SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

TASK 37

Advanced Housing Renovation
by Solar and Conservation

# Energy Analysis of the Norwegian Dwelling Stock

## Subtask A - Internal working document

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# Contents

# 1. Introduction

This report describes an analysis of the Norwegian dwelling stock. The report is a contribution to Subtask A of IEA SHC Task 37 '*Advanced Housing Renovation by Solar & Conservation*'. The aim of the analysis was to reveal the potential for reducing the energy demand within the dwelling stock, related to:

- Typical dwelling types, i.e. large dwelling segments with high energy saving potential
- Different kinds of ownership and decision processes (motivation) that lead to the initiation of energy-retrofit projects
- Retrofit scenarios that support ambitious and long term goals, and marketing aimed at decision makers including politicians

The report is mainly based on available statistics and analyses, and to a lesser extent on new work carried out specifically for this project.

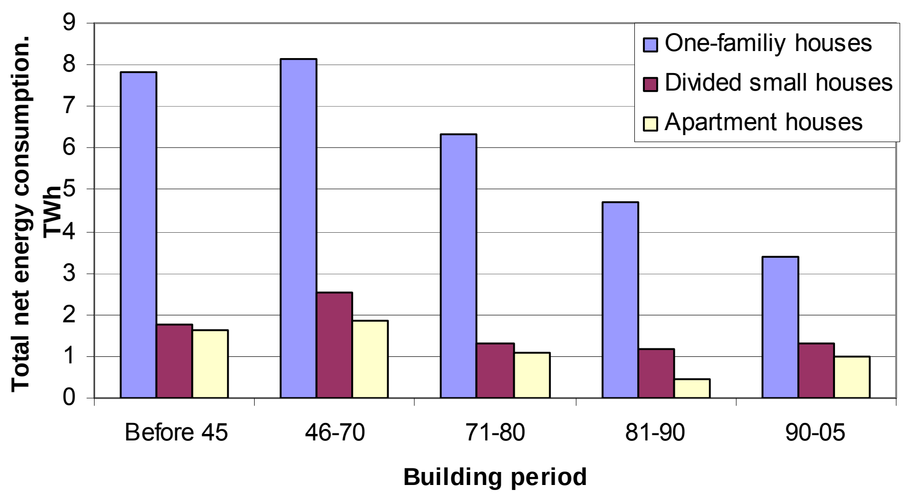
# 2. Summary

**Key statistics for the residential sector**

<u>Stationary energy use</u>
The stationary energy use in the residential sector has increased by 19 % from 1982 to 2005, to a total of 44 TWh in 2005.

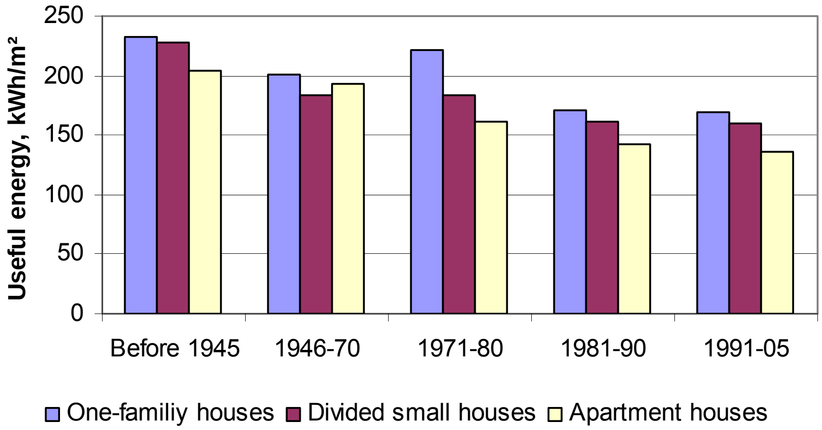
Small houses (i.e. detached, semi-detached, vertically divided, and terraced houses) account for approximately 85 % of the dwelling stock's energy use.
The main energy use in the dwelling stock is in detached and semi-detached houses built after the war and until the end of the eighties.

The figure below shows the total energy consumption used in the dwelling stock split into types of building and construction period.




Estimated total useful energy consumption per year for the housing sector split into building types and building period

The specific net energy consumption (useful energy) is shown in the figure below.

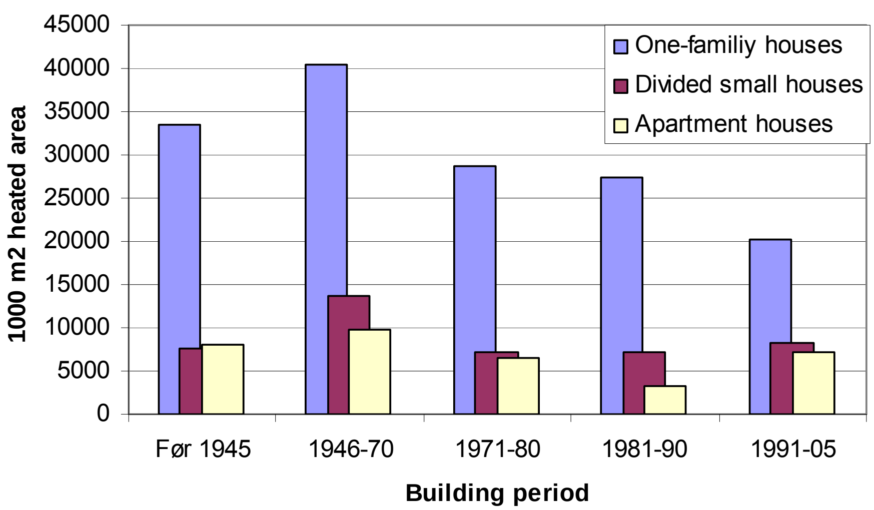



Average specific net energy consumption per m$^2$ for the stereotypes of residential buildings

Total utility floor area and utility floor area per inhabitant

Most of the Norwegian dwelling stock (i.e. about 90 %) was built after the Second World War. During the period 1982 to 2005 the number of dwelling units increased by 40 %. In the same period the total utility floor area in the dwelling stock increased by 16 %, reaching nearly 70 m$^2$ per inhabitant in 2005.

The estimated total heated area is approx. 230 million m², with a distribution as shown in the figure below.




Total heated area split into the three categories of dwelling, according to building age

Heating systems

About 78 % of the 2005 energy use was supplied by electricity. For the whole dwelling stock, electric heating is used in about 70 % of the dwellings, either as the only heating system or in combination with other types of heating systems. The corresponding number for hydronic heating systems is only 12 %. However, a large share of the hydronic heating systems in new dwellings is based on electricity.

CO2-emissions

Household $CO_2$ emissions were about 43.000 tons[1] ($CO_2$-equivalents) in 2005, which corresponds to 10 kg/year per inhabitant.

Ownership structure by type of ownership

The total number of dwellings in Norway was around 2.2 million in 2005. These can be categorized into three main groups:

- 57 % are located in the group termed single-family houses
- 21 % of the dwellings are in the group called divided small houses, which includes vertically and horizontally divided small houses, row houses and smaller terraced houses.
- The remaining 22 % of the dwelling stock is located in the group called apartments, which includes detached blocks of flats and combined buildings.

The predominant ownership of the Norwegian building stock is private homeowners. If we include housing co-operatives, the total own home ownership is 76%.

**Potentials for improvements / Scenario analysis /**

Potential for reduction of energy use and/or greenhouse gas emissions by renovations in the total housing stock or in selected segments.

The potential for energy conservation in the existing Norwegian dwelling stock (2005) depends highly on the level of ambition. If all residential buildings built before 1990 were upgraded with 10 cm additional insulation in the walls, floors and ceilings, new windows with an average U-value of 1,2 $W/m^2K$, and improved air-tightness value ($n_{50}$) to between 2.5 and 3 $h^{-1}$ (at 50 Pa), the reduction of the energy use would be approximately 12 TWh/yr, or 25 %. Similarly, a renovation package of 20 cm additional insulation in the walls, floors and ceilings, new windows with an average U-value of 0.7 $W/m^2K$, air-tightness of $n_{50}$=1.5, and 70%~75 % heat recovery of the ventilation exhaust air, would result in about 17 TWh reduction of the energy use (40 %). The single-family house segment accounts for the largest reduction potential, i.e. about 70 % of the total potential in the dwelling stock.

[1] In Norway, about 100 % of the electricity is produced in hydroelectric power stations. Therefore the electricity used in the households is regarded as hydro power in the statistics (Statistics Norway). However, the statistics do not take into consideration that Norway is a part of the Nordic electricity marked, and thus indirectly also the European marked, and that the electricity use in Norway affects the electricity production in the whole common marked.

Potential for reduction of energy use and/or greenhouse gas emissions by renovation according to scenario analyses.

Another way to estimate the energy conservation potential in the dwelling stock is to consider a possible future development of the stock, for instance towards 2035. Compared to a base scenario, whereby both new and renovated buildings keep the same energy standard as today, a scenario based on the assumption that new dwellings achieve the energy label C [2] (net energy demand: 121 kWh/m$^2$), and that the existing dwellings achieve the label D (net energy demand: 156 kWh/m$^2$), the energy-saving potential will reach about 6 TWh. Renovated buildings will account for about 4 TWh of the reduction.

Another scenario, based on the assumption that new buildings achieve energy label A by year 2035 (net energy demand: 60 kWh/m$^2$), and renovated buildings are gradually upgraded to energy label B (net energy demand: 90 kWh/m$^2$), gives about 11 TWh lower energy use than for the base scenario. For the renovated part of the stock, the energy reduction will be about 5 TWh lower than for the base scenario.

Market segments with the greatest potential for reductions.

See the paragraph for Recommendations

**Other interesting findings or information**

Challenges and opportunities

The predominant ownership of the Norwegian building stock is private homeowners. If we include housing co-operatives, the total own home ownership is 76%. Some of the main communication challenges regarding energy efficient renovation are related to:

- the customer is an individual; there are many potential customers
- it's not a "standard" product – it is difficult to give a fixed price
- it can be difficult to define the positive consequences relative to the extent of the investment
- As each renovation project of a single-family house represents small turnover figures for bigger construction companies, bigger construction companies may see this as a less interesting business opportunity.

If a thorough segmentation job is done, it should be possible to define a manageable target group of potential customers. However, it will probably not be sufficient if only the carpenter/contractor communicate the message to start sustainable renovation project. To build strong motivation by sufficient numbers of consumers, organisations and opinion leaders supporting the environmental and energy-efficiency aspects of

[2] According to the energy labelling system proposed by SINTEF and the Norwegian Building Research Institute in 2005 [1]

renovating a house should also communicate this message. In order to support this, there is a need for telling success stories in magazine articles, etc.

Driving forces and hindrances

One of the main challenges in implementing more sustainable solutions into the existing private owned housing stock is the fact that there exist few or none distributors of complete renovation packages. The market is dominated by traditional building warehouses and "DoItYourself"-shops, and some actors marketing of single products such as heat pumps. This and other market issues are discussed in a separate report made within this IEA Task 37 project.

Who can use the information in the analyses, and for what?

We see two main target groups for this report:

- Public authorities on different levels which have ambitions to take initiatives to encourage a more sustainable housing sector. As the report gives a status of the current situation, as well as illustrating scenarios for future development, it may serve as an important foundation for their policy making processes.
- Companies which are considering the potential in sustainable retrofitting. The report illustrates the building segments with highest potential for renovation business. As the report also discuss the decision making process among different types of house owners, companies will have important input for their discussion of strategic options.

The report is written in English of two main reasons:

- To make the information available for international researchers, so comparisons between countries can be facilitated.
- To make the information easy accessible for international companies looking for business opportunities in the Norwegian renovation market.

Plans for spreading the information in this analysis

The knowledge collected in this analysis will be disseminated through these activities:

- Presentation at regional conferences in Norway where we will gather important actors in the building industry and public authorities.
- Articles in periodicals with main focus on technical development and building industry.
- Presentation for the ministries and public bodies with responsibility for energy and for municipal governance.

**Recommendations from the dwelling stock analysis**

The main energy use in the dwelling stock, and probably the largest energy conservation potential, is in small houses and semi-detached houses built between the Second World War and until the end of the eighties. The oldest dwellings within this group must be assumed to be the objects having the most urgent need for renovation.

Hence, it is within this group of dwellings demonstration projects primarily should be initiated. On the other hand, it is probably within this dwelling group, and these building owners, the challenges are highest regarding communication of energy and cost efficient renovation solutions. Communication towards housing co-operative companies is easier. Further, each housing co-operative company has detailed information about every single housing co-operative. Therefore, it is possible together with the housing co-operative company to identify the housing co-operatives that are more likely to be interested in sustainable renovation or not. The fact that the occupants already have an established relationship with the housing co-operative company, they pay more attention and respect to ideas being launched by the company. Despite that the energy conservation potential in the housing co-operative segment is lower than in the segment of small houses, demonstration projects within this group may give higher response and effect in the market.

# 3. Dwelling stock statistics

This chapter describes statistics on the Norwegian dwelling stock, related to the energy use. The statistics are mainly based on information from Statistics Norway (SSB) and the Register of Real Properties, Addresses and Buildings (GAB).

## 3.1 The age and size of the Norwegian dwelling stock

### 3.1.1 A steady rise in the number of dwellings

Figure 3-1 shows the development of the number of dwelling units in the Norwegian dwelling stock. In total, the number of dwelling units has increased by 40 % from 1982 to 2005.

