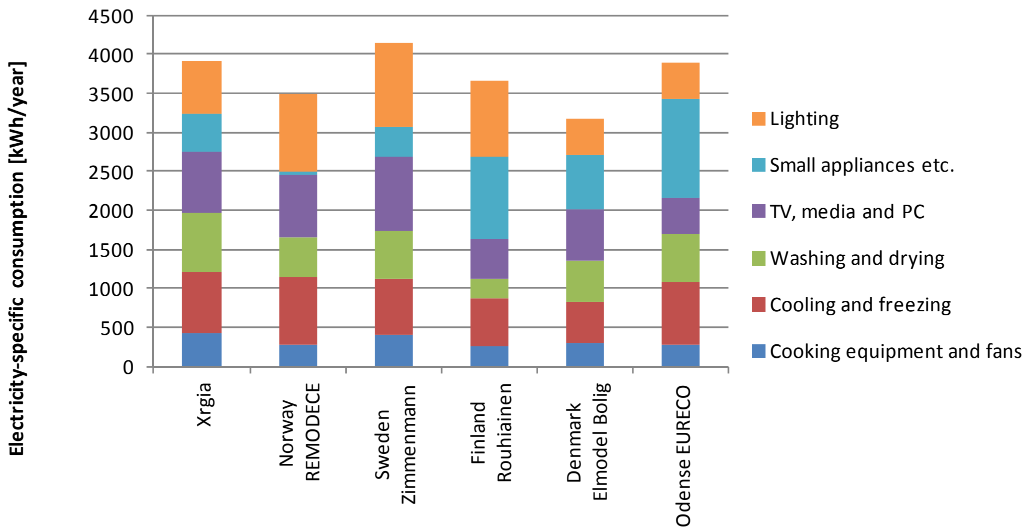

Figure 3.8 Xrgia's survey compared with other surveys

The results presented in Figure 3.8 are, however, not directly comparable. This is because the projects referred to, with the exception of Xrgia's survey, have *metered* electricity-specific consumption in addition to employing questionnaires, whereas Xrgia only employed a questionnaire. All the results only include the selected groups of appliances for which energy consumption was metered or which were asked about. Small electrical appliances and entertainment devices such as game consoles and computing equipment are among the appliances that were not included in the metering in all the projects. In some of the projects, energy consumption for lighting is included, in others some illumination points were metered, but not all. Nonetheless, based on Figure 3.8, the conclusion is that the results of Xrgia's survey appear reasonable.

The electricity-specific consumption of an individual household is highly dependent on the number of people in the household. This is evident from Figure 3.9, which shows that the difference is greatest between single-person and two-person households. The increase in electricity consumption is greatest in washing and drying, cooling and freezing and cooking equipment. Washing and drying is the category that increases most as the number of members in the household rises beyond two.

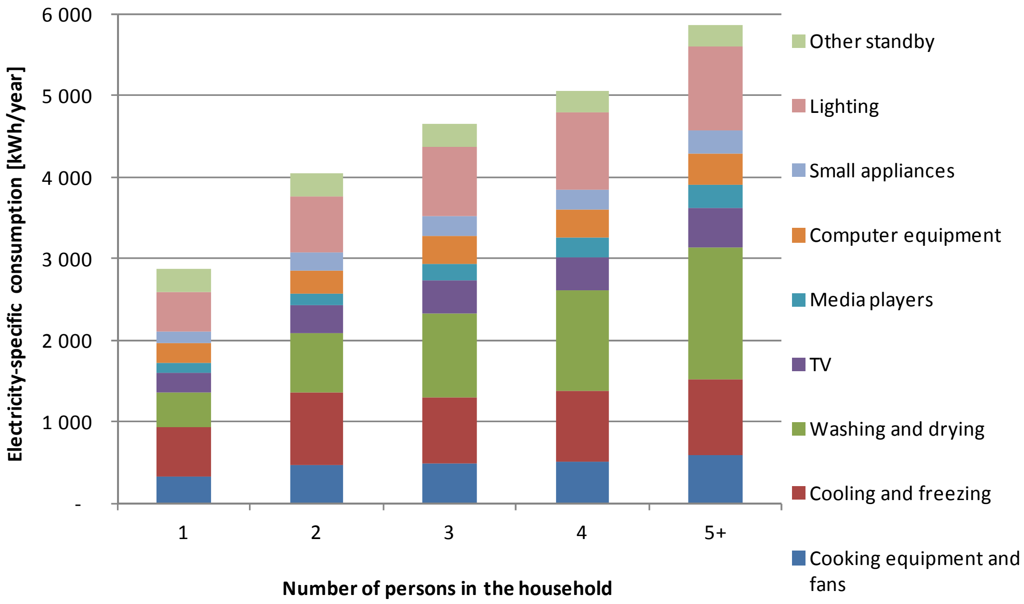

Figure 3.9 Electricity consumption in households of different sizes (Xrgia, 2011)

Figure 3.10 shows that the type of housing plays a large role in respect of electricity for appliances in households. Detached houses use the most electricity for appliances and lighting, and flats use the least. In flats, there are on average fewer people per household, and they therefore have fewer appliances. In townhouses and detached houses, there are more people and more space, which allows for more of the larger appliances such as refrigerators and freezers.

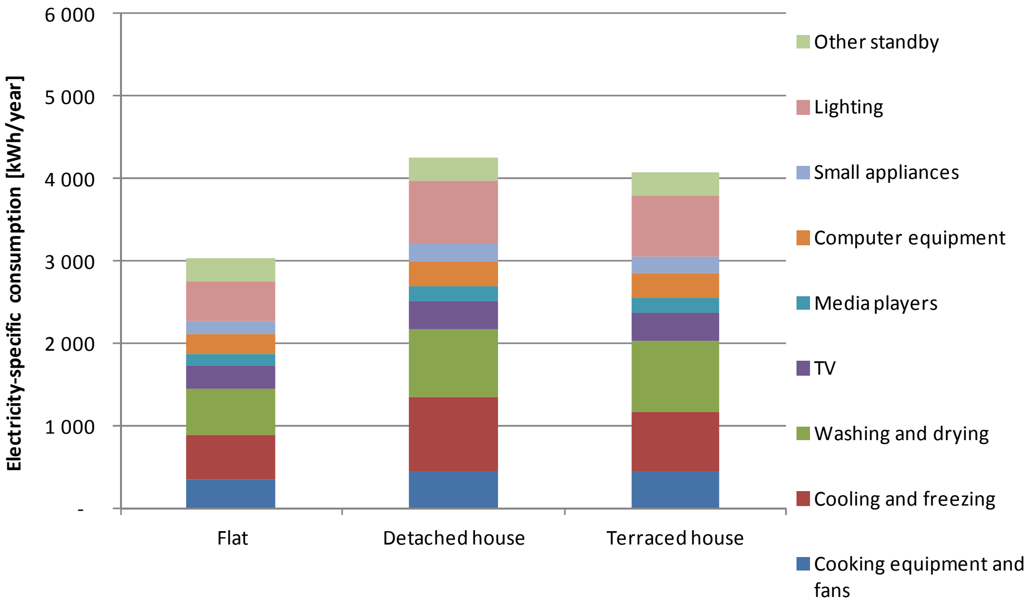

Figure 3.10 Electricity consumption in households in different types of housing (Xrgia, 2011)

Figure 3.11 shows that households with children under 18 living at home use considerably more electricity for appliances and lighting than households without children living at home. Here, washing and drying are especially distinctive as the group of appliances with the largest difference in consumption. On average, households with children living at home consume twice as much electricity for this purpose than households without children living at home. Consumption on other appliances increases somewhat with the increasing age of the youngest member of the household, primarily with regard to TV and computer equipment, but also refrigerators and freezers.

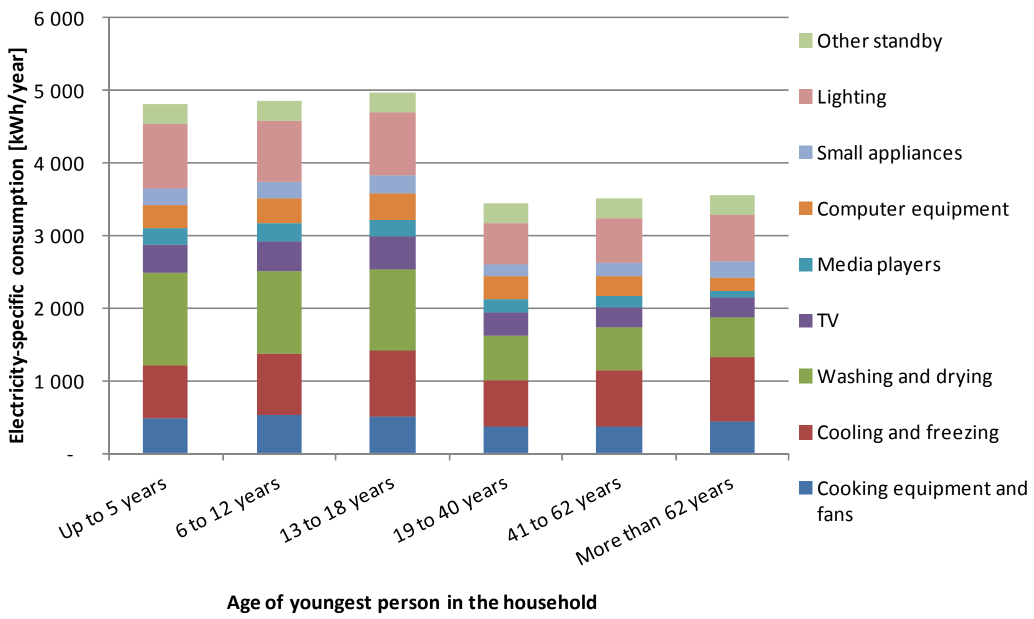

Figure 3.11 Electricity consumption in relation to the age of the youngest member of the household (Xrgia, 2011)

Figure 3.12 compares the electricity-specific consumption of different household types. Here we can see that it is families with children living at home that consume the most electricity. Families where the youngest family member is a teenager ("Families with teenagers" in the graph) use the most of all these family types, followed by families where the youngest member is under five ("Families with young children" in the graph). Families with teenagers use more electricity for storing and preparing food, while families with young children naturally use more electricity for washing and drying clothes.

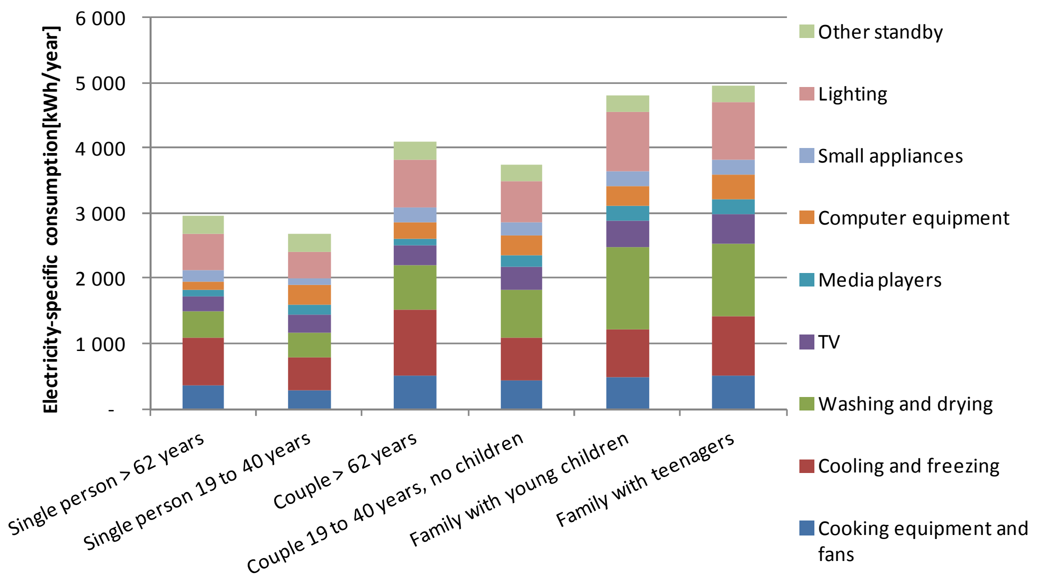

Figure 3.12 Comparison of electricity consumption in selected household types (Xrgia, 2011)

Besides families with children living at home, it is couples aged over 62 who consume most electricity for electricity-specific end-uses. This group consumes especially heavily for cooling and freezing and lighting. In such households there are likely to be older appliances that consume a lot of electricity, and they may well have an extra freezer or fridge. Single people aged 19-40 constitute the household group that consumes the least electricity for appliances and lighting.