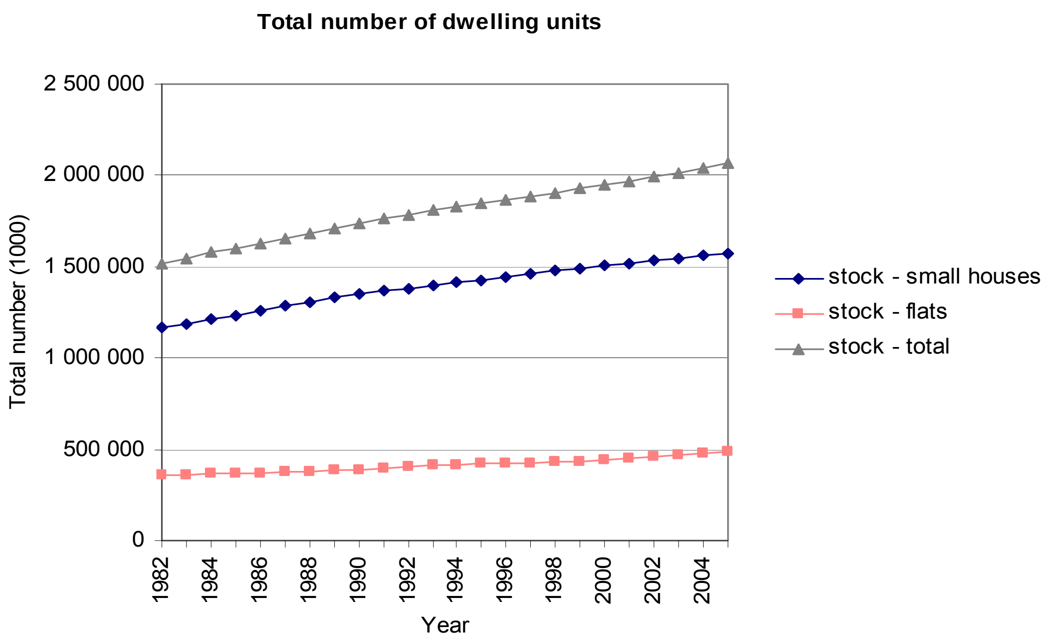



Figure 3-1 Growth in the number of dwelling units in the Norwegian dwelling stock. Source: GAB

### 3.1.2 A steady rise in the floor area in the dwelling stock

For the residential sector, utility floor space is used as a measure of activity/ consumption. Figure 3-2 shows the growth of the utility floor space in this sector since 1982, plotted together with the total energy consumption. Although the building mass has grown steadily, the total energy consumption has flattened - indicating a decrease in the energy intensity over this period.

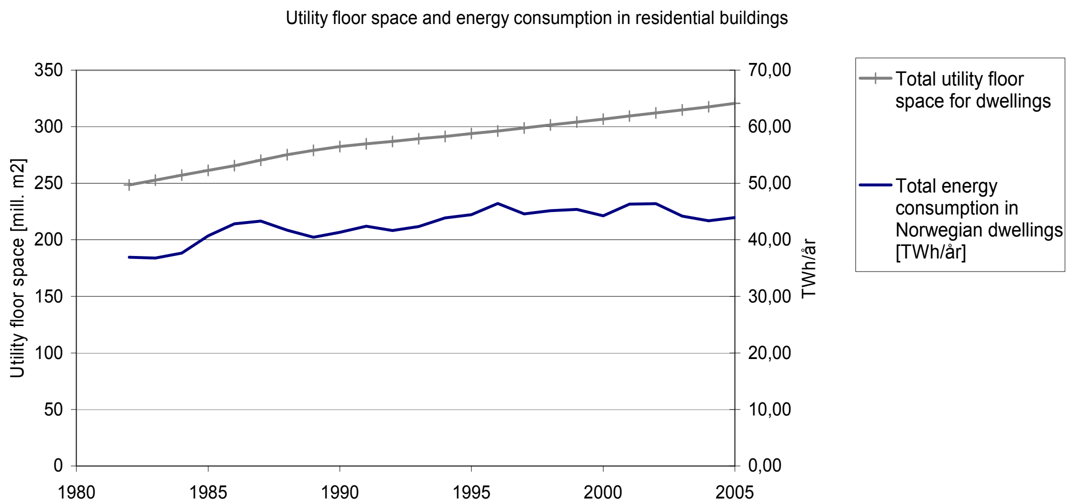



Figure 3-2 Utility floor space in the residential sector (mill. m$^2$) and total energy consumption from 1982-2005. Source: SSB and GAB

### 3.1.3 A steady rise in the floor space per capita in the dwelling stock

Figure 3-3 shows the utility floor space per inhabitant, which was calculated based on the utility floor area (Figure 3-2) and the development of the number of inhabitants in Norway (statistics from SBB). The figure shows that the utility floor space per inhabitant has increased by 16 % form 1982 to 2005.

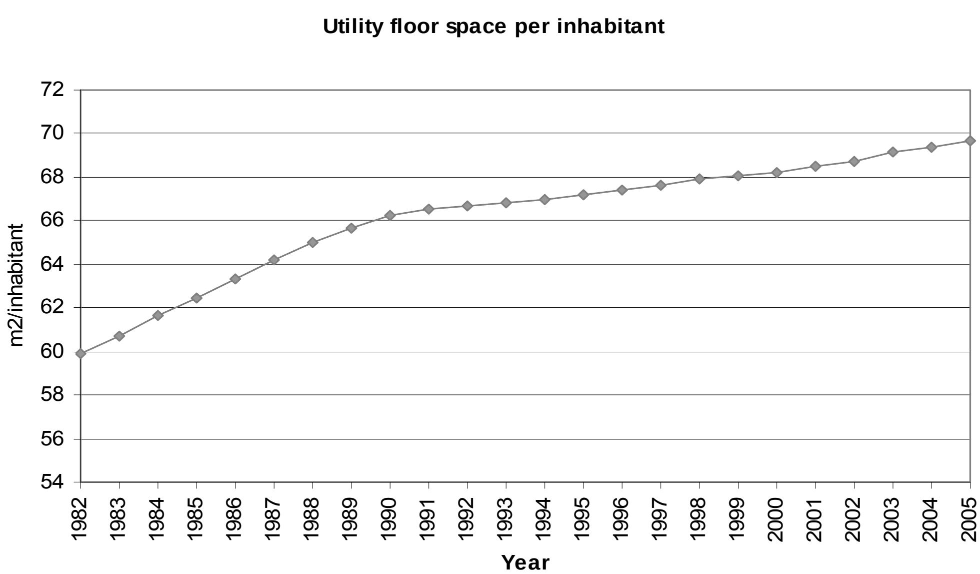



Figure 3-3 The utility floor area per inhabitant from 1982 - 2005

### 3.1.4 The age distribution of the dwelling stock

Most of the existing dwelling stock, i.e. about 90 %, was build after the Second World War. Figure 3-4 shows the age of the dwelling stock, depending on the type of dwelling. The figure also shows the average energy use per household, dependent on the year of construction. From the figure one can read that the main energy use in the dwelling stock is in detached and semi-detached houses built after the Second World War and until the end of the eighties.

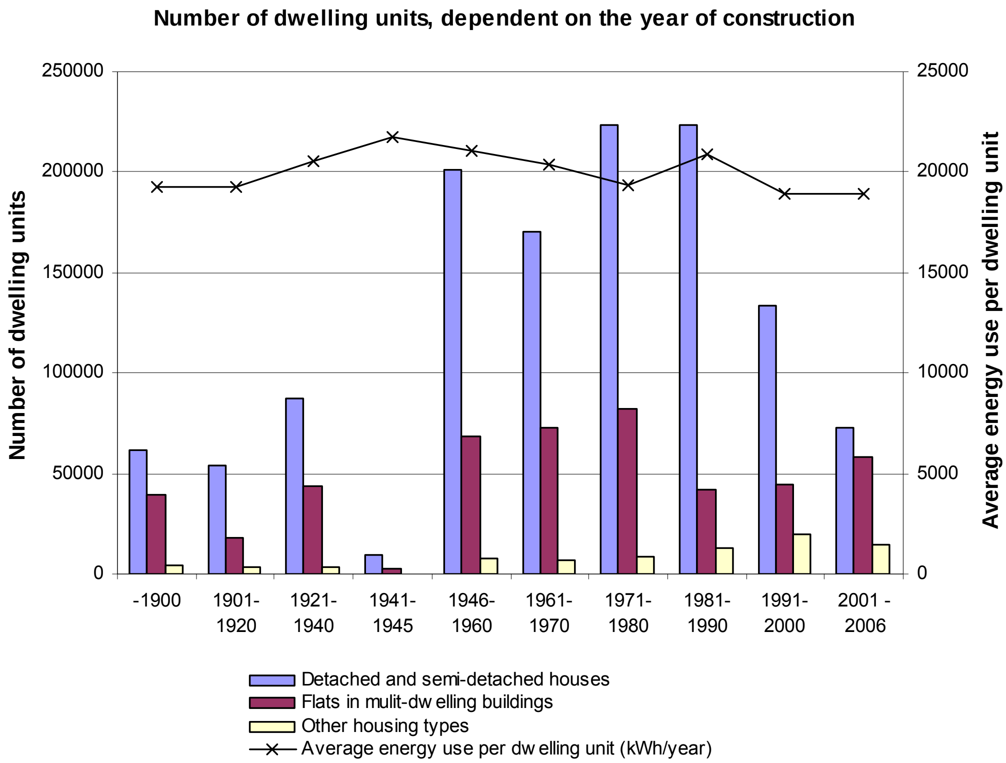



Figure 3-4 The number of dwelling units, dependent on the type of dwelling and the year of construction. Source: SSB

### 3.1.5 The renovation rate in the dwelling stock

There exist no official statistics on the rate of renovation by energy conservation in the Norwegian building stock. A rough estimate of the renovation rate and level in the existing dwelling stock is carried out and described in Chapter 4, based on older estimations on renovation (SSB, 1990) and qualified assumptions related to the renovation since 1990.

## 3.2 The energy use in the dwelling stock

Figure 3-5 shows the stationary energy consumption in the Norwegian residential sector from 1976-2005. The consumption of fuel oil has reduced approximately 75 % since the

1970's, while the use of fire wood has seen an almost equivalent increase in the same period. After a steady increase in the total consumption until the mid-1990's, the total consumption has stabilised over the last 10 years. Also the growth in electricity consumption has flattened out. Except for 2003, the year of the "electricity crisis" in Norway, the share of electricity has varied between 75 and 80 % since 1991.

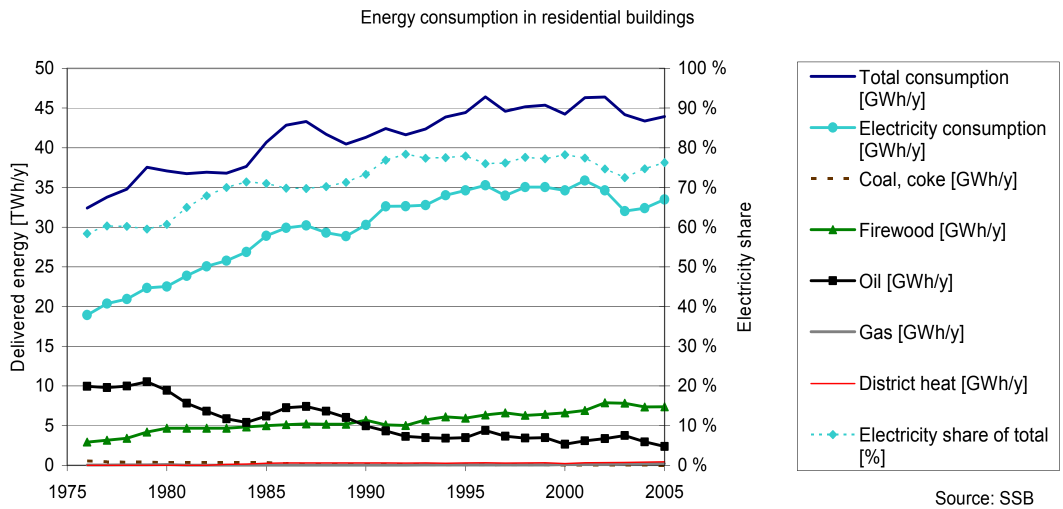



Figure 3-5 Stationary energy consumption in the residential sector from 1976 to 2005, by energy source.

## 3.3 Heating systems in the dwelling stock

The use of different types of heating systems has varied a lot over the past century. Figure 3-6 gives an overview of the heating systems used in the present dwelling stock. Electric heating is used in about 70 % of dwellings, either as the only system or in combination with other types of heating systems. The corresponding number for hydronic heating systems is only 12 %. However, a large share of the hydronic heating systems in new dwellings is based on electricity.

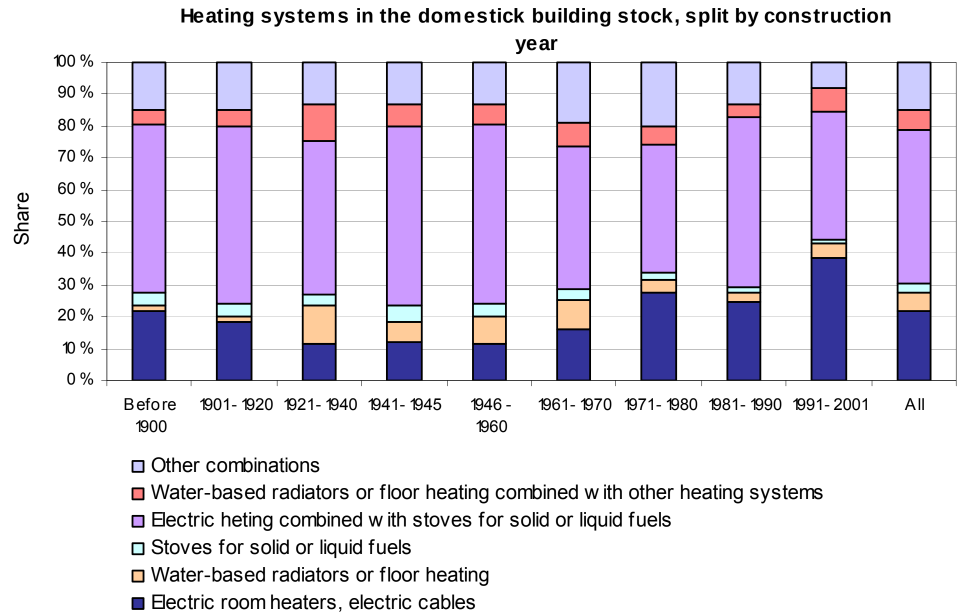



Figure 3-6 Heating systems in the Norwegian dwelling stock, by the year of construction. Source: SSB

## 3.4 Emissions to the atmosphere from the dwelling stock

Figure 3-7 shows carbon dioxide emissions ($CO_2$) to air caused by household stationary energy use, and compared with the total inland emissions. Household $CO_2$ emissions account for 1.5 % of the total emissions, and are mainly due to the use of heating oil.