3.3.3 Space and water heating

In Norwegian households, approximately three quarters of total energy consumption is for space heating and hot water. The most important energy source for heating is electricity. Electricity currently covers 70-80 per cent of heating requirements with the remainder primarily met by bioenergy (7 per cent), oil (7 per cent) and district heating (4 per cent). This is illustrated in Figure 3.13 (note that district heating is not included in this graph). The graph shows that there is a large difference in the amount of energy consumed in individual households depending on building type. A typical detached house uses some 25,000 kWh/year, while a flat in a block uses approximately 10,000 kWh/year. The graph also shows that consumption of firewood, wood pellets and oil products is higher in detached houses than in flats. This has to do with the type of heating systems that are typical in the different housing types. It is more common to use fuelwood for heating in detached houses than in townhouses. Flats usually have electric heaters or water-based heating with a shared central boiler.

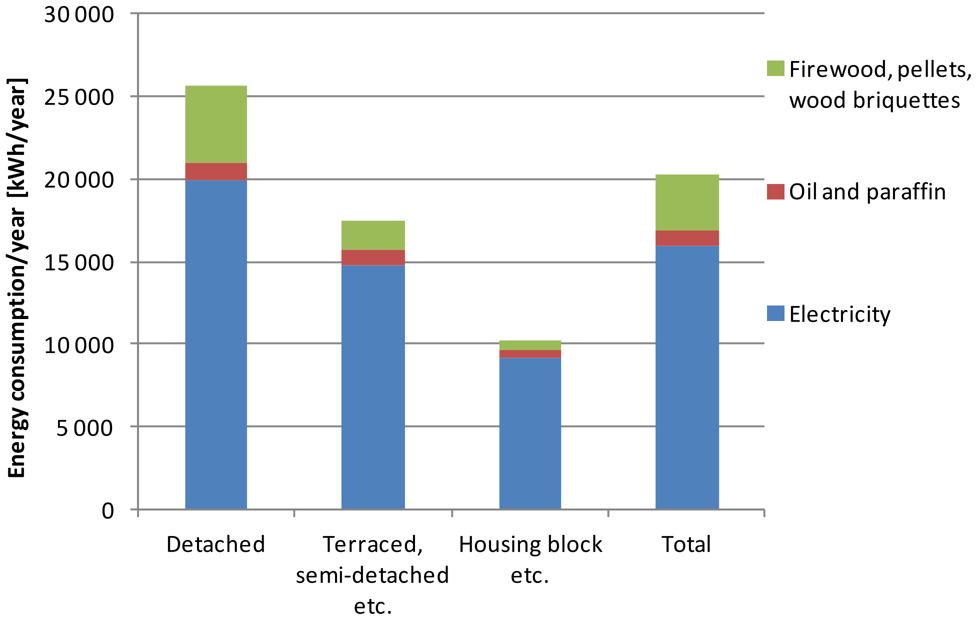

Figure 3.13 Household energy consumption broken down by electricity, bioenergy and fossil sources (SSB, 2012)

The Norwegian government's Climate Policy white paper signals an increased focus on the use of energy sources other than electricity for heating. There is also a focus on the energy performance of buildings. Making buildings energy-efficient is likely to have a major influence on residential energy requirements in as much as a high proportion of the energy requirements are for heating. It is anticipated that energy-efficiency measures and new technical building codes will produce a considerable reduction in the need for space heating in housing. Figure 3.14 illustrates the difference between the energy requirements of a house built to TEK07 standards (Lovdata, 2007) and a house built to the passive house standard, NS 3700 (Norsk Standard, 2010). The figure shows that there is a considerable potential for energy savings. In terms of the energy requirement for hot water, energy efficiency is less significant and only a slight drop is expected. In the figure, the energy requirement for hot water is constant.

Today, average energy consumption in Norwegian households is approximately 21,000 kWh/m^2. Of this, water heating accounts for about 2,600 kWh/m^2 and space heating about 13,900 kWh/m^2. The remainder is electricity-specific consumption. For comparison, energy consumption for space and water heating for a house built to the passive house standard will be in the order of 5-6,000 kWh/m^2.

Hot water

Energy for water heating is assumed to be more or less constant throughout the year regardless of the type of housing and of the building codes to which the house is built. Energy for water heating is typically 2,500-5,000 kWh/year for an ordinary household but varies in accordance with the number of people in the household. It is assumed that the energy requirement increases by around 1,000 kWh/year/person (Myhre & Dokka, 2006)

Typical factors that affect energy consumption for hot water are user behaviour and technology. Large savings can be achieved through a more careful use of hot water and use of more energy-efficient technology.

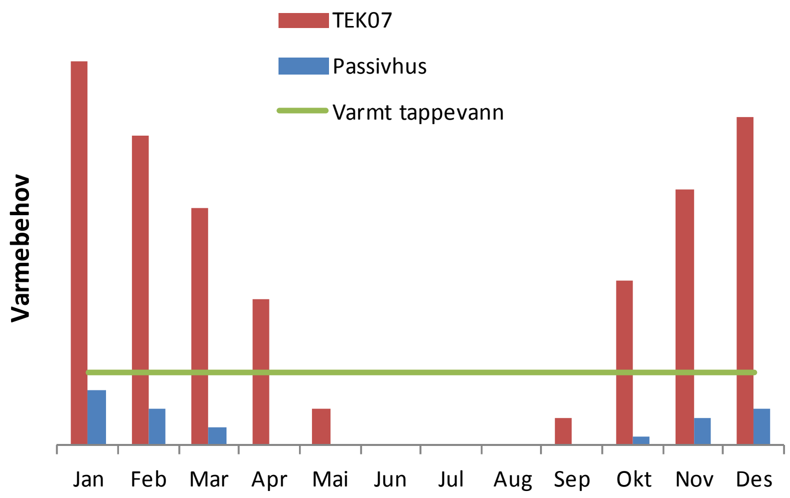

Figure 3.14 Energy requirements for space heating for TEK07 and passive houses, and hot water for a house in the Oslo climate (I.Andresen, et al., 2010).

Space heating

Two thirds of energy consumption in a house in Norway relates to space heating. The need for space heating is heavily dependent on the building shell's ability to retain heat. A comparison of the energy requirements of existing houses with new, better insulated houses shows a substantial reduction in energy consumption for space heating. Figure 3.15 illustrates how the energy for space heating, water heating and electricity-specific equipment in buildings is expected to fall as new technical building codes are introduced.

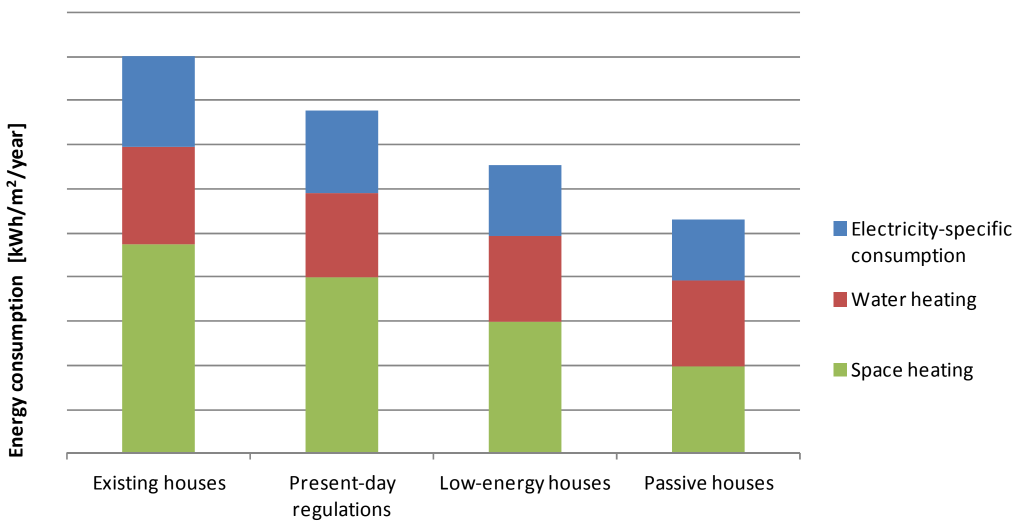

Figure 3.15 Typical energy consumption by end-use for houses built to different technical regulations

It is expected that the energy requirement for space heating will be further reduced in the time ahead as houses are renovated to new technical standards, new houses are built to low energy and/or passive house standards, and new and more efficient technology is introduced.

3.4 Heating and energy supply

In recent years, energy supply and heating solutions in Norway have been primarily based on electricity, where heating is done using electric heaters, electric heating cables and electric water heaters. An increasing focus on the use of renewable energy sources for heating purposes and energy efficiency is in the process of changing this scenario.

Norway has considerable potential for utilising renewable energy from sources such as bioenergy, ambient heat (heat extracted from ground water, seawater and the air using a heat pump), solar heating and district heating/local heating. Measures to stimulate increased production of energy from renewable energy sources have been introduced.

There is considerable potential for reducing energy consumption for heating in the housing sector. Especially effective are reductions due to improvements to the existing building stock (reduced heat loss from the building shell) and the introduction of new technical building codes. The most commonly used strategy when deciding on measures to reduce energy consumption in buildings can be illustrated by Trias Energetica, better known as the Kyoto Pyramid, shown in Figure 3.16.

Low energy houses are ones that are better insulated against heat loss than specified in current building regulations.

Passive houses have a significantly lower energy requirement than the current standard. The concept was developed in Germany. Energy requirements are reduced through passive measures such as extra insulation, a high level of draught proofing, super-insulated windows, use of solar energy and heat recovery.

The Norwegian criteria for low energy and passive houses are defined in standard NS 3700 (2010).

The strategy involves first reducing heat losses from the building shell, by reducing air leakage, providing very good insulation, using super-insulated windows and balanced ventilation with highly efficient heat recovery. Secondly, electricity consumption is reduced, in particular by using electrical equipment and lighting with low energy requirements. The next step is to utilise passive solar heating effectively. Finally, energy sources and heating solutions adapted to the residual heating requirements are selected, (Dokka & Hermstad, 2006). This strategy is also referred to as passive energy design and is widely used when constructing low-energy and passive houses.

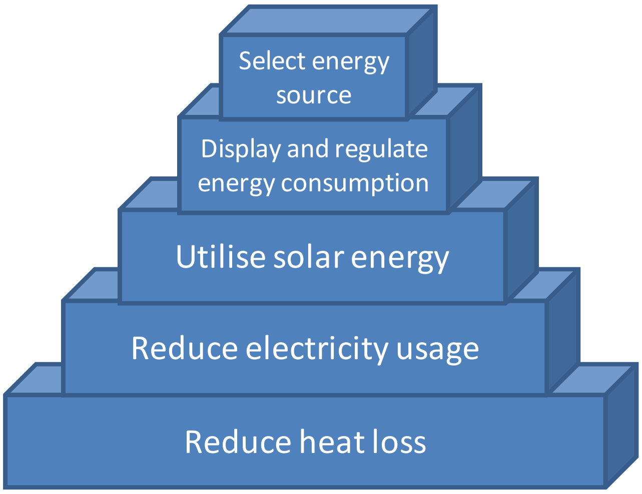

Figure 3.16 Trias Energetica/Kyoto Pyramid.

3.4.1 Heating solutions

There is an increasing interest in solutions for space heating that are focused on energy consumption, energy flexibility, the indoor environment and cost. It is important to have a heating system that is adapted to the building and to energy requirements. Solutions for space heating can essentially be divided into three main types (Dokka & Andresen, 2011):

- **Spot heating solutions**
  Spot heating is provided by standalone heat sources. The heat given off is a combination of radiant and convected heat, for example from a wood stove, electric heater, radiator or paraffin stove. The most common method of heating in Norwegian houses is spot heating in the form of electric heaters, radiators and wood stoves/fires. Electric heaters are a simple and reasonably priced means of heating that is easy to regulate. The drawback is being tied to electrical heating.

  Electric heaters and radiators are space heating solutions that suit low-energy houses and passive houses. Water-based heat derived from renewable energy carriers can be used to reduce the consumption of electricity for heating and thereby reduce the energy system's dependence on electricity. Wood stoves and fires may be suitable solutions, but must have good regulation in order to avoid overheating.

- **Heating solutions integrated into the building**
  Heating systems integrated into the building characteristically have large surfaces over which heat is released. Electric and water-based underfloor heating are the most common, but wall heating and ceiling heating are also used. The benefit of releasing heat from large surfaces, especially underfloor heating, is that low temperature systems provide good comfort and a sound indoor climate. The drawbacks are thermal inertia, which can make it difficult to control the temperature, and heat losses to the ground. In low-energy and passive houses, building-integrated systems are most suitable for damp rooms and others with a high heating requirement.

- **Air-based heating solutions**
  In air-based systems, heated air is distributed using a ventilation installation or an air-to-air heat pump. Such systems have historically not been much used in Norway, but experienced a boom from 2003 onwards when Enova provided subsidies for investment in air-to-air heat pumps. Air heating is more common further south in Europe, especially in Germany and Austria This is to do with the prevalence of passive houses, where this can be a suitable heating solution. In passive houses, heating using ventilation installations can be a simple and cost-effective solution. In low-energy houses that have greater heating requirements, it is less appropriate.

3.4.2 Energy supply

The most relevant energy supply solutions for heating houses, including detached houses, townhouses /one-family houses and housing blocks, classified by energy source, are:

- Direct electricity
- Bioenergy
- Solar heating
- Heat pumps - heat extracted from the surroundings, water and ground using a heat pump
- Local heating and district heating

Direct electricity
A common heating method in Norwegian houses is electrical heating in the shape of electric heaters and heating cables. Electric heaters are a simple and reasonably priced means of heating that is easy to regulate. The same applies to the energy requirements for water heating, which are also often met by electricity.

Bioenergy
Biofuel is the generic term for biomass used for energy purposes. Firewood, pellets, briquettes and straw are examples of biofuels. In Norway, biomass grows faster than it is cut down. There are therefore effectively no limitations in the country as a whole, but local access varies and must be considered for each development area.

Biofuel can be used both for spot heating and in larger biofuel plants. Firewood and wood pellets are best suited to spot heating appliances. Briquettes and wood chips are best in larger installations.

Ambient heating/heat pumps
Energy from the surroundings such as air, water (seawater or groundwater) or the ground (earth or rock), can be utilised for heating purposes. Heat pumps are used to raise the temperature of, for example, seawater to a higher level that can be used for space heating and water heating. Heating of buildings is normally achieved using water-based heat or air. The performance of heat pumps depends on the temperature of the medium, for example the temperature of the seawater that the heat is to be obtained from, and the temperature the medium is to be raised to. A small temperature increase yields a higher performance than a large one.

There are essentially three types of heat pumps:

- An **air-to-air heat pump** gets energy from the outside air and delivers heat into the building as warm air. Air-to-air heat pumps are suitable for use in detached houses, one-family houses and local standalone installations.
- An **air-to-water heat pump** gets heat from the outside air, or possibly air from a ventilation unit, and distributes it in the building via water-based underfloor heating or radiators. The heat pump can also be used to heat tap water.
- A **water-to-water heat pump** gets energy from bedrock (via a borehole), groundwater or seawater. The energy can also be utilised directly without a heat pump.

Solar heating

The use of solar heating can be divided into passive and active solar heating.

Passive solar heating - the solar energy is used directly for heating the house, for example through windows. This is the form of solar energy currently most utilised in Norway and contributes 3-4 TWh to the Norwegian building stock (Norsk solenergiforening). This corresponds to between 10 and 15 per cent of heating requirements. Greenhouses and conservatories make extensive use of passive solar heating. Nonetheless, there is great potential for exploiting more of the solar energy. In the Norwegian climate, the correct architectural design, the choice of building materials and the building's orientation can yield a significant reduction in heating requirements.

Active solar heating - energy from sunlight is absorbed and converted to heat in a solar collector. In the solar collector, the heat is transferred to a heat-conducting medium (liquid or air) that circulates through the solar collector. The heat from the solar-heating installation is distributed through a distribution network which may be water-based underfloor heating, radiators or ventilation. Thermal solar energy is able to meet much of the requirement for space heating and water heating. Solar collectors can be integrated into building facades and roofs. They can replace ordinary building materials and produce appealing architectural solutions. Solar heating installations are suitable for detached/one-family houses and larger buildings such as housing blocks, nursing homes, hotels etc. They are often combined with other renewable energy sources.

Local heating and district heating

District heating/local heating convey heat produced outside of the building. These may be large or small installations. Bioenergy, ground source heating, solar energy and waste incineration are some of the energy sources that district heating plants can use.

A district heating/local heating plant can heat everything from houses to commercial and public buildings. As a rule, a district heating plant supplies several buildings or entire neighbourhoods with district heating, whereas a local heating installation generally supplies a smaller number of buildings/smaller area. These solutions can be efficient and environmentally friendly and may be well-suited to large developments (district heating) and smaller ones (local heating), but detailed studies are required in each individual case to identify what is most suitable. Low energy requirements in buildings such as passive and low-energy houses can reduce the benefit of developing a district heating network.

3.5 Behaviour

By behaviour, in this context, we mean the conscious and unconscious choices that consumers make within defined frameworks such as legislation, regulations, provisions and what is available on the market.

Consumers' behaviour and attitudes are involved in determining energy consumption in a house, and may entail energy consumption being different than intended. Comfort, ambiance and security play a major role in energy consumption. Some people feel safer when leaving the light on in the sitting room at night, while others prefer a high temperature indoors. Energy consumption in two identical houses of exactly the same quality may therefore be very different (Xrgia, 2011). The reasons for this include the number of people living in the house and their energy-related behaviour.

3.5.1 What affects our behaviour?

Behaviour is determined by extrinsic and intrinsic motivation. Extrinsic motivation means that an activity is motivated by the potential for achieving a reward or reaching a goal outside of the activity itself (for example, to achieve higher status or financial gain). Conversely, when one does something for enjoyment of the activity itself, this is called intrinsic motivation (Wikipedia, 2012).

Acceptance by those around us is an important example of extrinsic motivation. For example, one may feel pressured by those around one to change behaviour through fear of being looked down on if one does not adhere to what is considered acceptable behaviour. It is those nearest us who have the greatest influence on us, but these are often people with similar preferences and attitudes and hence behaviour similar to our own. Neighbours and colleagues who are not chosen to the same degree as friends and family are, may have greater differences in behaviour and preferences. Group pressure from these can therefore be greater, because the initial dissimilarities are greater. If all his neighbours install heat pumps, a homeowner may feel that he is not perceived as very eco-friendly if he has not also installed a heat pump (Klöckner, 2011).

Another effect of extrinsic motivation may be a desire to increase one's status, for example by demonstrating one's environmental credentials. This can have some amusing outcomes, such as in the USA where some individuals have erected solar panels on the street-facing side of the house even though this is shaded and the solar panels accordingly have the worst possible output conditions. The intention is to show neighbours and passing pedestrians and drivers that the owner has invested in solar panels. This is perceived as more important than installing solar panels with the best possible orientation (Sexton & Sexton, 2011). The desire to demonstrate one's eco-credentials to others is also a key reason why a very large share of the hybrid car market in the USA has been taken by the Toyota Prius. There are many hybrid cars in the USA that are technically as good as the Toyota Prius, but they are hybrid versions of existing models (such as the Honda Civic). The Toyota Prius is produced only as a hybrid car and has an easily recognisable appearance that is valued by car owners. Many people decide to purchase a Toyota Prius because they think it signals their environmental awareness to those around them. Toyota was conscious of this when planning the Prius, as the designers were tasked with designing an easily recognisable car (Sexton & Sexton, 2011).

Economic benefits can be an important driver for energy behaviour. This applies both to investments in new energy-consuming equipment and in daily use of the equipment. In general, households require a very short payback time for their investments. As a result, people are unwilling to invest in energy-efficiency measures unless the energy saving is so high that the investment is paid back within a short period. People think carefully about the investments they make, but less about daily consumption (Energimyndigheten, 2007). Households therefore accord a much higher value to investment costs than to operating costs. This is an obstacle to many efficiency measures which households could implement if they could accept a longer payback time.

As stated above, when people do things for the enjoyment of the activity itself, it is called intrinsic motivation. This type of motivation may have various causes, for example one may decide to be energy-efficient out of a concern for the environment and the climate. By using less energy, one impacts the environment less, both through reduced greenhouse gas emissions and a reduced need for energy production and therefore less land disturbance. For many people, this in itself is a strong motivation.

Comfort is an important motivation for many people's energy consumption. For example, they may want a certain temperature at home and at work. Some like very hot water to shower in and to leave unoccupied rooms well lit.

Safety and security are other factors that may determine energy consumption. Some people like to leave a light on at home even if they are on holiday, to give the impression that the house is occupied. Others leave the light on at night to see where they are going and avoid injuring themselves if they have to get up.

3.5.2 What can be achieved by changing behaviour

Energy consumption in houses is affected by the occupants' behaviour. This is apparent in Figure 3.17, which shows energy consumption for heating for two years (from 1 June 1997 to 31 May 1999) in three flats in the same building in Austria. The red line shows energy consumption for heating in the end flat on the ground floor. The blue line shows energy consumption for heating in a flat in the middle of the building, while the green line shows energy consumption for heating in an end flat on the top floor.

A flat's location in the building is very significant for its heating requirements and we can see that the flat in the middle of the building (blue line) has a lower energy consumption for heating than the end flats. This is to be expected, since the flat in the middle of the building has fewer external walls than the end flats, and heating from the neighbouring flats will help heat this flat. But there are also differences in energy consumption for heating in the three flats that cannot be explained by their location in the building.

The flat on the top floor (green line) has a period with a large fall in energy consumption for heating in both cold seasons (the periods when heating is turned on to maintain the indoor temperature at an acceptable level). The two other flats do not exhibit the same pattern. After the fall in energy consumption in the first cold season, energy consumption in this flat is higher than in the other two. After the fall in the second cold season, energy consumption in this flat is much lower than in the others. This leads us to think that it is not climatic conditions that determine the heating pattern in the top flat (green line), but rather the occupants' behaviour.

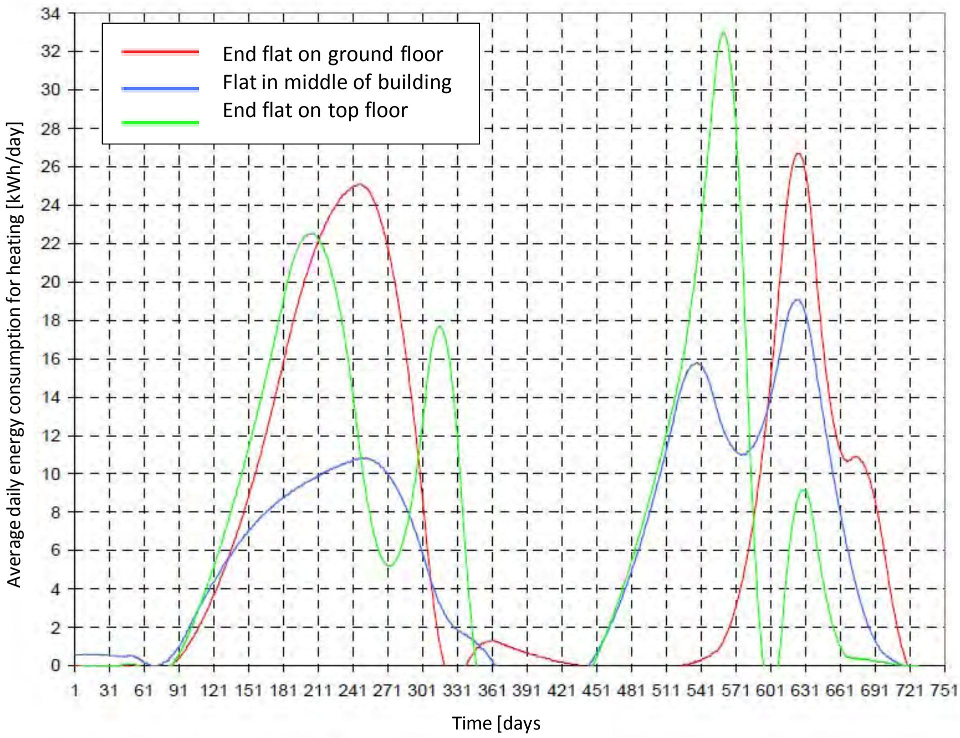

Figure 3.17 Energy consumption in three flats in the same housing complex measured from 1 June 1997 to 31 May 1999 (Stieldorf, Juri, Haider, König, & Unzeitig, 2001)

For the end flat on the ground floor (red line) the cold season starts in the second year around three months after the two other flats (see days 450 and 540 in the graph). The reason for this is not stated and there may be several explanations. Perhaps the occupants of this flat prefer a lower indoor temperature than those of the other two flats and do not need to heat during this period. But since this flat began its cold season at the same time as the others in the first year, this is not a likely explanation. A second reason could be that there was some type of improvement in this flat between the first and second heating seasons, resulting in less need to heat at the start of the second cold season. Perhaps the window frames were made draughtproof. But this flat has a flat trend in energy consumption at the end of the second cold season, while energy consumption in the other flats falls evenly, which rather weakens this theory. Another reason could be that this flat's occupants were not at home at the start of the second cold season. It could also be the case that new occupants moved into this flat in the second year, and their behaviour differed from that of the occupants in the first year.