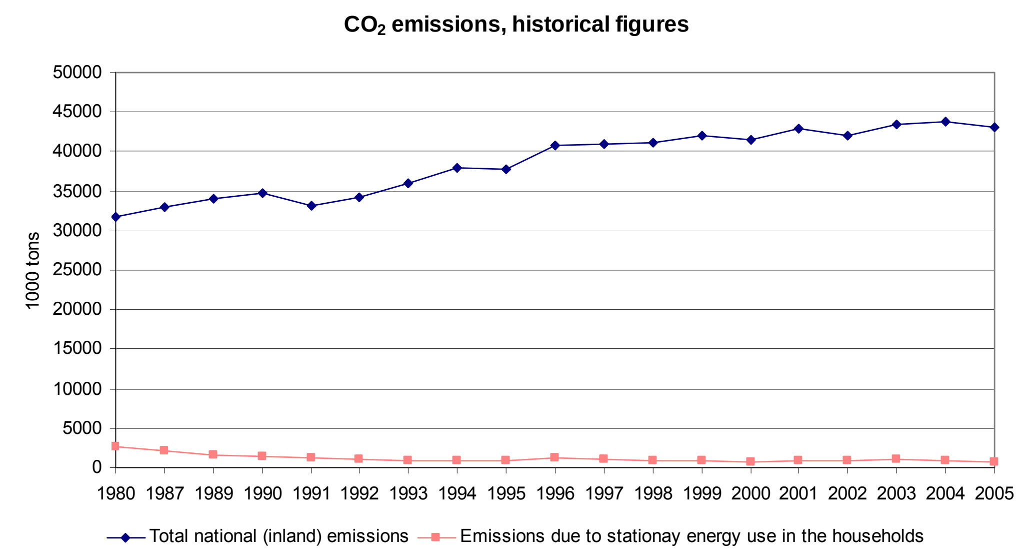



Figure 3-7 Total (inland) emissions in Norway and emissions due to the stationary energy use by households in the period 1980 – 2005. Source: SSB

Figure 3-8 shows other emissions to air, caused by stationary energy use in households. The figure shows the households' share of the total national emissions to air from the total stationary energy use in 2003. The relative high share of CO (carbon monoxide) and $PM_{10}$ (Particulate Matter of 10 µm or less) emissions is mainly due to wood-burning.

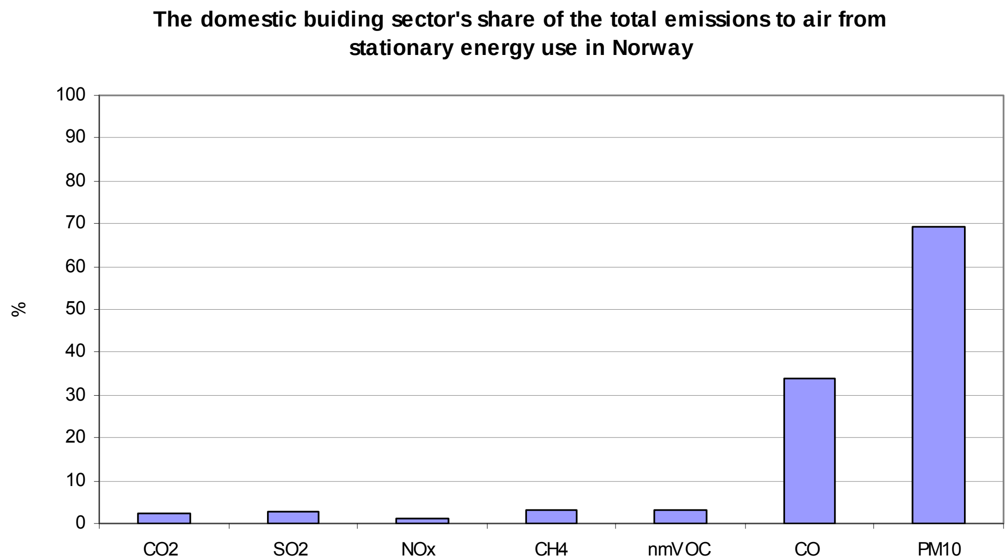



Figure 3-8 The household's share of the total national emissions to air from stationary energy use in 2003. Source: SSB

Nearly 100 % of the electricity used in Norway is generated nationally in hydroelectric power stations. Therefore the electricity used in the households is regarded as hydro-power in the statistics (Statistics Norway). However, the statistics do not take into account that Norway is a part of the Nordic electricity marked, and thus partly also the European marked, and that the electricity use in Norway affects the electricity production in the whole common marked. If a further increase in electricity consumption in Norway outstrips hydroelectric generation capacity, it could for example be supplied by fossil fuel power stations in Europe that are presently on the margin.

# 4. Typical dwellings

This chapter describes the dwelling stock, split into types of buildings, and their energy performance. Using this information, a dwelling-stock model was employed to estimate the total energy consumption. This model is further used as a basis to estimate the energy saving potential for two renovation scenarios for the total dwelling stock, described in Chapter 6.

## 4.1 Stereotypes of dwellings

The total number of dwellings in Norway was around 2.2 million in 2005. These can be categorized into three main groups:

- 57 % are located in the group termed single-family houses
- 21 % of the dwellings are in the group called divided small houses, which includes vertically and horizontally divided small houses, row houses and smaller terraced houses.
- The remaining 22 % of the dwelling stock is located in the group called apartments, which includes detached blocks of flats and combined buildings.

Each of these main groups of dwellings may be divided into five sub-groups according to the year of construction:

- constructed before 1945
- constructed between 1946 and 1970,
- constructed between 1971 and 1980,
- constructed between 1981 and 1990,
- constructed between 1991 and 2005.

These groups, based on construction period, are more or less based on common thermal insulation levels, typically used in the given periods.

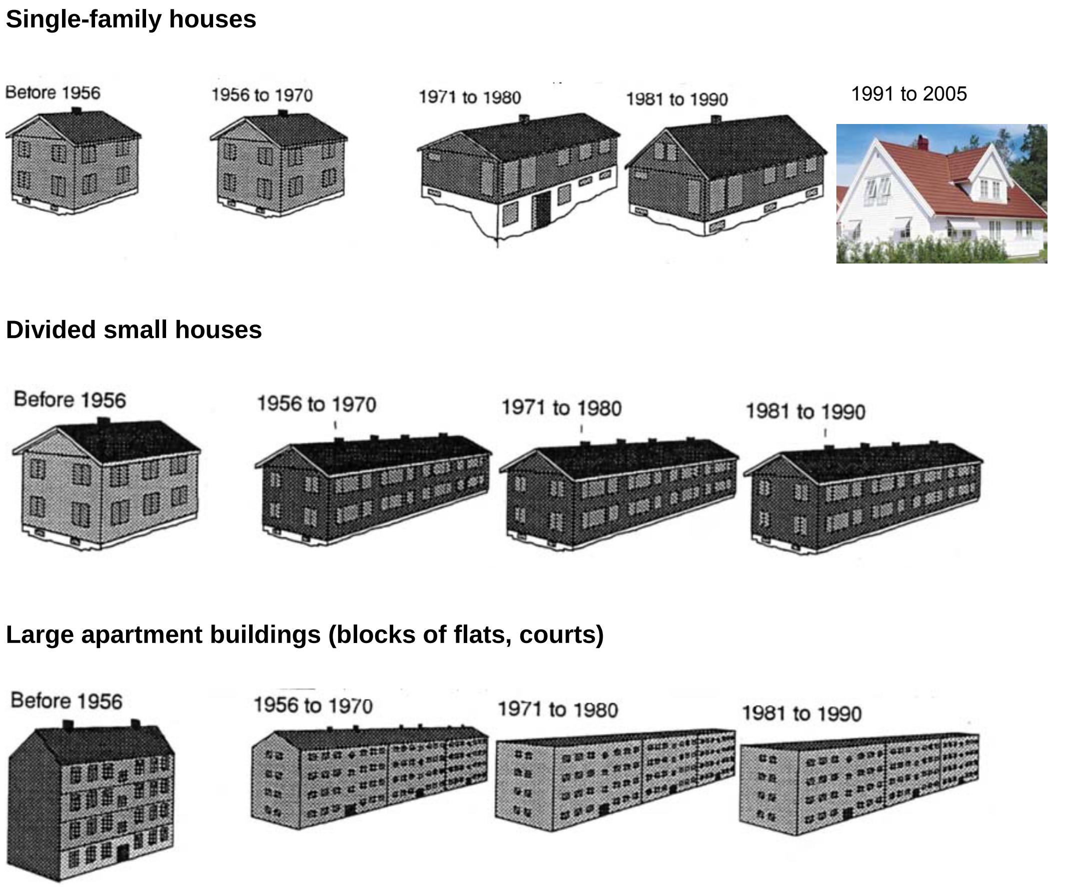



Figure 4-1 Illustration of some of the stereotypes (no illustration of divided small houses and large buildings for the period 1981 – 2005).

The physical parameters are partly based on typical constructions and insulation level when the dwellings were built, and assumed renovation rate and level for the buildings. These assumptions are based on the work presented in a PhD-thesis on energy saving measures [2] and a report from 2000 on future energy use in the Norwegian dwelling stock [3] in addition to qualified assumptions related to the renovation since 1999.

Table 4-1 Physical description of the stereotypes of houses defined for single-family houses

| | Before 1945 | 1945-1970 | 1971-1980 | 1981-1990 | 1991-2005 |
|---|---|---|---|---|---|
| Number of dwellings in the group | 277249 | 342225 | 214572 | 206920 | 159850 |
| Number of dwellings per house | 1 | 1 | 1 | 1 | 1 |
| Dwelling area per house | 121 | 118 | 133 | 133 | 144 |
| Number of storeys | 2 | 2 | 2 | 1 ½ | 1 ½ |
| **% of dwellings with additional thermal insulation** (W = walls and windows, F = floors, C = ceilings) | | | | | |
| - WFC | 45 % | 30 % | - | - | - |
| - WF or WC | 35 % | - | - | - | - |
| - W | 5 % | - | - | - | - |
| - FC | 5 % | - | - | - | - |
| - F or C | 5 % | 50 % | - | - | - |
| - New windows | - | - | 30 % | - | - |
| - Unimproved | 5 % | 20 % | 70 % | 100 % | 100 %% |
| **U-value of building envelope** (Original / additionally insulated | | | | | |
| | W/m²K | W/m²K | W/m²K | W/m²K | W/m²K |
| - Walls | 0.9 / 0.4 | 0.4 / 0.3 | 0.38 / - | 0.26 / - | 0.26 / - |
| - Floors | 0.69 / 0.34 | 0.27 / 0.17 | 0.36 / - | 0.20 / - | 0.20 / - |
| - Ceilings | 0.6 / 0.3 | 0.36 / 0.20 | 0.20 / - | 0.18 / - | 0.18 / - |
| - Windows | 2.8 / 2.0 | 2.8 / 2.0 | 2.8 / 2.0 | 2.0 / - | 1.8 / - |
| Rate of air exchange | | | | | |
| - Air leakage number [1] | 8 / 6 / 4 / 3 | 5 / 4 /3 | 4 | 4 | 3 |
| - Ventilation | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ |
| Heat recovery | 0 | 0 | 0 | 0 | 0 / 55 % |
| Indoor temperature | 20 °C | 20 °C | 20 °C | 20 °C | 20 °C |
| Window area | 20 % | 15 % | 15 % | 15 % | 15 % |
| Window orientation (s-w-e-n) | 35-35-20-10 | 35-35-20-10 | 35-35-20-10 | 35-35-20-10 | 35-35-20-10 |
| **Type of heating** | | | | | |
| - Firewood | 13 % | 13 % | 13 % | 13 % | 13 % |
| - District heating | 0 % | 0 % | 0 % | 0 % | 0 % |
| - Oil/gas | 5 % | 5 % | 5 % | 5 % | 5 % |
| - Heat pump air to air | 10 % | 10 % | 10 % | 10 % | 10 % |
| - Electricity floor heating | 5 % | 5 % | 5 % | 5 % | 5 % |
| - Electricity directly | 65 % | 65 % | 65 % | 65 % | 65 % |
| **System efficiency of heating system** | | | | | |
| - Firewood | 40 % | 45 % | 50 % | 55 % | 60 % |
| - District heating | 88 % | 88 % | 88 % | 88 % | 88 % |
| - Oil/gas | 80 % | 80 % | 80 % | 80 % | 80 % |
| - Heat pump air to air | 250 % | 250 % | 250 % | 250 % | 250 % |
| - Electricity floor heating | 100 % | 100 % | 100 % | 100 % | 100 % |
| - Electricity directly | 100 % | 100 % | 100 % | 100 % | 100 % |

1 Dependent on which other renovation measures that are assumed

Table 4-2 Physical description of the stereotypes of houses defined for divided small houses

| | **Before 1945** | **1945-1970** | **1971-1980** | **1981-1990** | **1991-2005** |
|---|---|---|---|---|---|
| Number of dwellings in the group | 83436 | 136153 | 72105 | 71460 | 90154 |
| Number of dwellings per house | 2 | 4 | 4 | 4 | 2 |
| Dwelling area per house | 92 | 101 | 100 | 101 | 124 |
| Number of storeys | 2 | 2 | 2 | 1 ½ | 2 |
| **% of dwellings with additional thermal insulation** (W = walls and windows, F = floors, C = ceilings) | | | | | |
| - WFC | 35 % | 30% | - | - | - |
| - WF or WC | 30 % | - | - | - | - |
| - W | 15 % | - | - | - | - |
| - FC | 10 % | - | - | - | - |
| - F or C | 5 % | 50 % | - | - | - |
| - New windows | - | - | 30 % | - | - |
| - Unimproved | 5 % | 20 % | 70 % | 100 % | 100 %% |
| **U-value of building envelope** (Original / additionally insulated | | | | | |
| | W/m²K | W/m²K | W/m²K | W/m²K | W/m²K |
| - Walls | 1.0 / 0.4 | 0.8 / 0.35 | 0389 / - | 0.26 / - | 0.26 / - |
| - Floors | 0.47 / 0.28 | 0.38 / 0.25 | 0.20 / - | 0.17 / - | 0.17 / - |
| - Ceilings | 0.6 / 0.3 | 0.32 / 0.18 | 0.20 / - | 0.18 / - | 0.18 / - |
| - Windows | 2.8 / 2.0 | 2.8 / 2.0 | 2.8 / 2.0 | 2.0 / - | 1.8 / - |
| Rate of air exchange | | | | | |
| - Air leakage number [1] | 8 / 6 / 4 / 3 | 5 / 4 /3 | 4 | 4 | 3 |
| - Ventilation | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ |
| Heat recovery | 0 | 0 | 0 | 0 | 0 / 55 % |
| Indoor temperature | 20 °C | 20 °C | 20 °C | 20 °C | 20 °C |
| Window area | 20 % | 15 % | 15 % | 15 % | 15 % |
| Window orientation (s-w-e-n) | 35-35-20-10 | 35-35-20-10 | 35-35-20-10 | 35-35-20-10 | 35-35-20-10 |
| **Type of heating** | | | | | |
| - Firewood | 13 % | 13 % | 13 % | 13 % | 13 % |
| - District heating | 0 % | 0 % | 0 % | 0 % | 0 % |
| - Oil/gas | 5 % | 5 % | 5 % | 5 % | 5 % |
| - Heat pump air to air | 10 % | 10 % | 10 % | 10 % | 10 % |
| - Electricity floor heating | 5 % | 5 % | 5 % | 5 % | 5 % |
| - Electricity directly | 65 % | 65 % | 65 % | 65 % | 65 % |
| **System efficiency of heating system** | | | | | |
| - Firewood | 40 % | 45 % | 50 % | 55 % | 60 % |
| - District heating | 88 % | 88 % | 88 % | 88 % | 88 % |
| - Oil/gas | 80 % | 80 % | 80 % | 80 % | 80 % |
| - Heat pump air to air | 250 % | 250 % | 250 % | 250 % | 250 % |
| - Electricity floor heating | 100 % | 100 % | 100 % | 100 % | 100 % |
| - Electricity directly | 100 % | 100 % | 100 % | 100 % | 100 % |

1 Dependent on which other renovation measures that are assumed

Table 4-3 Physical description of the stereotypes for apartment buildings

| | Before 1945 | 1945-1970 | 1971-1980 | 1981-1990 | 1991-2005 |
|---|---|---|---|---|---|
| Number of dwellings in the group | 106869 | 142764 | 83245 | 41380 | 88914 |
| Number of dwellings per building | 8 | 24 | 24 | 24 | 20 |
| Dwelling area | 75 | 68 | 79 | 78 | 81 |
| Number of storeys | 4 | 4 | 4 | 4 | 4 |
| **% of dwellings with additional thermal insulation** (W = walls and windows, F = floors, C = ceilings) | | | | | |
| - WFC | 35 % | 20 % | - | - | - |
| - WF or WC | 30 % | 30 % | - | - | - |
| - W | 10 % | - | - | - | - |
| - FC | 10 % | - | - | - | - |
| - F or C | 10 % | - | - | - | - |
| - New windows | - | - | - | - | - |
| - Unimproved | 5 % | 50 % | 100 % | 100 % | 100 %% |
| **U-value of building envelope** (Original / additionally insulated | | | | | |
| | W/m²K | W/m²K | W/m²K | W/m²K | W/m²K |
| - Walls | 0.9 / 0.4 | 0.4 / 0.3 | 0.38 / - | 0.26 / - | 0.26 / - |
| - Floors | 0.69 / 0.34 | 0.27 / 0.17 | 0.36 / - | 0.20 / - | 0.20 / - |
| - Ceilings | 0.6 / 0.3 | 0.36 / 0.20 | 0.20 / - | 0.18 / - | 0.18 / - |
| - Windows | 2.8 / 2.0 | 2.8 / 2.0 | 2.8 / 2.0 | 2.0 / - | 1.8 / - |
| Rate of air exchange | | | | | |
| - Air leakage number [1] | 8 / 6 / 4 / 3 | 6 / 5 / 4 /3 | 4 | 4 | 3 |
| - Ventilation | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ | 0.4 $h^{-1}$ |
| Heat recovery | 0 | 0 | 0 | 0 | 0 / 55 % |
| Indoor temperature | 20 °C | 20 °C | 20 °C | 20 °C | 20 °C |
| Window area | 20 % | 15 % | 15 % | 15 % | 15 % |
| Window orientation (s-w-e-n) | 60-0-0-40 | 60-0-0-40 | 60-0-0-40 | 60-0-0-40 | 60-0-0-40 |
| **Type of heating** | | | | | |
| - Firewood | 13 % | 13 % | 13 % | 13 % | 13 % |
| - District heating | 0 % | 0 % | 0 % | 0 % | 0 % |
| - Oil/gas | 7 % | 7 % | 7 % | 7 % | 7 % |
| - Heat pump air to air | 10 % | 10 % | 10 % | 10 % | 10 % |
| - Electricity floor heating | 5 % | 5 % | 5 % | 5 % | 5 % |
| - Electricity directly | 65 % | 65 % | 65 % | 65 % | 65 % |
| **System efficiency of heating system** | | | | | |
| - Firewood | 40 % | 45 % | 50 % | 55 % | 60 % |
| - District heating | 88 % | 88 % | 88 % | 88 % | 88 % |
| - Oil/gas | 80 % | 80 % | 80 % | 80 % | 80 % |
| - Heat pump air to air | 250 % | 250 % | 250 % | 250 % | 250 % |
| - Electricity floor heating | 100 % | 100 % | 100 % | 100 % | 100 % |
| - Electricity directly | 100 % | 100 % | 100 % | 100 % | 100 % |

1 Dependent on which other renovation measures that are assumed

Based on these values of stereotypes and official statistics on number of dwellings, the total dwelling area used for heating can be estimated (Figure 4-2). The estimated total heated area is approx. 230 million m², with a distribution as shown in the figure. It should be noted that this is about 30 % lower than the numbers presented in Figure 3-2. Some of the deviation is probably because heated area is slightly less than the utility floor area, and some deviation also is caused by assumed sizes of the stereotypes.

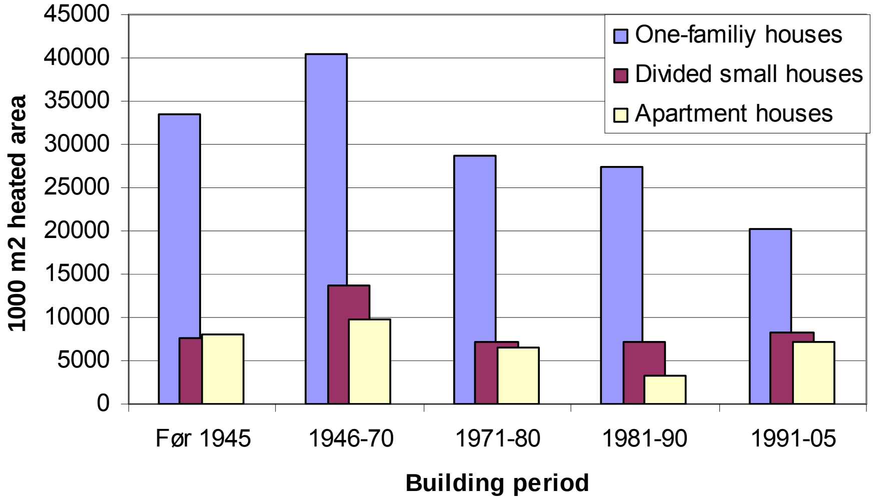



Figure 4-2 Total heated area split into the three categories of dwelling, according to building age

## 4.2 Estimated energy consumption in different dwelling types

The total energy consumption for the entire dwellings stock can be estimated by multiplying the energy consumption for each defined stereotypes of dwellings, with the number of dwellings within each group that the stereotype represents. The energy consumption for each of the stereotypes are calculated based on the physical parameters and the simplified monthly calculation method described in the Norwegian calculation standard “*NS 3031 Calculation of energy performance of buildings - Method and data*” (similar to EN-ISO 13790). This means that average climate data for Norway and standardized internal loads and energy use for tap water heating are used in addition to the information given in Table 4-1 to Table 4-3.

### 4.2.1 Specific net energy consumption

The specific net energy consumption (useful energy) for the 15 stereotypes of residential building as average is shown in Figure 4-3, and in more detailed split into the various renovation rates in Figure 4-4.

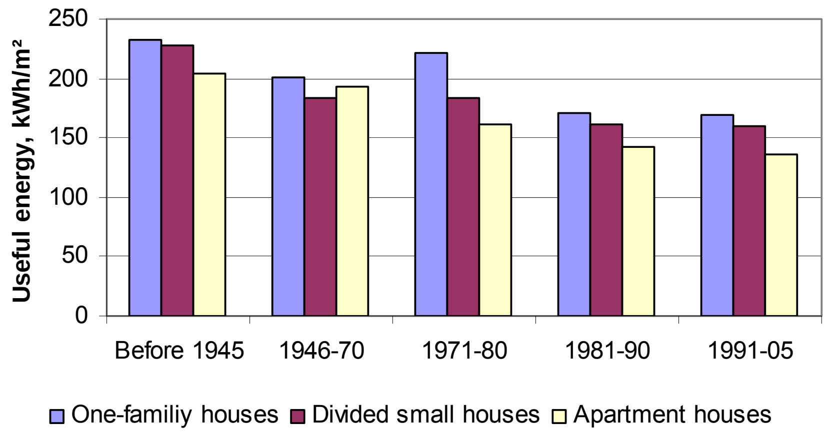



Figure 4-3 Average specific net energy consumption for the stereotypes of residential buildings

It should be noted that buildings constructed before 1945, retrofitted with additional insulated in both walls, ceilings and floors and new windows, have lower energy demand than original buildings from, for instance, the period 1946 to 1970.

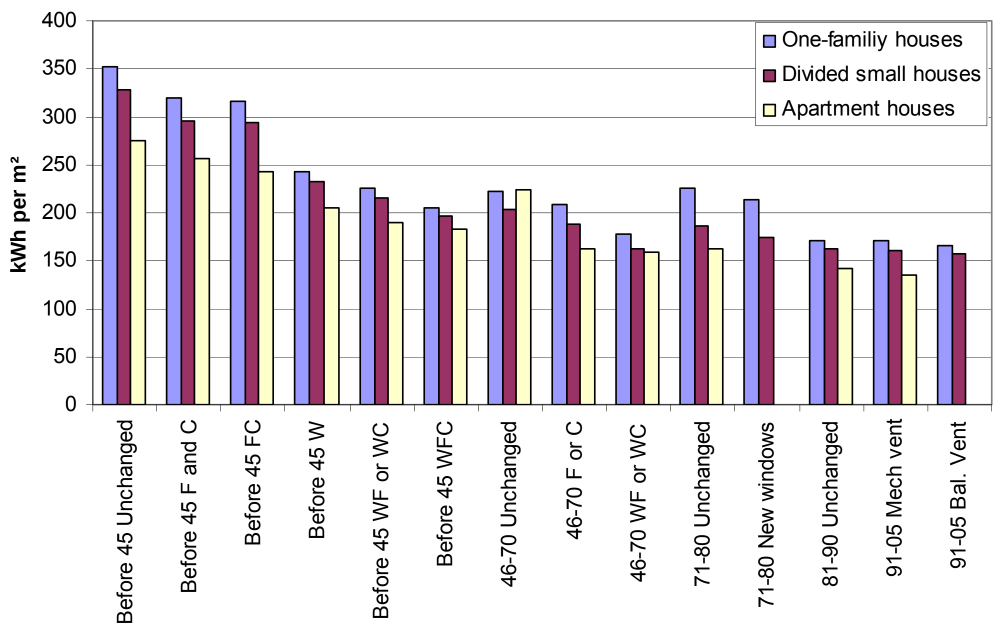



Figure 4-4 Estimated specific useful energy demand in kWh/m² for various renovation rates for the stereotypes of residential buidlings

### 4.2.2 Total energy consumption in the dwelling stock

The total energy consumption in the residential sector is estimated to be 49 TWh based on the physical descriptions in Table 4-1 to Table 4-3. This is approx. 8 % higher than the stationary energy consumption of about 45 TWh, based on official Norwegian statistics (see Figure 3-5). Approximately 85 % of the energy consumption is used in small houses (single-family homes and divided houses), whilst 15 % is used in apartment buildings. The total useful energy consumption for the dwelling stock is estimated to be 44 TWh.