Small adjustments in behaviour can have significant effects on energy consumption. Figure 3.9 shows the estimated heat requirements in houses that have the same temperature throughout their entire floor area (a single temperature zone), and in houses where 40 per cent of the floor area has a temperature that is 2^{0}C lower than in the rest of the house (two temperature zones). The heating requirement is calculated for low-energy houses and houses built to prevailing standard regulations. The heating requirement is calculated for houses with an indoor temperature of 22^{0}C (and, where relevant, 20^{0}C in parts of the house) and houses with an indoor temperature of 20^{0}C (and, where relevant, 18^{0}C in parts of the house).

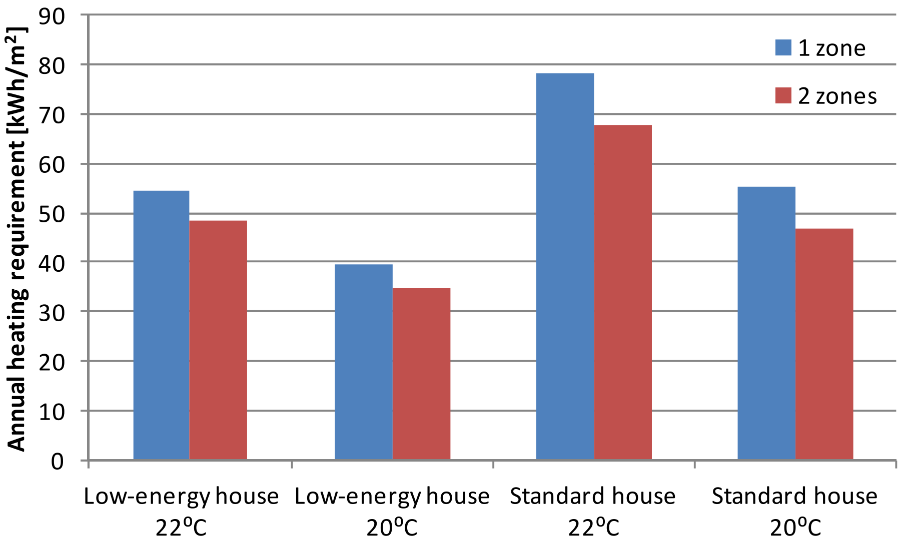

Figure 3.18 Reduced energy consumption from the introduction of temperature zones (Stieldorf, Juri, Haider, König, & Unzeitig, 2001)

Members in the same household may also have different energy behaviour. For example, some may like to come home to a house that is invitingly lit with lots of small lamps[11], while others are happy to find the house in darkness when they return. Energy consumption in each case will depend on who decides.

Most consumers do not have a clear understanding of the energy consumption of appliances when they are in standby mode. For an individual appliance, the consumption is not great, but, in combination, PCs, TVs and other electrical appliances left on standby in Norwegian households use a considerable amount of energy. For a typical Norwegian household, this comes to around 350 kWh per year. For 2.2 million Norwegian households combined, this comes to an annual 770 GWh. This is consumption that could easily be saved without it affecting anyone's comfort.

It is very important for people to feel that they are making a difference. This is problematical in respect of the heating of housing blocks that have shared billing. In that case, the heat consumption of each individual flat is not metered, but rather that of the block as a whole, and the costs are shared evenly between the flats (or possibly allocated according to the size of each flat). Here, a change in individual consumption will have little or no financial benefit. A person may feel that they are making an effort to reduce energy consumption, but since they cannot control their neighbours' behaviour, they do not see any direct results. If there were individual meters for each dwelling for all energy consumption, whether electricity, district heating or heat from a local central heating unit, this would increase awareness of individual consumption, and give occupants more control over their own energy costs. The ownership/rental problem also plays a role. Many people rent houses with energy consumption included in the rent, and have the impression that they do not pay for energy consumption and therefore see energy as free. This frequently leads to unnecessarily high energy consumption. There is no financial incentive to reduce energy consumption. This is also true in cases of joint ownership or

[11] This is a particularly Norwegian phenomenon. Elsewhere in Europe, few households leave lights on in rooms that are not in use, even when the house is otherwise occupied.

ownership within a cooperative where heating is included in the monthly common charges.

Awareness-raising and information about potential energy-saving solutions are crucial if consumers are to make use of them. Being unaware of a solution makes it impossible to employ it. Readily available, clear and relevant information is therefore important. The consumer must also trust whoever is informing him or her and be confident that they are not motivated by self-interest. Scepticism towards new solutions must also be overcome. Most consumers find it easier to adopt new solutions once they have already been tried out by others.

3.6 How homeowners can reduce energy consumption

3.6.1 Energy-efficiency measures prior to the construction of the house

A holistic approach to the planning of houses is important for reducing the building's energy requirements from the first year of its life. The building's siting is very important for its total lifetime energy requirement. Notably, the correct orientation of the building relative to the sun and prevailing wind can reduce the need for heating and cooling. In addition, the actual design of the building will influence its energy requirements for heating and cooling.

Judicious placement of windows with regard to what time during the day and in the year there is a need for passive heating from the sun is important. This is also important for making maximum use of daylight, to ensure that the house has the best possible quality of light. Reduced heating, cooling and lighting requirements may also make it possible to use simpler heating solutions than those currently prevalent. This may result in lower costs, both capital and operational.

A properly insulated and draught-proof building retains heat well and requires less energy. This can primarily by achieved by better/more insulation, less air leakage, fewer cold bridges and super-insulated windows.

3.6.2 Energy-efficiency measures once the house is occupied

A new building that is properly planned and constructed will have low energy requirements. In many older houses, some simple improvements can reduce the energy requirements. The most important measure is to reduce the house's heating requirement and the energy consumption of electrical appliances, and, having done that, switch to energy sources adapted to the heating requirement. This then accords with the Trias Energeticas model discussed in Figure 3.16. The building shell enclosing the home greatly affects the **energy requirement for space heating**. If the building is poorly insulated and leaks heat, a lot of energy will be required for heating. There are many ways for the individual to reduce this energy consumption. The most effective, but also the most extensive, measures are to insulate lofts, basements and walls. Insulating walls is a sensible measure to take when changing wall covering or building an extension. Insulating a loft or a basement can generally be done independently of other refurbishments.

Other simple measures might include draughtproofing around windows and doors. This is easy and inexpensive to do, and can have an excellent effect. It is also sensible to consider having different temperature zones in the house. Bedrooms, for example, do not need to be as warm as lounges and other living rooms that are constantly in use; see section 3.5.2. Keeping the doors to cold rooms such as cellars and lofts closed will also have a beneficial effect.

When it comes to energy consumption for heating water, substantial savings can be achieved by using water more sparingly, for example by having shorter showers, installing a water-saving shower and not rinsing the washing up under running hot water. Savings can also be made by installing better technology. Better insulated hot water tanks and water-saving showers in particular will help reduce energy requirements. It is also important that the hot water system is well designed. Properly insulated pipes and fittings connected to the hot water system reduce energy consumption. Energy losses in pipework can also be reduced by positioning the water heater close to the bath and kitchen, to keep the pipes as short as possible. Tap water can also be heated directly using heat pumps, solar heating, bioenergy and so forth, instead of electricity.

It is a good idea to **reduce energy consumption for electrical equipment**. When replacing or buying new appliances, it is sensible to choose energy-efficient products, such as household appliances labelled A+++. Many appliances also remain constantly on standby unnecessarily. TVs and other appliances that do not need to be on standby overnight, should be turned off completely. Standby consumption can also be reduced by connecting appliances to a multisocket with a master on/off switch and turning the multisocket off when the appliances are not being used. Relevant appliances here include PCs, printers, TVs and other entertainment devices.

Once the energy requirement has been reduced, a good next step might be to **switch to a different heat source** better suited to the house's energy requirement. There may be a number of reasons for switching to another heat source: it might lead to lower energy consumption and emissions of CO_2. It may also reduce dependence on a single energy source. Old wood stoves can be replaced by new clean-burning wood or pellet stoves. Electric heaters can be replaced by a heat pump, a paraffin stove can be replaced by a heat pump or a wood or wood pellet stove, and an oil-fired boiler can be replaced by a heat pump or wood pellet boiler.

Enova's advice:
Enova offers free advice and tips on how to reduce energy consumption in the home. The key recommendations are:

- Add extra insulation to walls and cold lofts
- Install ventilation units (with heat recovery)
- Install a heat control system
- Switch to triple-glazed low energy windows
- Switch heat sources
- Switch to energy-saving appliances

Enova can be contacted for a free consultation on freephone number 800 49 003 or svarer@enova.no.

4 EU Directives

This chapter discusses three EU Directives implemented in Norwegian law that affect Norwegian households. These are the Renewable Energy Directive, the Energy Performance of Buildings Directive and the Energy Labelling Directive. The Renewable Energy Directive is aimed at ensuring that the proportion of renewable energy increases, while the other two concern reductions in energy consumption.

Energy requirements in the years ahead and the need to reduce greenhouse gas emissions have led to binding targets in the EU concerning the proportion of renewable energy and emissions reductions. In 2007 the EU Heads of State adopted the so-called 20-20-20 targets, which commit the EU, by 2020, to reducing greenhouse gas emissions by 20 per cent relative to 1990 levels, increasing the proportion of renewable energy to 20 per cent, and reducing energy consumption by 20 per cent relative to what it would have been without reduction measures being taken.

Energy efficiency has been high on the agenda in the EU since the 1990s, with a series of directives on energy-labelling of consumer goods to help consumers to purchase more energy-efficient products. Subsequently, the energy-efficiency concept was transferred to the building stock with the introduction of the Energy Performance of Buildings Directive. In 2006 the EU implemented the Energy End-use Efficiency and Energy Services Directive (not yet incorporated into the EEA Agreement) with a requirement for an energy-saving target of 9 per cent of annual end-use by 2016. This Directive is replaced by the Energy Efficiency Directive which was proposed by the Commission in 2011 and agreed upon by the European Council and Parliament in October 2012. This is a framework directive for measures to promote energy efficiency. The requirements will come into force in the EU in 2014.

Illustrations

4.1 The Renewable Energy Directive

The Renewable Energy Directive of 2009 covers both the production and consumption of renewable energy. The Directive replaces, amends and updates provisions and obligations in the Renewable Energy Sources Directive of 2001 and the Biofuels Directive of 2003.

The Renewable Energy Directive describes a method for calculating the share of renewable energy in a country's total energy consumption. It is calculated as a ratio between renewable energy consumption and total energy consumption.
This *renewable energy ratio* measures how much of a country's energy consumption can be calculated as renewable (see Renewable energy ratio fact box). Energy consumption affects the renewable energy ratio directly in both the denominator and the numerator. In the years ahead, it will therefore be even more important for energy consumption to be based on renewable sources.

4.1.1 The background to the Directive

Both the production and consumption of fossil energy causes greenhouse gas emissions. For a long time now, there has been increased focus on the relationship between greenhouse gas emissions, global warming and climate change. There is therefore wide international agreement that emissions must be reduced. At the same time, demand for energy is increasing. Since renewable energy (see Renewable energy fact box) causes few greenhouse gas or other emissions, energy production must be more extensively based on renewable energy sources than before. Renewable energy production can be more costly than fossil energy production. Therefore incentives are required for investment in renewable production.

The objective of the Renewable Energy Directive is to ensure long-term cooperation in Europe to promote the production and use of renewable energy. The Directive provides a common framework for stimulating the construction and upgrading of installations to generate more renewable energy. It sets mandatory national targets for the share of renewable energy (see Renewable energy ratio fact box) and a binding national target of 10 per cent of

Renewable energy
Renewable energy comprises energy from sources that are continually replenished with new energy and cannot be depleted. Renewable energy sources include solar energy, hydroelectricity, wind power, bioenergy, wave power, geothermal energy and ground heat, tidal energy and osmotic power. The counterpart of renewable energy is non-renewable energy, which is characterised by limited natural resources that can be depleted within a timeframe of some tens or hundreds of years Examples include coal, crude oil and natural gas. Renewable energy is considered to be more sustainable than non-renewable energy, since renewable energy sources cannot be depleted and they are more evenly distributed geographically. They are more environmentally friendly than non-renewable sources, since they cause few greenhouse gas and other emissions. Biomass is considered to be CO_2 neutral in the long term, since emissions of CO_2 from biomass combustion equate to the quantity of CO_2 that the plant took from the atmosphere as it grew. (Bøeng, 2011)

renewable energy in the transport sector by 2020. The Directive came into force in EFTA/EEA on 20 December 2011.

The implementation of the Renewable Energy Directive has given Norway an overarching target of 67.5 per cent of energy consumed in the country to be renewable energy by 2020. This share of renewable energy in 2020 shall preferably be achieved through more electricity and heat generation based on renewable energy sources and more use of, for instance, bioenergy for heating and land-based transport.

The share of renewable energy is calculated as a ratio whose numerator is renewable electricity generated, renewable heating/cooling consumed and renewable energy in the transport sector, and whose denominator is energy consumption including heating/cooling, electricity and consumption in the transport sector. See the Renewable energy ratio fact box. The more overall energy consumption that originates from renewable energy production, the higher the ratio of renewable energy will be.

Renewable energy ratio

The renewable energy ratio is a measure of the share of renewables in total energy consumption. It can be stated as:

$$\frac{Renewable\ electricity\ prod. + Renewables\ for\ energy\ heating\ and\ cooling + Renewables\ for\ transport}{Total\ electricity\ consumption + Energy\ for\ heating\ and\ cooling + Energy\ for\ transport}$$

The three items **above** the fraction line constitute renewable energy consumption. The first item includes renewable electricity generation as a measure of renewable electricity consumption, since it is assumed that electricity that is generated is actually used. The second item includes the consumption of renewable energy other than electricity, such as biomass, for heating and cooling. The third item includes the consumption of renewable energy such as biodiesel, hydrogen and electricity for transport.

The three items **below** the fraction line constitute gross energy consumption, i.e. both renewable and non-renewable energy consumption. Gross energy consumption includes all energy products (renewable and non-renewable) supplied for energy uses to the manufacturing industries, the transport sector, households, the service sectors, agriculture, forestry and fishing. The energy sector's consumption of electricity and heating for the purposes of generating electricity and heating is included in energy consumption, along with distribution losses incurred during the transmission of electricity and heating.

There are a number of factors that may assist in achieving the target of 67.5 per cent of renewable energy in 2020, including increased generation of electricity from renewable sources. To make it more profitable to invest in this development, Norway and Sweden have agreed to create a Norwegian-Swedish electricity certificate market aimed at increasing electricity production from renewable energy sources by 26.4 TWh/year by 2020. For comparison, in 2010, Norway produced 118 TWh of electricity from renewable sources (hydroelectricity and wind power).

In addition to increasing production of renewable energy, the target can be reached by more energy consumption being based on renewable energy. Chapter 3.1 gives an example of how household energy consumption has become more based on renewable energy as oil and paraffin for heating have been replaced by electricity and biofuels. As shown in Figure 3.1, oil and paraffin made up 4 per cent of households' energy consumption in 2010. The target could also be achieved by reducing overall energy consumption (i.e. the denominator in the ratio), for example by using energy-efficiency measures as described in Chapter 3.6.

The renewable energy ratio in a given year depends on both electricity production and energy consumption. Both hydroelectricity and wind power depend on specific climatic conditions for ensuring the target is reached. In a dry year, the water reservoirs will be filled below average. This may cause higher electricity prices and more demand for alternative energy products such as oil, gas and biofuel. A dry year in 2020, for example, might affect whether the target is reached, if electricity production from renewable sources is insufficient.

In the same way as in 2010 (see Chapter 2), a cold winter could impact the renewable energy ratio. When temperatures fall, it is especially the consumption of district heating, bioenergy, heating oil and paraffin that increases. A cold winter in 2020 could therefore result in increased energy consumption and a reduced share of renewable energy.

The share of renewable energy varies from year to year as shown in Figure 4.1. In 2009, it was a full 65 per cent, in part due to a fall in energy consumption as a result of the financial crisis. In 2010, it was however down to 61 per cent because of the cold winter and ensuing record-high energy consumption (SSB, 2012).

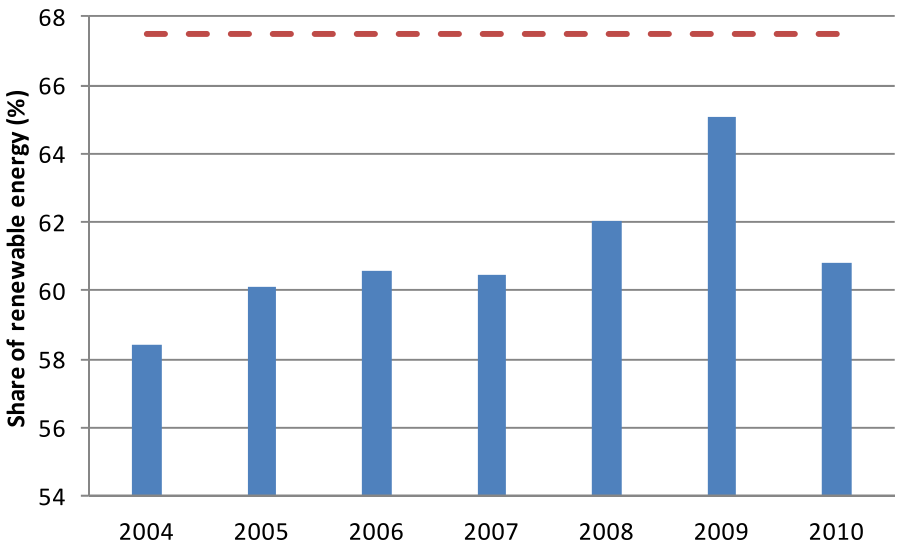

Figure 4.1 Share of renewable energy. The dotted line shows the renewables target of 67.5 per cent in 2020. 2004-2010. (SSB, 2012)

This report focuses on household energy consumption and it is therefore natural to examine what consequences the Renewable Energy Directive may be expected to have for households, firstly in the form of electricity certificates, which may affect the price of electricity, and then biofuels, which may affect the energy consumption of motor vehicles.

4.1.2 Electricity certificates – consequences for households

In order to achieve the renewables target in 2020, Norway has decided to support the expansion of renewable electricity through the electricity certificates scheme. The Act on certificates for electricity production[12] was adopted by the Norwegian Parliament in the summer of 2011. It means that electricity producers who invest in the generation of renewable electricity will receive electricity certificates that can be sold on the market and it thereby yields higher returns for producers of renewable electricity. All suppliers of electricity to households and other end-users are obliged to purchase a certain share of certificates in proportion to the quantity of electricity they sell to end-users. In this way, the electricity certificates become an extra source of revenue for the producers. The electricity certificates make it more profitable to invest in the production of renewable electricity and thereby help to achieve the target of more renewable electricity.

The costs of purchasing electricity certificates are added to electricity bills. It is therefore the electricity end-customers who finance the scheme. Costs resulting from the electricity certificate obligation are included in the price in fixed and variable price contracts, and in the premium in the case of spot price contracts. Since the electricity certificate price is set by a market, it will vary in response to the supply and demand for certificates. It is therefore uncertain what the electricity certificate price will be in the long term. Even though the costs are covered by the customers, this does not necessarily mean that electricity will be more expensive over time. Access to more renewable electricity may also result in the electricity price falling. It is therefore uncertain whether the electricity price that households pay will go up or down or remain unchanged.

NVE administrates the electricity certificate scheme in Norway and publishes relevant information on its website. At www.nve.no/no/Kraftmarked/Elsertifikater the cost of electricity certificates can be calculated using NVE's dedicated online calculator.

Electricity certificates

Electricity certificates are an economic subsidisation scheme that makes it more profitable to invest in power production based on renewable energy sources such as water, wind, sun and bioenergy. The scheme is regulated pursuant to the Act on certificates for electricity production and appurtenant provisions. Power plants included in the scheme receive electricity certificates based on how much power they produce.

Power suppliers and certain electricity users are obliged to purchase electricity certificates for a specific proportion of the power they supply or consume.

As of 1 January 2012, Norway is part of the Norwegian-Swedish electricity certificate market, which is aimed at promoting increased production of renewable electricity. Up to the year 2020, Sweden and Norway shall increase electricity production based on renewable energy sources by 26.4 TWh.

[12] http://lovdata.no/cgi-wift/wiftldles?doc=/app/gratis/www/docroot/all/nl-20110624-039.html&emne=elsertifikat*&

4.1.3 More consumption of biofuel and electricity for transport

Energy consumption for transport is discussed in Chapter 2.2. The share of renewable energy in transport is shown in Figure 2.1 and was 3.6 per cent in 2009 and has to increase to 10 per cent by 2020 in order to fulfil the requirements of the Renewable Energy Directive.

The biofuel sale obligation[13] for road traffic increased from 2.5 to 3.5 per cent on 1 April 2010. Car manufacturers allow the use of diesel with a blend of up to 7 per cent biodiesel and petrol with a blend of up to 10 per cent bioethanol. Higher blends require the engine to be adjusted for the fuel for optimal operation. It is currently possible to purchase diesel with a blend of up to 7 per cent biodiesel at many service stations in Norway. There is also a market for diesel containing from 30 to 100 per cent biodiesel. Diesel with such large amounts of biodiesel added is primarily suitable for lorries, but some cars are also able to run on it.

Biofuel

Biofuel is made from biological matter. There are several types of biofuel. The best known are biodiesel and bioethanol which can both be used in their pure forms, but are normally added to diesel and petrol made from fossil oil. Other biofuels are:

- Hydrogen
- Dimethyl ether (DME)
- Methanol
- Synthetic diesel
- Biogas

Biofuels can be classified as either first or second generation. First-generation biofuels are biodiesel produced from oil-rich plants like rape or palm, and bioethanol based on the fermentation of sugar-rich plants.

Second-generation biofuels are more energy-efficient and have better climate credentials, and involve a switch in raw materials to cellulose-rich plants, primarily wood products treated biochemically or thermally. Wood alcohol (methanol) has been produced in this way in Norway for many decades. (SSB, 2008)

It is expected that the biofuel sale obligation will increase to five per cent when environmental and sustainability criteria for biofuels are introduced. This may be a key contribution to attaining the objective of 10 per cent renewable energy for transport by 2020.

Biofuel contributes to the principle of not increasing the concentration of CO_2 in the atmosphere, which is an important motivation for targeting biofuels. First generation biofuels are based on agricultural products. For the world's population, it may be problematical that biofuel production uses ordinary food crops. Development of second-generation biofuels (see Biofuels fact box) based on wood, straw and other agricultural products is therefore desirable (Econ Pöyry og Nobio, 2008). In order to stimulate increased use of second-generation biofuels, this type of fuel counts double when calculating the share of renewable energy for transport. This will also result in the number above the fraction line in the renewable energy ratio being slightly larger, thereby increasing the ratio (see the

[13] http://www.regjeringen.no/mobil/nn/dep/md/aktuelt/nyheter/2010/Pabud-om-okt-omsetning-av-biodrivstoff.html?id=599548

Renewable energy ratio fact box). A second fuel that counts double when calculating the share of renewable energy for transport is biogas from biodegradable waste or manure. To adapt technology to use biogas is still relatively expensive, but there is a growing market with a number of suppliers. The fuel is particularly used in public transport (HOG Energi, 2010).