Figure 4-5 shows the total energy consumption used in the dwelling stock split into types of building and construction period.

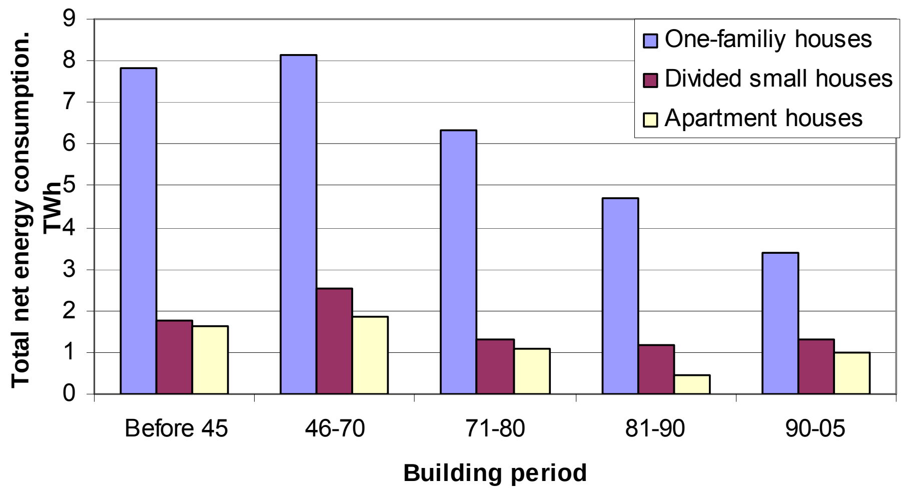



Figure 4-5 Estimated total useful energy consumption per year for the housing sector split into building types and building period

It is estimated that about 7 TWh comes from firewood, 0.5 TWh from district heating, 2.4 TWh from oil and gas, approximately 1 TWh from heat pumps, and the remaining from electricity. This distribution of energy sources seems to be a fairly good estimate compared with official statistics from SSB (e.g. Figure 3-5).

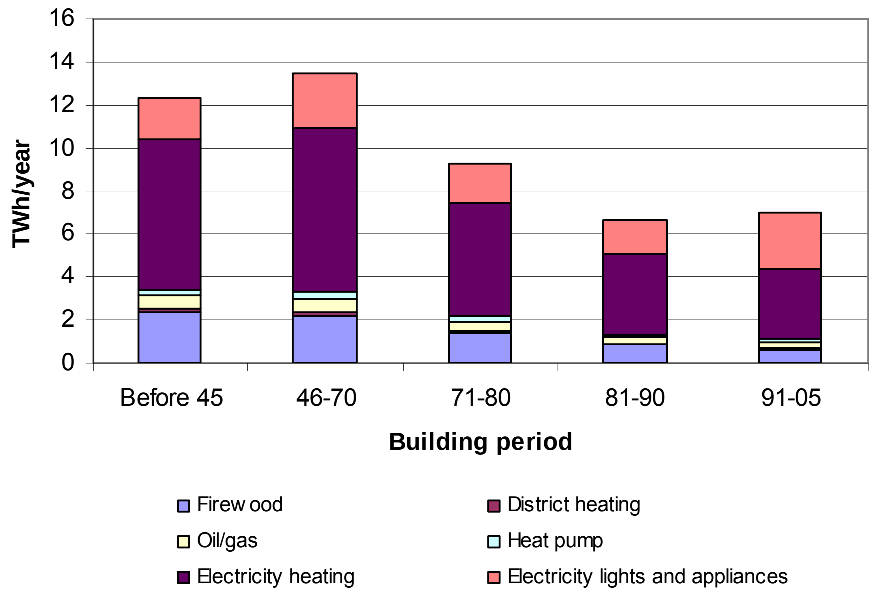



Figure 4-6 Estimated total energy consumption for the residential sector split into energy sources and building period.

Figure 4-7 gives the energy consumption split into the various groups of buildings and renovation level.

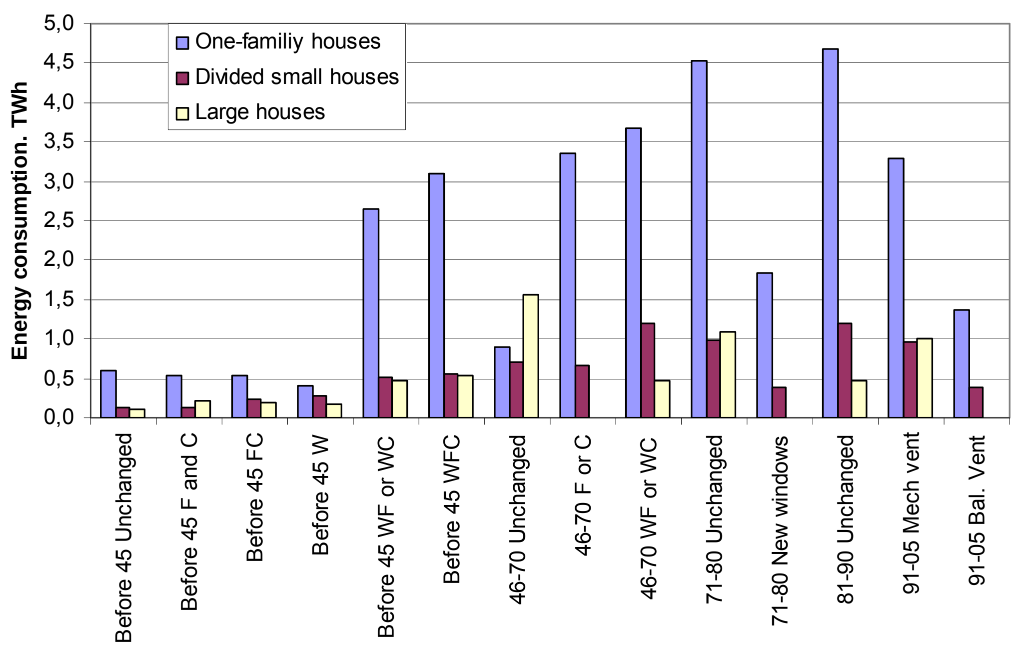



Figure 4-7 Estimated useful total energy consumption per year for the housing sector split into building types, technical condition and building period

As the figure shows, the potential for further energy reduction is significant, even if most buildings from the period before 1945 and up to 1970 have had some renovation.

### 4.2.3 Discussion of the accuracy of the model

The 8 % deviation between the statistics and the fairly coarse estimation model of energy consumption for the whole residential sector, is adequate for the purpose of this study. This model should therefore be able to predict the possible energy saving potential for the existing housing stock in some detail.

When an estimate of the energy consumption for the whole residential building sector is based on a simplified model such the one described here, it should be noted that some of the input parameters influence the total estimated energy consumption. For instance, a 10 % reduction in indoor temperature decreases the total energy consumption by 3 TWh to approx. 45 TWh, while a 20 % change of assumed U-values will change the total energy consumption approximately the same amount.

It may therefore be concluded that the level of accuracy from the used model is adequate for estimating the energy consumption of the entire housing stock, both the existing consumption and the energy-saving potential.

# 5. Energy scenarios

This chapter describes two different energy scenarios.

- **Scenario A**: In the first scenario, the energy saving potential is estimated for the existing dwelling stock (from 2005, described in Chapter 4). This scenario model is carried out for Subtask A of IEA SHC Task 37 '*Advanced Housing Renovation by Solar & Conservation'*.
- **Scenario B**: The second scenario has been developed in a project concerning how the market for thermal energy carriers affects flexibility in the Norwegian energy supply system. These scenarios are based on an assumed future development of the dwelling stock towards 2035, including the effect of substituting the electricity use for heating with other energy sources.

## 5.1 Energy scenarios – A

### 5.1.1 Packages of energy saving measures

Simplified analyses of the energy saving potential in the residential building sector are carried out taking the 2005 housing stock (described in Chapter 4) as the starting point. Two packages of energy saving measures are evaluated. As a simplification all buildings, except buildings built after 1980, are renovated with the same packages of measures. For buildings built in the period between 1981 and 1990, some fewer measures are assumed. For residences built after 1990, it is assumed that these are in fairly good condition, which means that energy related measures could probably not be combined with other renovation needs, so no measures are assumed for these buildings. For some of the older dwellings that already are renovated to some extent, such other types of renovation (for instance changing façade cladding) is perhaps not needed from a renovation point of view, but as a simplification this is not considered since the energy reduction potential is probably still significant.

Two main packages of measures to achieve reduced energy consumption are analyzed (see Table 5-1 and Table 5-2). Note that only building-related technical solutions are preliminary considered, not the type of heating system or energy sources.

Table 5-1 Moderate measures package

| Type | Description |
|---|---|
| Walls | 10 cm additional insulation |
| Floor | 10 cm additional insulation |
| Ceilings | 10-15 cm additional insulation |
| Windows [1] | New windows and doors 1.2 W/m²K |
| Air leakages [2] | Reduced air leakage values to 2.5 $h^{-1}$ |

1 Also for buildings built in the period of 1981 to 1990

2 For buildings built in the period between 1981 and 1990: Air leakage 3.0 $h^{-1}$

Table 5-2 Ambitious measures package

| Type | Description |
|---|---|
| Walls | 20 cm additional insulation |
| Floor | 20 cm additional insulation |
| Ceilings | 20-30 cm additional insulation |
| Windows | New windows and doors 0.7 W/m²K |
| Air leakages | Reduced air leakage values to 1.5 $h^{-1}$ |
| Heat recovery | Balanced ventilation with 70 and 75 % percent recovery |

Compared with the proposed energy labelling system [1], the moderate package will improve the labelling level from 1 to 3 levels . The ambitious package will improve the labelling level with 2 to 5 levels depending on the condition of the building before the renovation.

Figure 5-1 shows the specific energy-saving potential of both measures for single-family houses presented in Table 4-1. The energy-saving potential for each house is of course most significant for houses were only smaller measures are carried out until now. The moderate measures package results in specific total energy consumption of about 150 kWh/m$^2$, while the ambitious package gives an energy consumption of about 100 kWh/m$^2$.

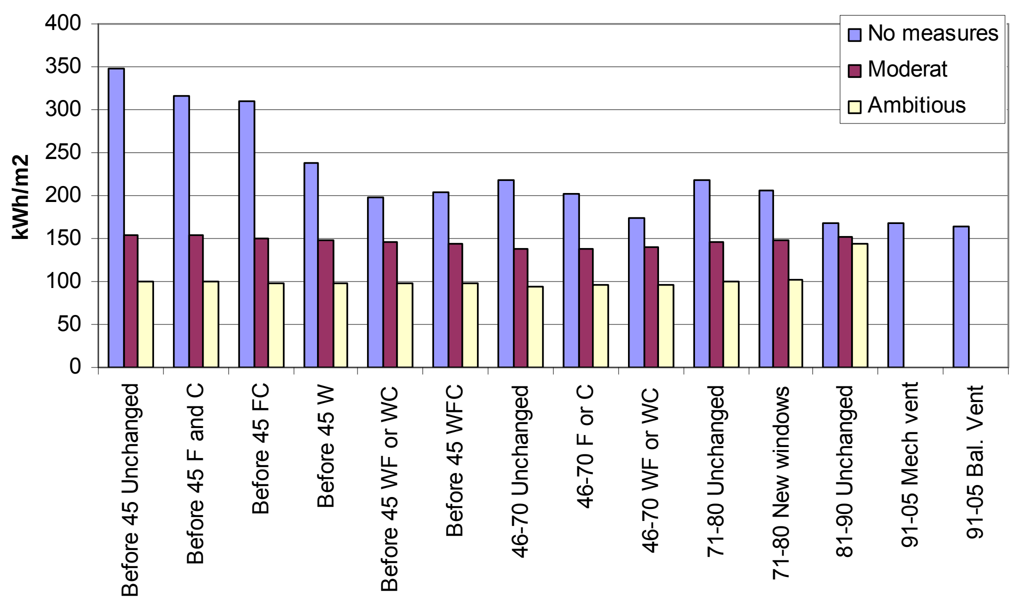



Figure 5-1 Detailed overview over specific useful energy consumption in single-family houses for the two measure packages.

Figure 5-2 shows the specific energy consumption as average for the three main groups of residential building, split into building periods.

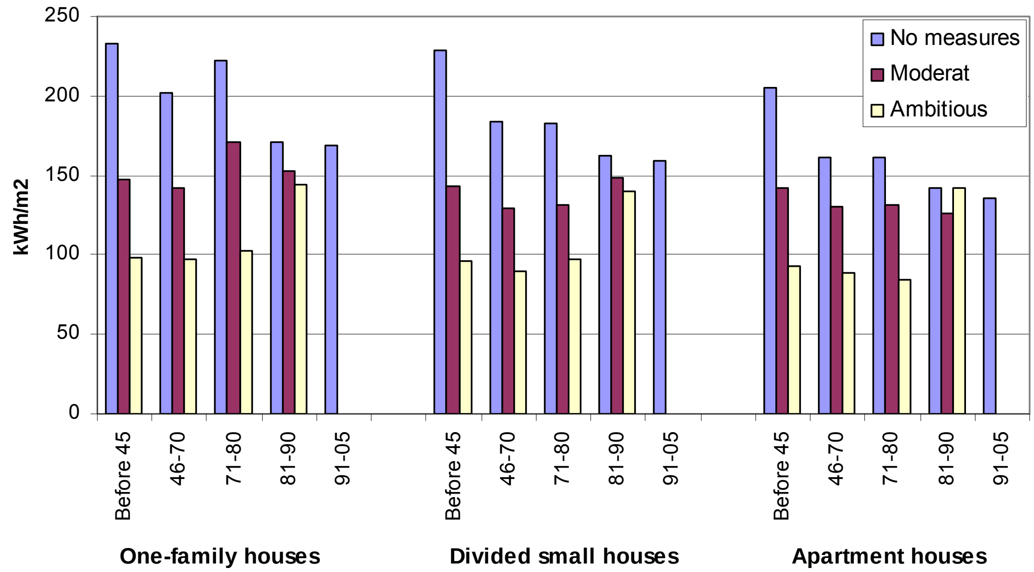



Figure 5-2 The specific useful energy consumption for the single-family houses, divided houses and apartment building, split into building periods

### 5.1.2 Total energy saving potential

Using the same estimation models as used to estimate the existing energy consumption, the theoretical energy reduction potential for the building sector in 2005 is 12 TWh or 25 % for the moderate measure package, and 17 TWh or 40 % for the ambitious measure package. The energy-saving potential for single-family houses is respectively 7.9 TWh and 11.9 TWh for moderate and ambitious measures, 1.9 TWh and 2.9 TWh for divided houses and 1.3 TWh and 2.4 TWh for apartment buildings.