Electric cars. In order to stimulate increased use of electricity from renewable sources for road transport, its use is rewarded in the calculations by a factor of 2.5. As with second-generation biofuels, this will result in a higher figure in the renewable energy ratio's numerator and hence a higher renewable energy ratio. In Norway, all electricity used for operating trains, trams and the metro, as well as electric car charging, is counted as renewable energy in the transport sector. At the end of 2010 there were 3,392 electric cars among Norway's 2.7 million registered cars. By June 2012, this number had increased to 7,000 (Grønn Bil, 2011). In 2010, there were 2,600 charging stations across the country and the first rapid charging stations, which can charge an electric car in around 30 minutes, came in 2011. At www.gronnbil.no there are statistics on the number of electric cars and charging stations per county and municipality in Norway.

In order to boost the number of electric cars on the road, the authorities have granted a range of benefits in connection with their use. The Climate Agreement, adopted in Parliament on 7 June 2012, states that the existing tax benefits on the purchase and use of zero-emissions cars are to be continued for the next parliamentary session (2017) or until the number of vehicles reaches 50,000 or more.

Electric cars are exempt from the one-time registration tax, value-added tax and reduced annual road tax. Electric cars can travel free on ferries and park free in public car parks, use bus lanes and are exempt from road tolls. As shown in Chapter 2.2, energy consumption for transport in 2011 came to 71 TWh. Of this, electricity consumption constituted 700 GWh, of which 20 GWh was for road transport. Electric cars do not account for more than 2.8 per cent of total electricity consumption in the transport sector, with the rest used for trains, trams and the metro. Even though electricity consumption for road traffic is multiplied by 2.5 in the ratio calculation, its share remains very small. It is hard to imagine that even a large increase in the number of electric cars on the road could result in a significant increase in the share of renewable energy for transport by 2020.

4.2 The Energy Performance of Buildings Directive

The Energy Performance of Buildings Directive (2002/91/EC) from 2002 aims to improve energy efficiency in the building stock. In 2003, the Directive was implemented in Norway. It requires that each country sets a minimum standard for buildings' energy performance, that a scheme is established for energy certification of all buildings, as well as a scheme for energy assessment of some technical installations in buildings. In Norway, these requirements are fulfilled through technical building regulation[14] (TEK10) which is administrated by the Norwegian building authority and the energy labelling

[14] http://lovdata.no/cgi-wift/wiftldles?doc=/app/gratis/www/docroot/ltavd1/filer/sf-20100326-0489.html&emne=byggteknisk*%20%2b%20forskrift*&

regulations[15] which are administrated by NVE. The key significance of the Directive for households is that houses must be energy-certified before sale and renting and that the energy standard for new buildings is higher.

The EU introduced more stringent regulations in 2010 with a new Energy Performance of Buildings Directive (EU, 2010). The most important new requirement is that new buildings must be so-called nearly zeroenergy buildings by the end of 2020. For the time being, this Directive is not part of the EEA Agreement and does not apply to Norway.

In Norway, as in many other European countries, energy consumption in buildings constitutes a large proportion of the country's total energy consumption, about 40 per cent. Improvements to buildings' energy performance is therefore crucial for reaching the 20-20-20 targets the EU has set for 2020. Both requirements for more energy-efficient solutions and for the use of renewable energy will aid attainment of the targets of 20 per cent more renewable energy and 20 per cent energy savings. Both aspects also contribute to reaching the target of a 20 per cent reduction in CO_2 emissions. The Energy Performance of Buildings Directive has been implemented in most European countries, but with large national differences. The EU Commission has established a number of projects to support implementation of the Directive, including the development of European standards for energy calculations, support for testing different models and information exchange between countries.

The energy labelling scheme entered into force on 1 July 2010. The scheme is mandatory for anyone selling or renting out houses or commercial buildings. Commercial buildings of more than 1,000 m^2 must always have a valid energy certificate. The energy certificate consists of an energy label that shows the building's energy standard under normal use. The energy label is therefore calculated independently of how the owner/lessee actually uses the building. The certificate may in many cases also provide an indication of the building's technical condition.

The energy label consists of an energy grade and a heating grade. The energy grade runs from A (best) to G (worst). The grade provides an overall assessment of the building's energy requirement, i.e. the number of kilowatt hours that the building or house requires per square metre during normal use. The energy grade is based on a calculation of energy supplied, and is independent of the actually metered energy consumption.

The heating grade provides information about the extent to which the energy requirements for space heating and hot water can be met by energy sources other than electricity and oil. The heating grade indicates nothing about how much energy the building or house consumes, only the form in which energy is supplied.

[15] http://lovdata.no/cgi-wift/wiftldles?doc=/app/gratis/www/docroot/for/sf/oe/oe-20091218-1665.html&emne=energimerkeforskrift*&

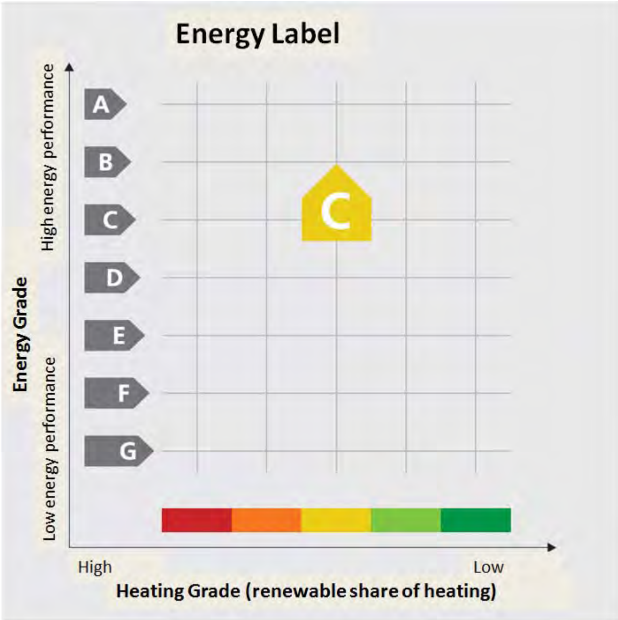

Figure 4.2 The energy label consists of an energy grade and a heating grade. The energy grade runs from A (best) to G (worst). The heating grade, represented here by a red A, provides information about the extent to which the energy requirements for space heating and hot water can be met by energy sources other than electricity and oil.

In addition to the energy label, the energy certificate usually includes information about metered energy consumption in the last three years, a list of measures that could make the house more energy-efficient and a summary of the main data items used as a basis for the energy labelling. This allows new owners to verify the basis for the energy label.

During the labelling scheme's first year, no less than 100,000 energy certificates for houses and 4,400 for commercial buildings were issued. This is considered to be an excellent result. For further work, the aim is for more commercial buildings to be energy labelled, and that the energy label becomes a natural point of referral in the market for the energy quality of buildings. At June 2012, more than 200,000 buildings were energy labelled.

NVE is responsible for the energy labelling scheme and has created a dedicated web page for it, including www.energimerking.no. This provides information about the scheme, and is also a portal for performing energy labelling. Energy labelling is performed by entering details about the house or commercial building on the website. For houses, the system has been developed so that the owners of the house can carry out the energy labelling. The user can choose between simple and detailed registration. For new buildings and commercial buildings, the energy certificate must be produced by an expert. This expert is able to enter, and is responsible for, the individual input parameters, He is also responsible for recommending measures to improve the energy grade/heating grade.

It is the owner of the building or house who is responsible for carrying out the energy labelling. If the building is put on the market, the energy certificate must be part of the marketing.

4.3 Energy Labelling Directive

As early as the 1990s, legislation was introduced in Norway requiring energy labelling of major household appliances put on the market. The background to energy labelling was a need for standardised product information and the reduction of energy and resource consumption on the European internal market of which Norway is a part through the EEA Agreement. Energy labels are intended to give consumers better information about household appliances' energy consumption to allow them to request energy-efficient products. A range of household appliances are included in the regulations[16]. Household appliances that must be energy labelled are: refrigerators/freezers, dishwashers, washing machines, tumble dryers, combined washer/dryers, light sources, ovens and air conditioners.

Energy labels are standardised and identical throughout the EEA. The energy label contains details that the consumer must be informed about before purchasing the appliance: a scale using coloured arrows distinguishes energy-efficient products from less energy-efficient ones; the appliance's energy consumption is stated in kWh/annum; the volume of the fridge/freezer compartment is stated in litres; and the appliance's noise level is stated in decibels (dB).

The energy label originally consisted of a scale from A to G, where A was best and G was worst, but as major household appliances have gradually become even more energy-efficient, the scale has been extended with a set of plus signs after the A, so that it is now possible to purchase household appliances labelled right up to A+++; see Figure 4.3. It is the ecodesign regulation[17] that defines the lower limit for a product's energy class. For example, the ecodesign regulation states that from 1 July 2012 refrigerators with an energy label worse than A+ may not be imported into and sold in Norway. Since importers are allowed to sell off already imported refrigerators, A-labelled refrigerators may still be found in the shops after this date.

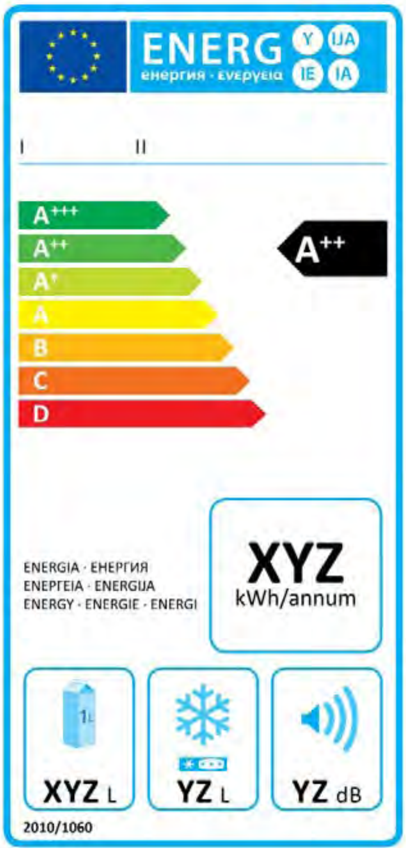

Figure 4.3 Example of new energy label from 30 November 2011

Products offered for sale or for hire must be marked with energy labels. It is the shops' responsibility to affix the correct energy labels on the displayed appliances. The suppliers are responsible for providing the shops with the correct labels for the products. NVE investigates

[16] Regulation no. 16 of 10 January 1996 of the Ministry of Industry and Energy, Forskrift om angivelse av husholdningsapparaters energi- og ressursforbruk ved hjelp av merking og standardiserte vareopplysninger. http://www.lovdata.no/for/sf/oe/te-19960110-0016-0.html

[17] Forskrift om miljøvennlig utforming av energirelaterte produkter. Fastsatt av Norges vassdrags- og energidirektorat 23. februar 2011. http://www.lovdata.no/for/sf/oe/xe-20110223-0190.html

annually how the shops are complying with the labelling scheme. The most common fault is having the energy label hidden, for example inside the appliance. NVE orders such faults to be corrected and, following a change in the law in 2011, NVE can fine shops that do not meet the requirements.

New energy labels from 2011. From 2011, the new label was made mandatory for products comprised by the new energy labelling regulations. The new label derives from a new energy labelling directive adopted in the EU in 2010. This Directive 2010/30/EU is a framework directive, and new regulations are constantly being developed for increasingly more products. The Directive has not yet been incorporated into the EEA Agreement. Products that currently must be energy labelled in accordance with this new Directive are refrigerators and freezers, dishwashers, washing machines and TVs (air conditioners from 1st January 2013). In Norway, use of this new energy label is voluntary until the revised energy labelling directive has been approved and implemented in Norwegian legislation.

More energy-efficient household appliances. Technical developments have resulted in major household appliances being considerably more energy-efficient now than even a few years ago. As shown in Chapter 3.3.1, electricity-specific consumption constitutes a full 22 per cent of household energy consumption. Big savings can therefore be made by selecting the right appliance. The energy label states the annual electricity consumption for running the appliance.

Table 4.1 Annual electricity consumption of the main household appliances. Source: Xrgia, 2011

	Electricity consumption [kWh/year]	Annual cost NOK 1/kWh
Cooker	400	400
Dishwasher	300	300
Refrigerator	400	400
Freezer	400	400
Tumble dryer	600	600
Washing machine	300	300

Table 4.1 illustrates the typical consumption of the main appliances in an average household over a year. Usually, an appliance's energy consumption will not only depend on its energy class but also on how the household uses it, as shown in Chapter 0. Individually, the appliances do not use a lot of electricity although their combined usage amounts to a considerable consumption of electricity. In a Norwegian household, it is common to consume approximately 4,500 kWh per year for electrical appliances.