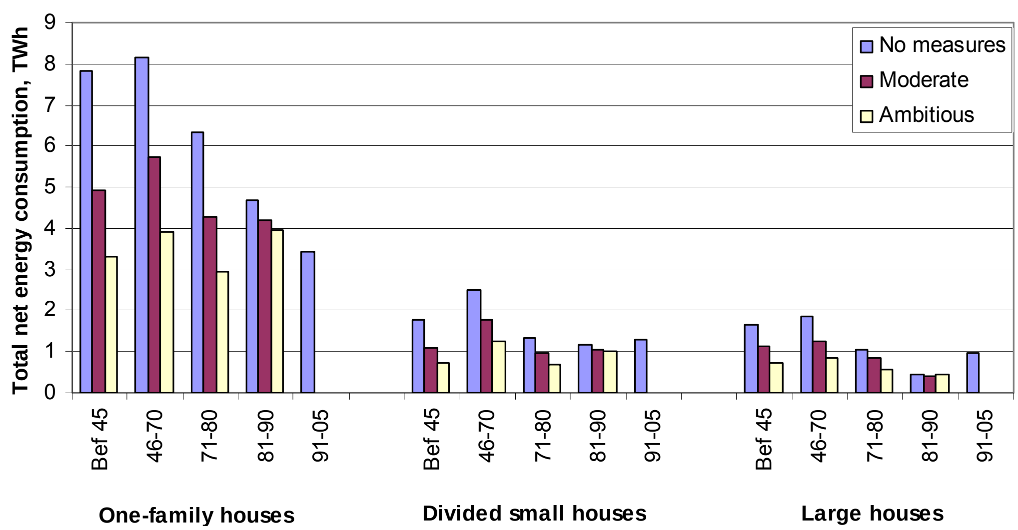



Figure 5-3 Total energy consumption for state of the art and the two measure packages for the various building periods

Taking into account the number of dwellings in each of the main groups, and the specific energy saving potential, the largest potential is found in single-family houses built before 1945, were the saving potential is nearly 2.9 TWh and 4.5 TWh for the two measure packages respectively.

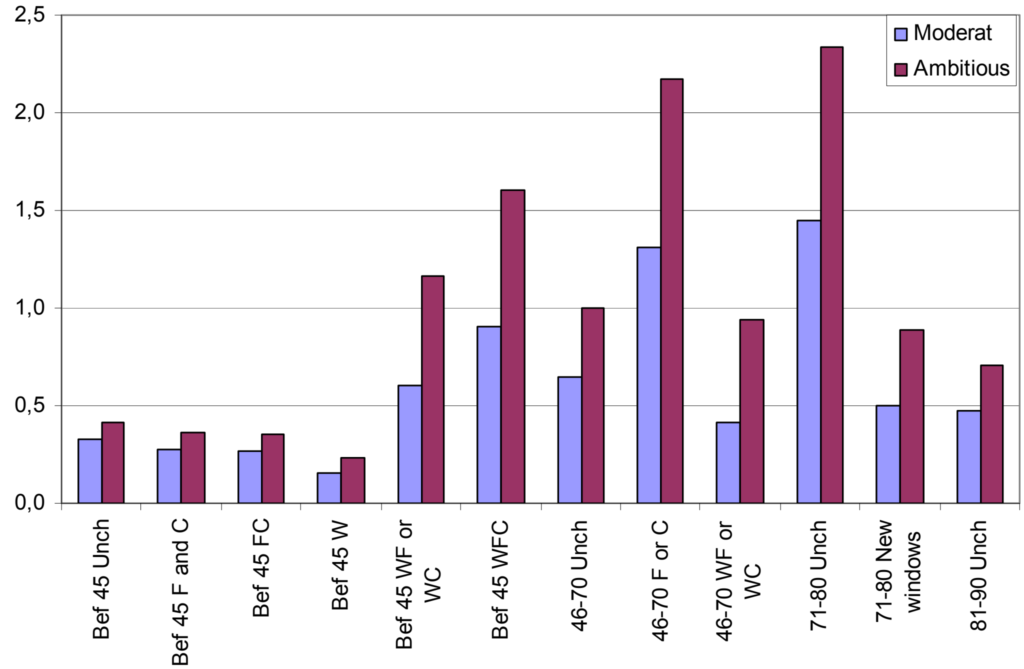



Figure 5-4 Detailed overview over energy saving potentials in single-family houses for the two measure packages

The largest saving potential is in the building stock that is already renovated to some degree and fairly “new” houses from the 1970’s, because of the large number of such houses.

Even if this simplified energy saving potential is fairly theoretical, and does not take into account the probability of carrying out the assumed measure packages, the model indicates a possible energy saving potential, and in which groups of residential building that such measures should be done. When looking at each individual building, the specific energy saving potential is of course largest in the buildings with less insulation.

## 5.2 Energy scenarios – B

The scenario analysis described in this chapter has been developed in a project concerning how the market for thermal energy carriers affects flexibility in the Norwegian energy supply system. The project was financed by the Norwegian Ministry of Petroleum and Energy (OED). The analysis is also partly based on a previous project (ePlan 2006) financed by NVE (Norwegian Water Resources and Energy Directorate) and Statsbygg (The Directorate of Public Construction and Property).

The historical trends regarding energy consumption and area can be used to establish a base scenario for the future development. The base scenario can then be compared with alternative trends. Three alternative scenarios have been established here;

1. **The first scenario** assumes a successful implementation of the Energy Performance in Buildings Directive (EPBD) in Norway.
2. **The second scenario** focuses on the effect of substituting electricity use for heating with other energy sources.
3. **The third scenario** focuses on reducing the energy demand in the residential sector via passive measures and increased use of heat pumps.

Note that the actual development will be affected by many factors, and even the base scenario will depend strongly on the assumptions made. These concern the expected technological development as well as the related barriers/limitations, market mechanisms, political decisions and legal issues. The main purpose of the scenarios is to show the effect of different strategies to reduce future demand of energy and electricity in the dwelling stock.

#### *5.2.1.1 Heat and energy demand in buildings*

The introduction of EPBD in Norway has called forth several studies where the energy consumption in Norwegian residential buildings has been analysed [4-7]. Scenarios for the energy consumption in the building sector towards 2030 has also been made [4]. This provides the basis for more detailed analysis of the energy consumption in the Norwegian dwelling stock in the future.

In the energy scenarios presented here, the energy consumption of the different carriers $E_i$ is calculated as the product of the activity and the intensity $E_i = A_i x I_{ij}$, where the activity $A_i$ is defined as the utility floor space for building type $i$ and the intensity $I_{ij}$ is defined as yearly delivered energy per utility floor space for building type $i$ and energy carrier $j$ (kWh/m$^2$·year).

#### *5.2.1.2 The development of the building stock*

The GAB database (Register of Real Properties, Addresses and Buildings) has been used to analyse the historical development of the activity in the residential sector. In GAB the total building stock in Norway is divided into eight main categories which are further divided into sub categories, see Appendix A.

The energy statistics is however not available at the same level of detailed. Statistics Norway (SSB) has coherent statistics on the energy use from 1976-2005 divided into the sectors power intensive industry, wood processing industry, other industry and mining, private households, private services, public services and other consumers. Thus, although statistics on the energy consumption for the total residential sector is available, there is little information about how the consumption is distributed between different kinds of dwellings. However, a rough estimate of the energy consumption in different dwellings types is carried out in Chapter 4.2.

In order to assure consistency with the energy statistics, we have not differentiated between different dwelling types in the scenario analysis described in this chapter.

It is assumed that the further development of the building stock will follow the population growth. According to Statistics Norway, the population in Norway is expected to grow linearly towards 2050. A linear growth in the residential building stock is therefore assumed here.

In order to estimate the growth, the average activity in new construction, renovation and demolition for the period 1996-2005 has been calculated. The stock for the years towards 2035 is calculated as the existing stock at year *y-1* plus new buildings built in year *y* minus demolished buildings in year *y*. This is used as basis for all energy scenarios.

#### *5.2.1.3 The energy intensity and end user preference for heating*

From historical data for the stationary energy consumption in the residential sector, the energy intensity for an average dwelling (*Rs*) can be calculated.

Based on the reports carried out regarding the introduction of EPBD in Norway [1, 8, 9] it is also possible to calculate the intensity *Rr*, that represents the requirement for new buildings in the revised building code from 2007 (TEK97-rev07). It is also possible to estimate the electrical share of this demand, i.e. the share that only can be covered by electricity. The remaining share represents the theoretical limit for use of thermal energy carriers such as oil, biomass or district heating.

From the energy statistics the consumption of each energy carrier is known. This makes it possible to estimate how much of the heating demand each energy carrier covers, including renewable energy from the surroundings via heat pumps. The share-distribution of the different energy carriers used to cover the heating demand is called the *end user preference for heating*.

*The end user preference for heating* is thus defined as the share of the different carriers used to cover the space and tap water heating demand. This preference will change over time as a function of how much space heating that is needed and the trend development for use of the different energy carriers.

We have chosen to predict the future *end user preference for heating* as a linear trend based on historical data from 1996-2005, see Figure 5-5. The electricity share is calculated as the remainder, thus evolving linearly until the phase out of oil in year 2028.

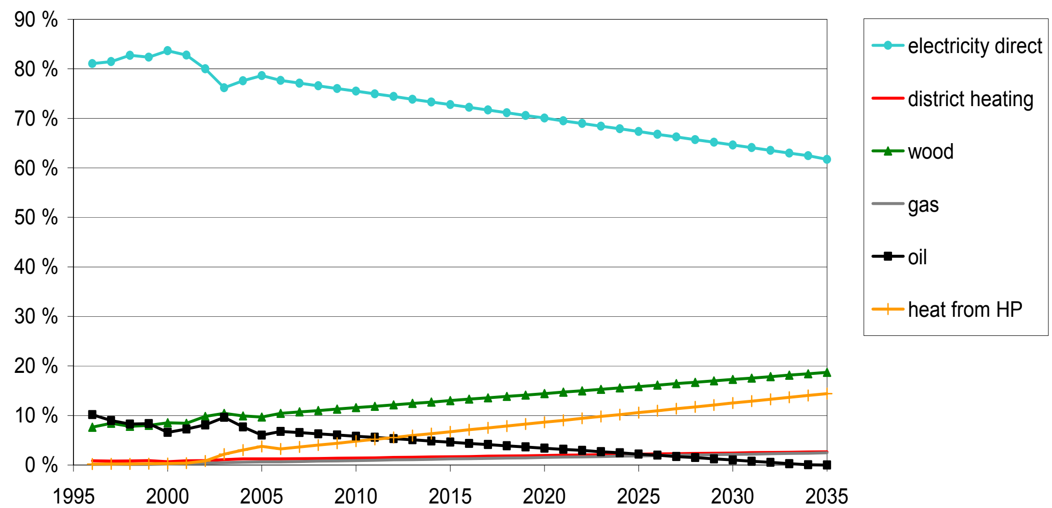



Figure 5-5 End user preference for heating in dwellings

### *5.2.1.4 Definition of archetypes*

If the scenario results should give any useful information, they must result from logical choices and strategies. We have therefore chosen to establish *archetype buildings* based on a proposal of an energy labelling system for Norwegian dwellings (related to the introduction of the EPBD in Norway) [1]. An archetype is an abstract entity that is a statistical composite of the features found within a category of buildings in the stock. Archetypes with different end user preference for heating have been established for each energy label. An average dwelling is an example of such an archetype, see Appendix B. For this archetype the end user preference for heating is calculated based on the average consumption in Norwegian dwellings from 1996-2005. From the numbers in the archetype we can see that the net electrical demand (including cooling) constitutes 20.5 %, while the actual share of the net demand covered by electricity is 85.7%, resulting in an end user preference for use of direct electric heating of 82 %. This shows the potential for replacing electric consumption with other energy sources for this archetype.

Based on the trend development of the end user preference for heating, a similar archetype representing an average dwelling in the year 2035 has been established. In addition, several other archetypes representing different energy labels and with different end user preference for heating has been made. All archetypes used in the scenario analysis are shown in Appendix B.

### *5.2.1.5 Assumptions for energy scenarios for residential buildings towards 2035*

Based on the assumptions regarding the development of the residential building stock and the archetypes described above, four scenarios for the development towards 2035 has been established, see Table 5-3. The energy demand is calculated separately for new, renovated and existing (unchanged) buildings. Note that the category '*Existing (unchanged) buildings*' gradually diminishes due to renovation and demolition, while the categories '*New…*' and '*Renovated buildings*' grow gradually with time. The net demand divided on el-specific, cooling and heating is then calculated for each category. In addition the delivered energy is calculated for each energy carrier as well as the renewable energy provided by the heat pumps[3].