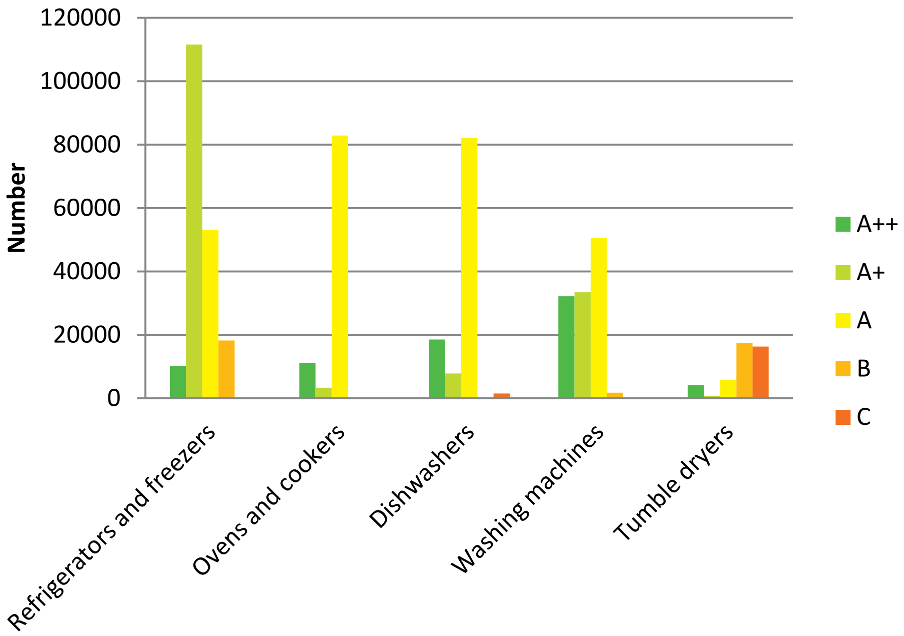

Figure 4.4 Household appliances sold in 2011 by type and energy label. (Elektronikkbransjen, 2012)

A summary of household appliances sold in 2011 broken down by type of appliance and energy label is illustrated in Figure 4.4. The electronics sector's sales statistics cover the majority of sales of household appliances in Norway. In 2011, 560,000 energy-labelled appliances were sold in Norway. No appliances with the best energy class of A+++ were sold in 2011. This class, which is reserved for the best technologies, has not yet been implemented in the Norwegian regulations. Use of this energy class is voluntary until the revised Energy Labelling Directive has been approved and implemented in the Norwegian regulations and it is anticipated that appliances labelled A+++ will have been sold in 2012. As an example, it is noteworthy that an A+++ labelled refrigerator uses 55 per cent less electricity than one labelled A and 50 per cent less than one labelled A+.

49 per cent of household appliances sold in 2011 were energy class A, 28 per cent were A+ and 14 per cent were A++. 190,000 refrigerators and freezers were sold, corresponding to 34 per cent of household appliances. The category 'refrigerators and freezers' include refrigerators, combined refrigerator/freezers, side-by-side refrigerators,chest freezers and upright freezers. In terms of energy consumption, this is the most important group of household appliances and accounts for 23 per cent of households' electricity-specific energy consumption (Xrgia, 2011). Figure 4.4 shows that more than 60 per cent of refrigerators and freezers sold in 2011 were energy class A+ or A++. Most other household appliances are labelled A. Tumble dryers are distinct in that most modelsare energy classes B or C. Energy-class A tumble dryers are still considerably more expensive than those in other classes. To achieve energy class A, a tumble dryer must be equipped with a heat pump.

5 Electricity consumption and power lines

In Chapter 2, it was shown that electricity consumption in mainland Norway has flattened out since the late 1990s. Twenty years of low investment in power lines have, however, created a need for new investment in and improvements to the central grid. A fall in the use of electricity for the heating of buildings may nonetheless reduce power peaks in the years ahead.

This chapter explains how the consumption of electricity affects the power grid. It is not a comprehensive description of the Norwegian grid. This is described in White Paper no. 14 (2011-2012) Vi bygger Norge – om utbygging av strømnettet.

5.1 Why more power lines when electricity consumption is flattening out?

In spite of electricity consumption in mainland Norway flattening out, Statnett has called attention to the need for a NOK 40-50 billion investment in the central grid over the next decade (Statnett, 2011). One important reason for this is illustrated in Figure 5.1. Whereas in the 1970s and 80s billions of Norwegian Kroner were invested annually in the central grid, the last two decades have seen considerably less investment. The result is that much of the grid's spare capacity was swallowed up by **increased electricity consumption in the 1990s**. The flattening out in electricity consumption from 1998 has, on the other hand, helped postpone and reduce the need for investment. But the high electricity consumption of the winters of 2009/2010 and 2010/2011 put the power grid to the test. In many parts of Norway, there was insufficient transmission capacity, resulting in very high electricity prices in these areas. Upgrading of and new investment in the power grid are therefore called for in order to cater for new cold winters.

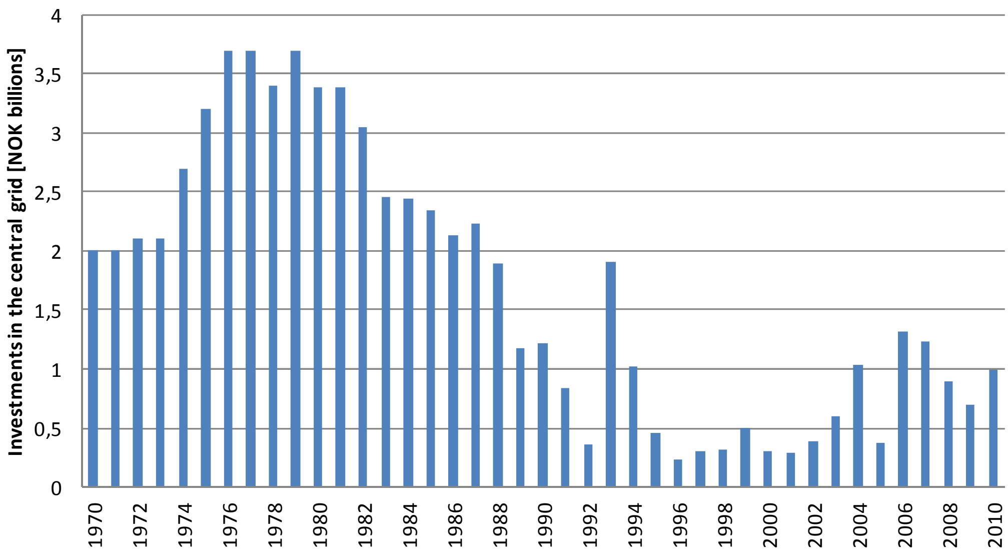

Figure 5.1 Investments in the central grid. NOK billions. Non-adjusted prices. Source: NVE

A second reason for the need for new power lines is that **electricity consumption is moving geographically**. In the last 20 years, major changes have taken place in electricity consumption in the energy-intensive industries and the petroleum sector. Many factories within the energy-intensive industries have closed down. This has helped reduce the electricity consumption in the affected areas. In other areas, new plants have been set up in the energy-intensive industries and petroleum sector which has led to an increase in electricity consumption in these locations.

When new energy-intensive companies are established in an area or existing companies expand their production capacity significantly, more power needs to be brought into that area. This power can be transported from areas with surplus power. An example of this is the new power line from Fardal in Sogn to Ørskog in Møre og Romsdal.

Figure 5.2 provides an overview of trends in annual electricity consumption in the counties[18] of Norway where consumption has changed most since 1993[19]. Four counties, Hordaland, Møre og Romsdal, Finnmark and Akershus, stand out for their notable rise in electricity consumption. A common feature of the first three of these is electrification of installations in the petroleum sector. Large installations such as Troll/Kollsnes in Hordaland, Ormen Lange in Møre og Romsdal and Snøhvit in Finnmark, have led to a large increase in electricity consumption in these counties[20].

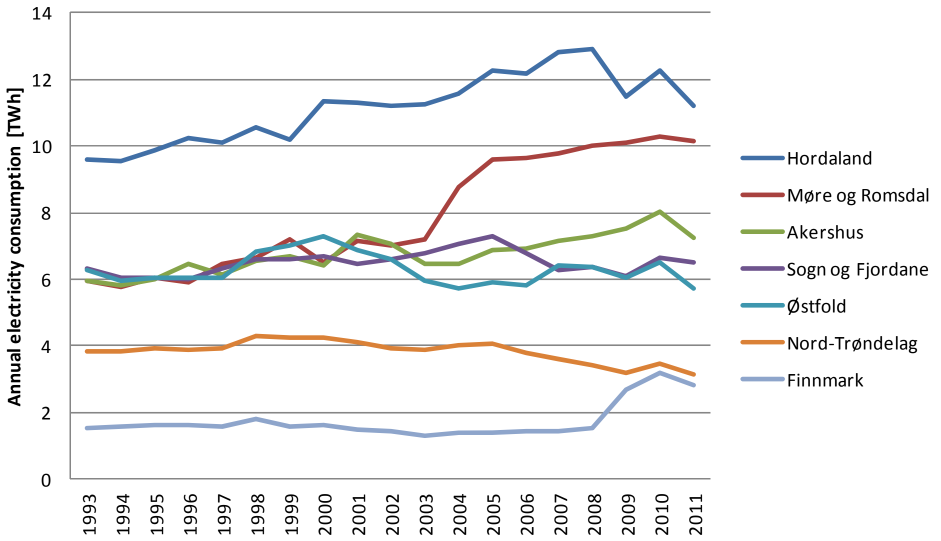

Figure 5.2 Annual electricity consumption in selected counties. Source: Statistics Norway/NVE

In Finnmark, electricity consumption nearly doubled once the gas installation at Melkøya came into operation, but more than 90 per cent of this plant's power requirements are generated in a separate power plant and do not impact the grid. In Møre og Romsdal, electricity consumption has risen by 70 per cent since 1993. In addition to Ormen Lange,

[18] County boundaries do not fully match the grid areas in Norway, so there may be discrepancies between consumption by county and by associated grid areas. For example, Sør-Norge Aluminium is included in the figures for electricity consumption in Hordaland but the company is outside the BKK area.
[19] 1993 is the first year for which we have comprehensive statistics for electricity consumption by county. The figures for 2011 are provisional and may be amended when the final figures are published.
[20] Figure 5.2 shows that consumption in Hordaland has fallen since 2009. This is a result of a number of companies in the metals industry having stepped down production due to the financial crisis.

this county has also seen the establishment and expansion of a number of factories in the energy-intensive industries in the last two decades.

The last mentioned county with a significant rise in electricity consumption is Akershus. This is the Norwegian county with the strongest population growth in the last two decades. The result is a rise in electricity consumption of more than 20 per cent since 1993. Oslo has also experienced a large rise in population, but here consumption only rose by six per cent from 1993 to 2011. The reason for this difference may be that residents across Akershus live in larger houses than in Oslo, with greater floor area and greater consumption of electricity per resident in Akershus than in Oslo. In addition, more and larger service industry companies have been established in Akershus than in Oslo since 1993. Overall electricity consumption in Oslo and Akershus was about 16 TWh in 2011, which is 2 TWh higher than in 1993. There are no large energy-intensive businesses in Oslo and Akershus. Nearly all electricity consumption is for houses and commercial buildings. This makes electricity consumption in the region very sensitive to fluctuations in outdoor temperatures. This was evident in the cold year of 2010, when electricity consumption here rose nearly ten per cent from the previous year, up to 17.7 TWh. High historical population growth, and expectations of continued high growth, give rise to a need for upgrading the power grid around Oslo and Akershus.

While there are four counties notable for a marked rise in electricity consumption, there are three that have experienced a marked fall in consumption in recent years. These are Østfold, Sogn og Fjordane and Nord-Trøndelag. The fall in these counties is a result of factory and plant closures within the energy-intensive industries. The factories were closed after the year 2000, so it is particularly in recent years that energy consumption has fallen. This is shown in Figure 5.2.

A third reason for the need to invest in the power grid is **an increased need for security of supply**. Society's requirement for security of supply has increased considerably in recent decades. A key reason for this is increasing dependence on electronics, electronic communications, payment solutions, IT and a lot of other electrical equipment. Reliable electricity supplies are a prerequisite for the functioning of a modern society. This is especially true in towns and cities where many of the institutions crucial for society are located, such as hospitals and the police. Reliable electricity supply means that consumers have electricity even if a fault occurs in a component in one part of the power grid. A number of Norwegian cities do not currently have adequate security of supply, and the power grid therefore needs to be developed around these cities to rectify this.

Even though this chapter concentrates on the consumption of electricity, **increased production of electricity** is another important reason for installing more power lines. The cooperation between Norway and Sweden to increase power production based on renewable energy sources to 26.4 TWh by 2020 through the electricity certificates schemes may necessitate investment in the power grid in a number of places in Norway.

5.2 Peak demand and the power grid

When constructing the power grid, account must be taken of the hour during the year when electricity consumption is at its highest. This is called the power grid's peak demand or peak load. This means that there must be capacity in the power system to transmit the amount of power required when the demand is greatest. The highest peak demand measured in Norway occurred on 6 January 2010, with a maximum power output of 23,994 megawatts for one hour.

Power and peak demand

When analysing electricity consumption, the usual unit to use is kilowatt hours, kWh. This is described in the fact box on units in Chapter 2. When analysing the operation of the power grid, the relevant unit is power measured in watts (W), or the maximum consumption arising over one hour. The grid is scaled in relation to the number of watts it has to be capable of carrying.

The maximum power that can be transmitted down a power line is called the peak load or peak demand and designates the transmission capacity of this power line. In the central grid, it is usual to use the unit of MW (megawatt = one million watts) to describe how much electricity can move through the grid.

In a twenty-four hour period, peak demand most often occurs in the morning between 8 and 10 o'clock. Most hot water tanks in Norway are run on electricity and designed so that they begin heating fresh water as soon as hot water is drawn. When many people shower before going to work, this means that the hot water tanks in many homes will heat up fresh water from 7 to 10 o'clock in the morning. In addition to household electricity consumption, technical installations in commercial buildings start running from 5 to 6 o'clock in the morning. The first workers then arrive and need lighting, ventilation and heating or cooling, depending on the season. From 8 o'clock and for the rest of the day, most technical installations in commercial buildings run at full power.

Figure 5.3 illustrates the demand profile for electricity consumption around the clock for a weekday for households and commercial buildings. The figure shows that there is low demand in the middle of the night (hours 1-4), but that this increases from 4 o'clock and reaches a demand peak at around 9 o'clock in the morning for both the sectors. In the middle of the day, demand in households falls somewhat, since many people are at work and then rises to a new peak in the early evening when people come home from work. In commercial buildings, demand tails off evenly from the middle of the day, helping to make combined electricity consumption in households and commercial buildings lower in the afternoons than in the morning.

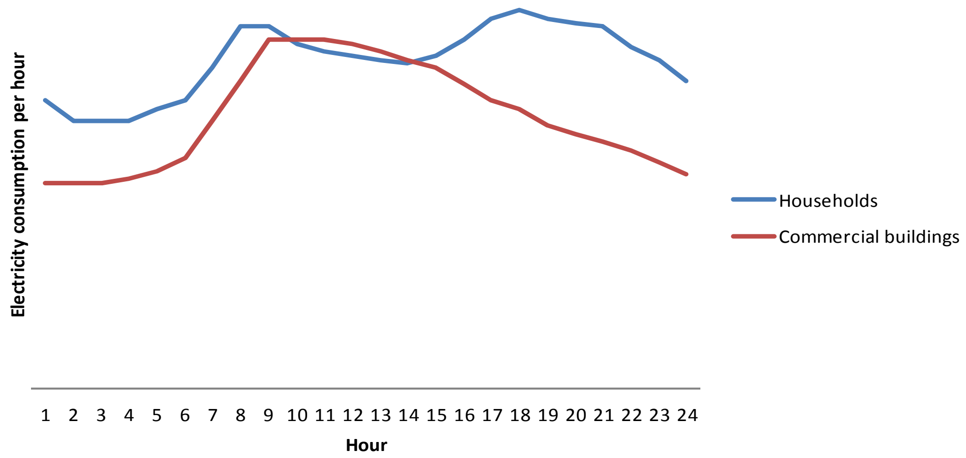

Figure 5.3 Illustration of the daily profile of electricity consumption in households and commercial buildings. Source: Statistics Norway/Statnett

Over the year, most electricity in Norway is used in winter time. On the coldest winter days, a lot of electricity is used for heating. Two thirds of annual energy consumption in houses (see Chapter 3) and around 40 per cent of annual energy consumption in commercial buildings is spent on space heating. Much of the energy for space heating in Norway is from electricity. Heating is necessary in the cold season, which typically lasts from September to May, while minimal amounts of energy are used for space heating in the warm season from May to August. More than twice as much energy is consumed in houses and commercial buildings in a cold winter month than in a warm summer month. This is illustrated in Figure 5.4, which shows monthly electricity used for general consumption[21] from 2000 to 2011.

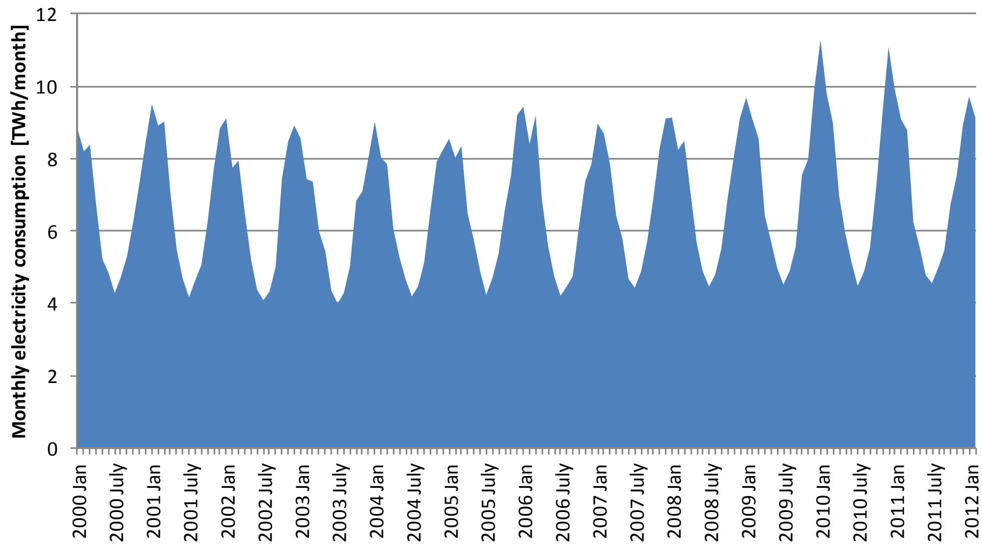

Figure 5.4 Monthly electricity used for general consumption. Source: Statistics Norway

[21] General consumption here includes electricity used in households, the service sectors, the pulp and paper industries, other manufacturing industries, the petroleum sector and transport.

The figure shows that total electricity used for general consumption is around 4 TWh in mid-summer (July), whereas in cold winter months (January) it is up to 8-10 TWh. This difference is essentially due to the extensive use of electricity for space heating. Electricity used for lighting, appliances and water heating varies little over the year. Figure 5.4 shows that this pattern repeats regularly for all the years that the graph covers. In January 2010 and January 2011, electricity used for general consumption was more than 11 TWh, the highest consumption measured for a single month.

Whereas electricity consumption in buildings varies throughout the day and the year, consumption of electricity in the manufacturing industries and in the petroleum sector is more constant. The large installations in the energy-intensive industries and the petroleum sector preferably need to run at a constant pace throughout the year in order to ensure optimal operation. Figure 5.5 shows monthly electricity consumption in the energy-intensive chemical products and metals industries. The figure shows that energy consumption in energy-intensive industries is more even over the year than in general consumption and has no obvious seasonal or periodic fluctuations. New factories in an area may however increase peak demand in that area considerably.

The consumption of electricity in industry varies little over the year, but is affected by economic trends. From 1996 to 2000, new factories were set up and existing factories expanded in step with the prevailing time of prosperity. Figure 5.5 shows that this led to higher electricity consumption. From 2001, trends worsened. Less electricity was generated and consumed. In the autumn of 2003, trends once again improved, production increased and new factories opened. The financial crisis in 2009 brought about a new heavy decline in manufacturing and electricity consumption in these industries, and a number of factories were closed down.

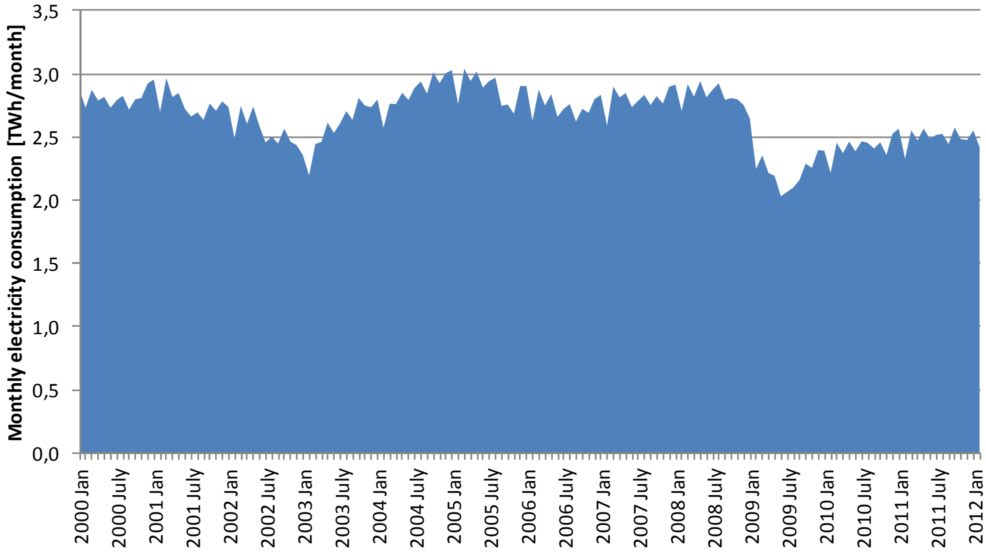

Figure 5.5 Monthly electricity consumption in the chemical products and metals industries. Source: Statistics Norway

Since electricity consumption in Norway is highest in the winter and the highest consumption on a daily basis is at around 9 o'clock in the morning, peak demand in

Norway is on cold winter mornings. At that time, a lot of electricity is used for space heating in both houses and commercial buildings while hot water tanks are running at full power.

5.3 What measures could reduce peak demand in winter?

Since peak electricity demand in Norway occurs on cold winter days, and much of this demand is due to space heating, measures to **reduce electricity consumption for space heating** in houses and commercial buildings are the most effective ways to reduce the need for investment in the power grid**.** The high demand in 2010 clearly showed the significance of outdoor temperatures for electricity consumption in buildings and where measures to reduce peak demand should be implemented.

Vestlandsforskning's household study showed that energy-efficiency measures and converting to more efficient heating systems had been very important in depressing household energy consumption (Vestlandsforskning, 2011). New, strict technical business regulations and financial support from Enova will help dampen future heating requirements in commercial buildings and households. The signals in the Climate Policy White Paper concerning passive houses from 2015 onwards will further reduce the need for space heating in buildings. Figure 3.15 shows how energy for space heating is reduced relative to present-day houses through the construction of low-energy and passive houses, and, since electricity is the most commonly used energy product for space heating in Norway, it is electricity consumption that will be most reduced through the construction of passive houses.

It is also possible to **shift some demand from the peak demand periods** in the morning to other times of the day. For example, fitting timers to household hot water tanks can make them start re-heating water later in the day when the peak has passed. This will become more relevant with the introduction of smart metering (AMS). One important motivation for people's willingness to switch consumption to other times of the day is significantly lower prices for electricity at these times than in the morning peak demand hours.

When large plants are closed down or expanded, capacity problems in the power grid may arise in the areas in question. It is, however, a strategic political goal in Norway to facilitate industrial activity which makes it difficult to introduce measures that prevent companies from establishing themselves in an area. The most effective means of reducing grid overload by large energy users is **system protection**[22] **and interruptible power**. This means that all or some of the electricity supply to these large plants will be able to be disconnected in the event of capacity problems on the grid.

[22] System protection means that the system manager (Statnett) may require the installation of equipment to automatically intervene in the power system to prevent outages in the regional and central grids. In practice, this will mean disconnecting all or some of the supply to major energy users in the event of a constrained power situation in a particular area.

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