The archetype for year 2001 is based on data for the period 1996-2005. The future trend for the end user preference for heating is based on the same data. Even though statistical data are available until 2005, 2001 is used as a starting year for the calculations. This makes it possible to compare the results for the 5 first years with statistically observed values.

Table 5-3 Scenario for energy demand in residential buildings towards 2035

| Scenario | Building Category | Energy class | | The carrier distribution from year 2001 to year 2035 for buildings changed in the actual period | |
|---|---|---|---|---|---|
| | | Year | | Year | |
| | | 2001-2010 | 2010-2035 | 2001-2010 | 2010-2035 |
| **Base** | Existing (unchanged) buildings | E | E | According to trend | According to trend |
| | New buildings | D | D | According to trend | According to trend |
| | Renovated buildings | E | E | According to trend | According to trend |
| **EPBD** | Existing (unchanged) buildings | E | E | According to trend | According to trend |
| | New buildings | D | C | According to trend | According to trend |
| | Renovated buildings | E | D | According to trend | According to trend |
| **Substitution** | Existing (unchanged) buildings | E | E | According to trend | According to trend |
| | New buildings | D | D | According to trend | Substitution |
| | Renovated buildings | E | E | According to trend | Substitution |
| **Conservation** | Existing (unchanged) buildings | E | E | According to trend | According to trend |
| | New buildings | D | C->A | According to trend | Conservation |
| | Renovated buildings | E | D->B | According to trend | Conservation |

All scenarios will be equal until the year 2011. The reason is that we expect the development towards 2010 to follow the trend from 1996-2005. Another fundamental presumption is that for all buildings built or renovated before 2010, the distribution with

[3] The renewable energy from heat pumps is here defined as the heat delivered by the heat pump minus the total electricity consumed by the heat pump system.

respect to energy carrier will evolve according to the trend for the end user preference for heating shown in Figure 5-5. The assumptions for buildings constructed or renovated after 2010 will however vary from scenario to scenario.

### 5.2.2 Base-scenario

In the first scenario, both new and renovated buildings achieve the same energy standard as today during the whole analysis period (until year 2035). Thus the net demand does not change for any of these building categories. However, the distribution of different energy carriers is allowed to change for all buildings according to the end user preference for heating, see Figure 5-5. Below it is explained more in detail how this is implemented for the different building categories.

#### *5.2.2.1 Existing (unchanged) buildings*

The group of buildings that does not undergo major renovation maintain the same energy standard throughout the simulation period. According to the labelling system proposed by SINTEF [1, 8], they will thus maintain energy label E. This means that the net energy demand does not change for these buildings. How this net energy demand is covered is however allowed to change with the end user preference for heating, see Figure 5-5. This implies that changing the energy system from for example an oil burner to a heat pump or pellets burner is not regarded as a major renovation.

The intensity is calculated by use of the archetypes as follows for this group:

$$I_{net\ demand}(y) = Class\ E_{net\ demand}(2001) = Class\ E_{net\ demand}(2035) = Constant.$$

$$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$$
$$= Class\ E_{ec}(2001)*(1-f(y)) + Class\ E_{ec}(2035)*(f(y))$$

where ec= energy carrier and f(y) increases linearly from 0 in year 2001 to 1 in year 2035

#### *5.2.2.2 New buildings*

New buildings are assumed to maintain the same net energy demand as today throughout the whole period of the analysis, i.e. energy class D. In the same way as for existing (unchanged) buildings we assume that the distribution of energy carriers evolves with the end user preference for heating shown in Figure 5-5.

The intensity with respect to net energy demand and an energy carrier is calculated as follows:

$$I_{net\ demand}(y) = Class\ D_{net\ demand}(2001) = Class\ D_{net\ demand}(2035) = Constant.$$

$$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$$
$$= Class\ D_{ec}(2001)*(1-f(y)) + Class\ D_{ec}(2035)*(f(y))$$

where ec= energy carrier and f(y) increases linearly from 0 in year 2001 to 1 in year 2035

#### *5.2.2.3 Renovated buildings*

In this scenario it is assumed that renovation affects neither the net energy demand nor distribution with respect to energy carriers. The calculation of the intensity for this group of buildings is therefore identical with the calculation of intensity for i.e. existing (unchanged) buildings:

$I_{net\ demand}(y) = Class\ E_{net\ demand}(2001) = Class\ E_{net\ demand}(2035) = Constant.$

$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$
$= Class\ E_{ec}(2001)*(1-f(y)) + Class\ E_{ec}(2035)*(f(y))$

where ec= energy carrier and f(y) increases linearly from 0 in year 2001 to 1n in year 2035

### 5.2.3 The EPBD scenario

In this scenario it is assumed that the introduction of the Energy Performance in Buildings Directive (EPBD), here called *building energy directive*, has the intended effect. This means that from year 2011, new buildings will be in class C instead of D, while renovation will cause an upgrade from class E to class D.

It is assumed that the building energy directive will not bring about changes before 2011. The reason is that the EPBD is implemented in the revised building code (TEK97 rev 07) which will replace the former building code (TEK97) first in August 2009. Building applications sent to the building authorities before August 2009 do not have to act in accordance with the revised code. After the application is sent, the construction has to be initiated within 2.5 years, thus increasing the delay of the improvement in energy efficiency.

As for the basis-scenario, the distribution with respect to which energy carrier that is utilized to cover the demand is assumed to change with the end user preference for heating. This is implemented as follows for the three building categories:

#### *5.2.3.1 Existing (unchanged) buildings*

Based on the archetypes, the intensity with respect to net demand and energy carrier is calculated in the same way as for the base scenario:

$I_{net\ demand}(y) = Class\ E_{net\ demand}\ (2001) = Class\ E_{net\ demand}\ (2035) = Constant.$

$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$
$= Class\ E_{ec}(2001)*(1-f(y)) + Class\ E_{ec}(2035)*(f(y))$

where ec= energy carrier and f(y) increases linearly from 0 in year 2001 to 1 in year 2035

#### *5.2.3.2 New buildings*

For new buildings the energy class changes from D to C from year 2011. The intensity for a particular year y represents the average intensity for all buildings in this category. This means that until 2010, the whole group will have a net demand in accordance with class D. In 2011 it is assumed that all new buildings are class C, and this will result in a small reduction in energy intensity for the whole group of buildings built new since year 2001. Towards the end of the period the intensity will approach class C since most buildings then will be class C buildings. The net intensity in year y is calculated as follows:

$$I_{net\ demand}(y) = \{Class\ D_{net\ demand}(2001) * A_{new}(2001\text{-}2010) + Class\ C_{net\ demand}(2001) * A_{new}(2010\text{-}y)\} / A_{new}(2000\text{-}y)$$

When it comes to the distribution with respect to energy carrier, it is assumed that a new building built in year y will have a distribution according to the end user preference for heating that year. We have also assumed that buildings built new previous years will change their distribution with respect to energy carrier with the end user preference for heating in the same way as existing buildings. This is implemented as follows:

<u>The period 2001-2010</u>

For the period until 2010, the intensity with respect to energy carrier is calculated in the same way as before:

$$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y)) = Class\ D_{ec}(2001)*(1-f(y)) + Class\ D_{ec}(2035)*(f(y))$$

<u>The period 2011-2035</u>

In this period, the group will consist of a mix of class C and class D buildings. The calculation of intensity is thus more complex because it involves four archetypes, namely class C and D with end user preference as in year 2000, and class C and D with end user preference as in 2035. In order to estimate the correct intensity, the different archetypes must be weighted according to how large share of the total they represent. In addition the carrier share is treated in the same way as for the other scenarios:

$$I_{ec}(y) = \{[Class\ D_{ec}(2001)*A_{new}(2001\text{-}2010) + Class\ C_{ec}(2001)*A_{new}(2010\text{-}y)] / A_{new}(2001\text{-}y)\} * (1-f(y)) + \{[Class\ D_{ec}(2035)*A_{new}(2001\text{-}2010) + Class\ C_{ec}(2035)*A_{new}(2010\text{-}y)] / A_{new}(2001\text{-}y)\} * f(y))$$

#### *5.2.3.3 Renovated buildings*

While the energy class for new buildings is changed in 2011 from D to C for new buildings, the renovated buildings are improved from class E to class D. Except for this, the same methodology as before is used both with respect to net intensity and carrier share:

$I_{net\ demand}(y)$ = {Class $E_{net\ demand}(2001)$ * $A_{renov}(2001\text{-}2010)$
+ Class $D_{net\ demand}(2001)$ * $A_{renov}(2010\text{-}y)$} / $A_{renov}(2001\text{-}y)$

Intensity with respect to energy carrier:

<u>The period 2001-2010</u>
$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$
= Class $E_{ec}(2001)*(1-f(y))$ + Class $E_{ec}(2035)*(f(y))$

<u>The period 2010-2035</u>
$I_{ec}(y)$= {[Class $E_{ec}(2001)*A_{renov}(2000\text{-}2010)$+Class $D_{ec}(2001)*A_{renov}(2010\text{-}y)$]
/$A_{renov}(2000\text{-}y)$} * (1-f(y))
+ {[Class $E_{ec}(2035)*A_{renov}(2001\text{-}2010)$ + Class $D_{ec}(2035)*A_{renov}(2010\text{-}y)$]
/$A_{renov}(2001\text{-}y)$} * f(y)

### 5.2.4 The substitution scenario

The purpose of the substitution scenario is to analyse the potential for reducing electricity consumption through the use of alternative energy carriers for heating. This is assumed to take place in all buildings built new or renovated after 2011. From this year, only 25 % of the heating demand is covered via direct use of electricity, while the remainder is covered equally by firewood, gas and district heat (25 % each).
See Appendix B for a full overview over the energy consumption for the archetypes used in the substitution scenario.

For the period 2001-2010, the same assumptions as for the base scenario are used. The energy intensity is calculated as follows for the different building categories:

#### *5.2.4.1 Existing (unchanged) buildings*

$I_{net\ demand}(y)$ = Class $E_{net\ demand}$ (2001) = Class $E_{net\ demand}$ (2035) = Constant.

$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$
= Class $E_{ec}(2001)*(1-f(y))$ + Class $E_{ec}(2035)*(f(y))$

where ec= energy carrier and f(y) increases linearly from 0 in year 2001 to 1 in year 2035

#### *5.2.4.2 New buildings*

$I_{net\ demand}(y)$ = Class $D_{net\ demand}$ (2001) (= Constant)

Intensity for different carriers:

<u>The period 2001-2010</u>
$I_{ec}(y) = I_{ec}(2000)*(1-f(y)) + I_{ec}(2035)*(f(y))$
= Class $D_{ec}(2001)*(1-f(y))$ + Class $D_{ec}(2035)*(f(y))$

<u>The period 2010-2035</u>
$I_{ec}(y)$={[Class $D_{ec}(2001)*A_{new}(2001\text{-}2010)$ + Class $D_{ec}(\text{substitution})*A_{new}(2010\text{-}y)$]
/$A_{new}(2000\text{-}y)$} * (1-f(y))
+ {[Class $D_{ec}(2035)*A_{new}(2001\text{-}2010)$ + Class $D_{ec}(\text{substitution})*A_{new}(2010\text{-}y)$]
/$A_{new}(2001\text{-}y)$} * f(y))

#### *5.2.4.3 Renovated buildings*

$I_{net\ demand}(y)$ = Class $E_{net\ demand}(2001)$ (=Constant)

Intensity for different carriers:

The period 2001-2010

$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$
= Class $E_{ec}(2001)*(1-f(y))$ + Class $E_{ec}(2035)*(f(y))$

The period 2010-2035

$I_{ec}(y)$= {[Class $E_{ec}(2001)*A_{renov}(2001-2010)$+Class $E_{ec}(substitution)$ *$A_{renov}(2010-y)$]
/$A_{renov}(2001-y)$} * (1-f(y))
+ {[Class $E_{ec}(2035)*A_{renov}(2001-2010)$ + Class $E_{ec}(substitution)$ *$A_{renov}(2010-y)$]
/$A_{renov}(2000-y)$} * f(y)

### 5.2.5 The conservation scenario

The purpose of the conservation scenario is to look at the effect of an active policy to reduce energy demand in new and renovated buildings from year 2011, see Table 5-3. This scenario both involves passive conservation measures and more widespread use of heat pumps. As shown in the archetypes in Appendix B, heat pumps are assumed to cover 50 % of the space heating demand in both new and renovated buildings.

#### *5.2.5.1 Existing (unchanged) buildings*

$I_{net\ demand}(y)$ = Class $E_{net\ demand}$ (2001) = Class $E_{net\ demand}$ (2035) = Constant.

$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$
= Class $E_{ec}(2001)*(1-f(y))$ + Class $E_{ec}(2035)*(f(y))$

where ec= energy carrier and f(y) increases linearly from0 in year 2001 to 1 in year 2035

#### *5.2.5.2 New buildings*

$I_{net\ demand}(y)$ = {Class $D_{net\ demand}(2000)*A_{new}(2001-2010)$
+ (Class $C_{net\ demand}$ (2001)*(1-0,5*g(y)) + Class $A_{net\ demand}(2001)$*0,5*g(y))
*$A_{new}(2011-y)$} / $A_{new}(2001-y)$

Intensity per energy carrier:

The period 2001-2010

For the period 2001-2010, the same assumptions as those mad in the basis scenario are used:

$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y))$
= Class $D_{ec}(2001)*(1-f(y))$ + Class $D_{ec}(2035)*(f(y))$

The period 2010-2035

$I_{ec}(y)$ = {[Class $D_{ec}(2001)*A_{new}(2001-2010)$ + (Class $C_{ec}$(conservation)
*(1-0,5*g(y)) + Class $A_{ec}$(conservation)*0,5*g(y)) * $A_{new}(2010-y)$]
/$A_{new}(2000-y)$} * (1-f(y))
+ {[Class $D_{ec}(2030)*A_{new}(2001-2010)$+(Class $C_{ec}$(conservation)*(1-0,5*g(y)) +
Class $A_{ec}$(conservation)*0,5*g(y)) * $A_{new}(2011-y)$]
/$A_{new}(2000-y)$} * f(y)

where ec= energy carrier and f(y) increases linearly from 0 in year 2000 to 1 in year 2035 while g(y) increases linearly from 0 in year 2010 to 1 in year 2035

#### *5.2.5.3 Renovated buildings*

$$I_{net\ demand}(y) = \{Class\ E_{net\ demand}(2001)*A_{renov}(2001-2010) + (Class\ D_{net\ demand}(2001)*(1-0,5*g(y)) + Class\ B_{net\ demand}(2001)*0,5*g(y)) *A_{renov}(2010-y)\} / A_{renov}(2001-y)$$

Intensity per energy carrier:

<u>The period 2001-2010</u>

$$I_{ec}(y) = I_{ec}(2001)*(1-f(y)) + I_{ec}(2035)*(f(y)) = Class\ E_{ec}(2001)*(1-f(y)) + Class\ E_{ec}(2035)*(f(y))$$

<u>The period 2011-2035</u>

$$I_{ec}(y) = \{[Class\ E_{ec}(2001)*A_{renov}(2001-2010)+(Class\ D_{ec}(conservation)*(1-0,5*g(y)) + Class\ B_{ec}(conservation)*0,5*g(y))* A_{renov}(2011-y)] / A_{renov}(2001-y)\}*(1-f(y)) + \{[Class\ E_{ec}(2030)* A_{renov}(2001-2010) + (Class\ D_{ec}(conservation)*(1-0,5*g(y)) + Class\ B_{ec}(conservation)*0,5*g(y))* A_{renov}(2011-y)] / A_{renov}(2001-y)\}*f(y)$$

where ec= energy carrier and f(y) increases linearly from 0 in year 2001 to 1 in year 2035 while g(y) increases linearly from 0 in year 2011 to 1 in year 2035

### 5.2.6 Results

Based on the assumptions presented above, the energy demand in Norwegian dwellings from 2001 to 2035 has been calculated. The results are here presented graphically for each scenario, both for the total dwelling stock and for the group of dwellings that has been renovated during the actual period.

The graphs show the statistical energy demand of different carriers in the residential building stock from 1980 to year 2001 and the predicted demand towards 2035. For the period 2001-2005, the statistical electricity demand in Norwegian dwellings is also shown for comparison.

## The total dwelling stock

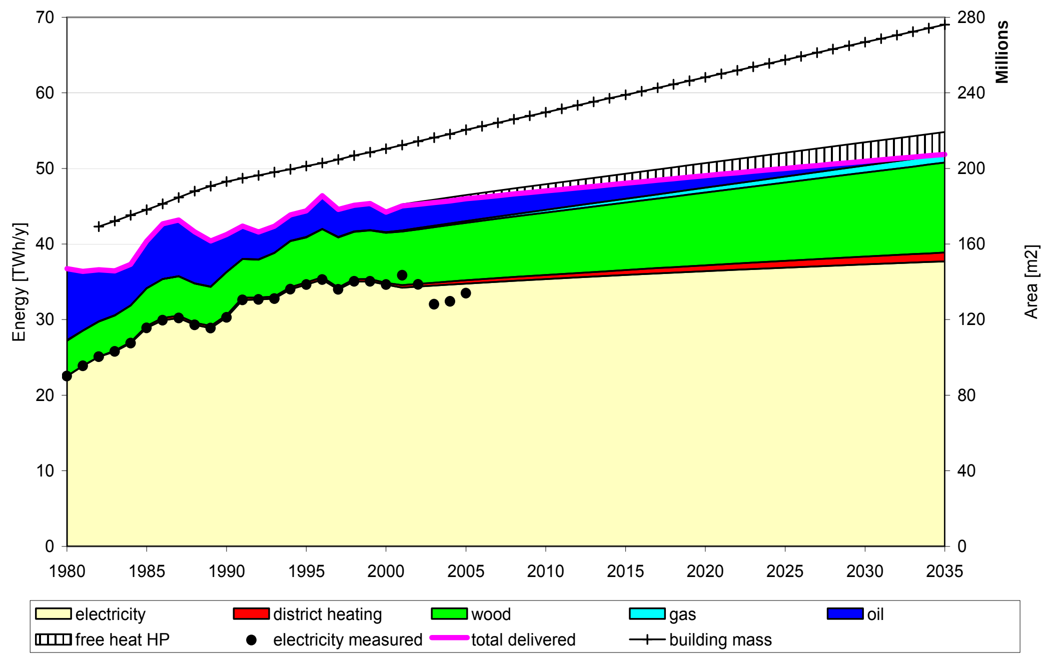



Figure 5-6 The development of the energy demand in residential buildings and the building stock in the Base scenario.

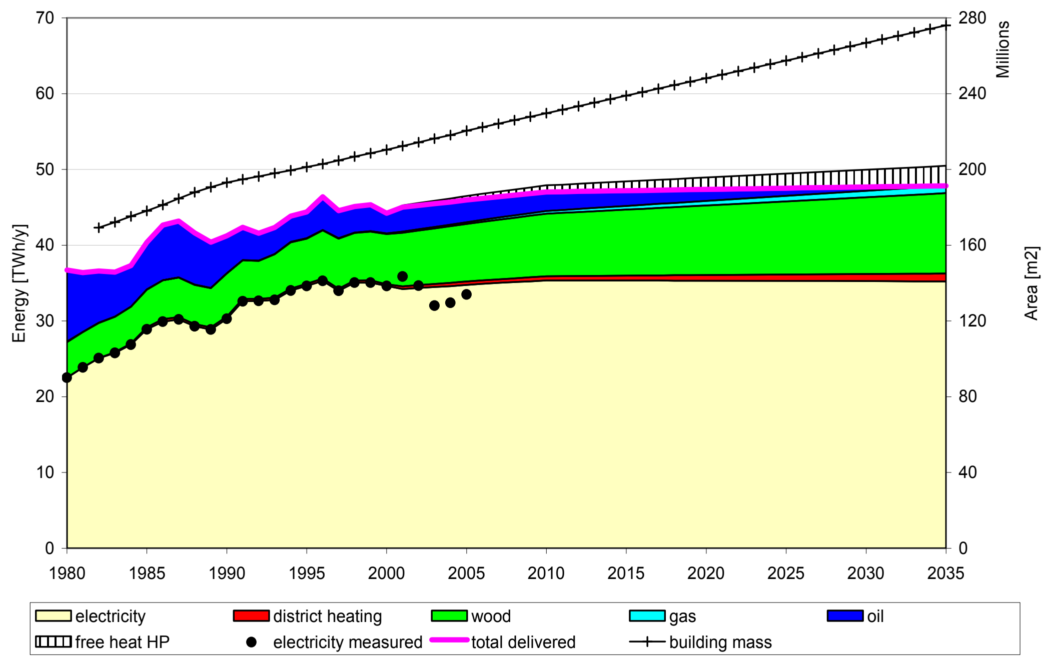



Figure 5-7 Development of the energy demand in residential buildings and the building stock in the EPBD scenario.

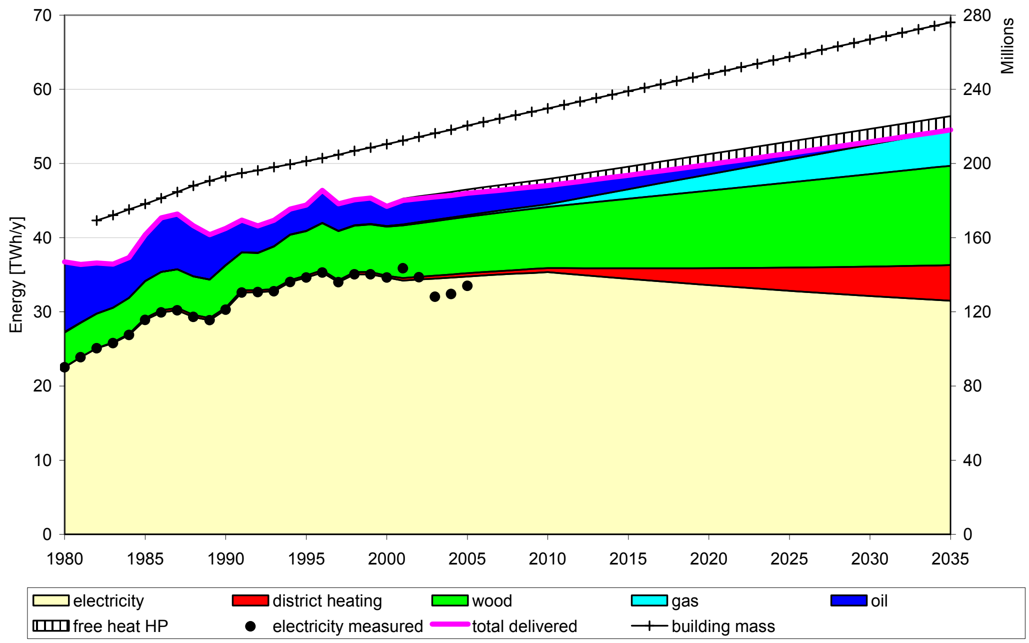



Figure 5-8 The development of the energy demand in residential buildings and the building stock in the substitution scenario.

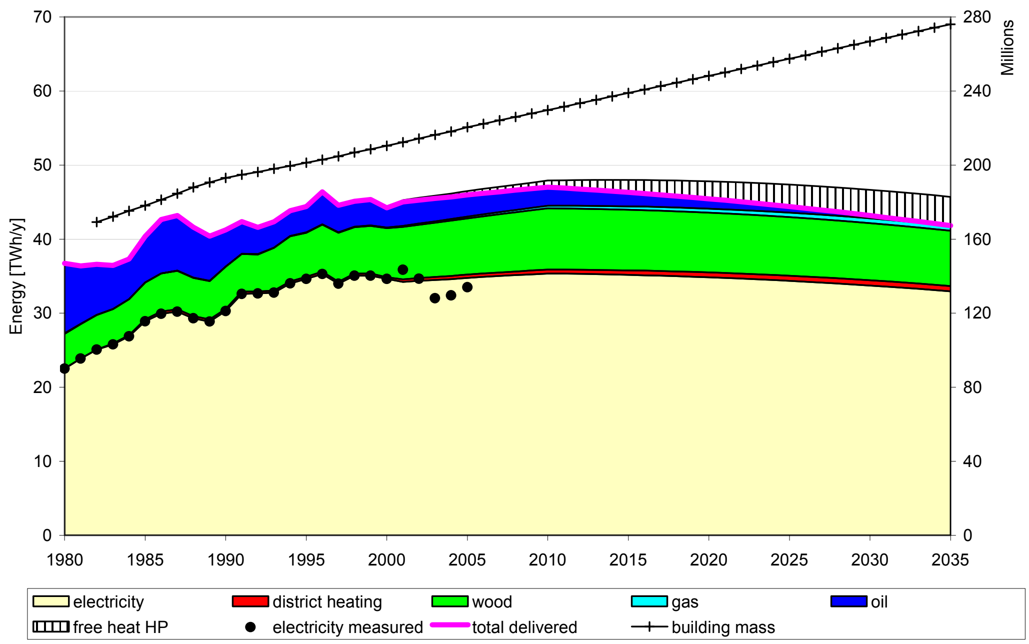



Figure 5-9 The development of the energy demand in residential buildings and the building stock in the conservation scenario.

**Renovated dwellings**

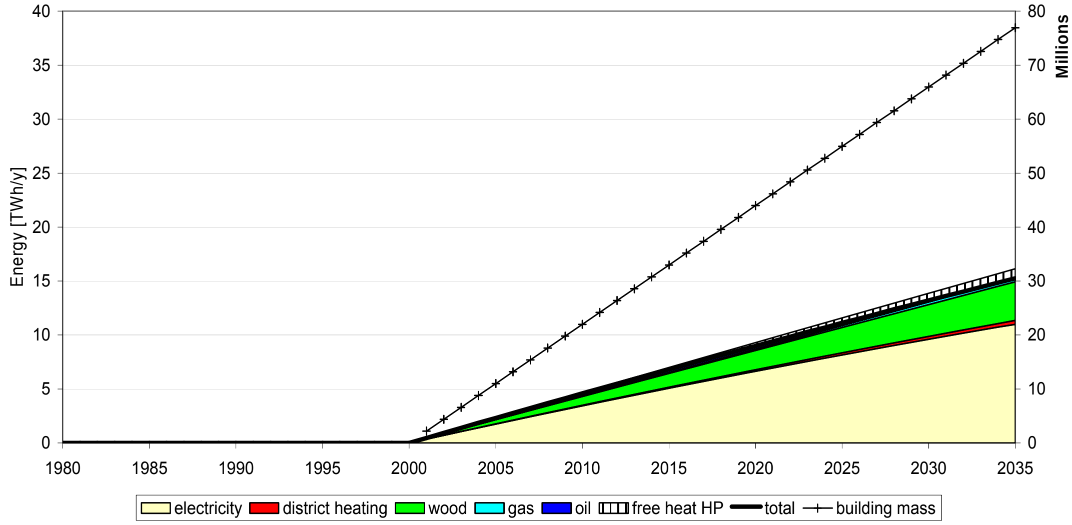



Figure 5-10 The energy demand and building mass for renovated residential buildings from 2000-2035 in the Base scenario.

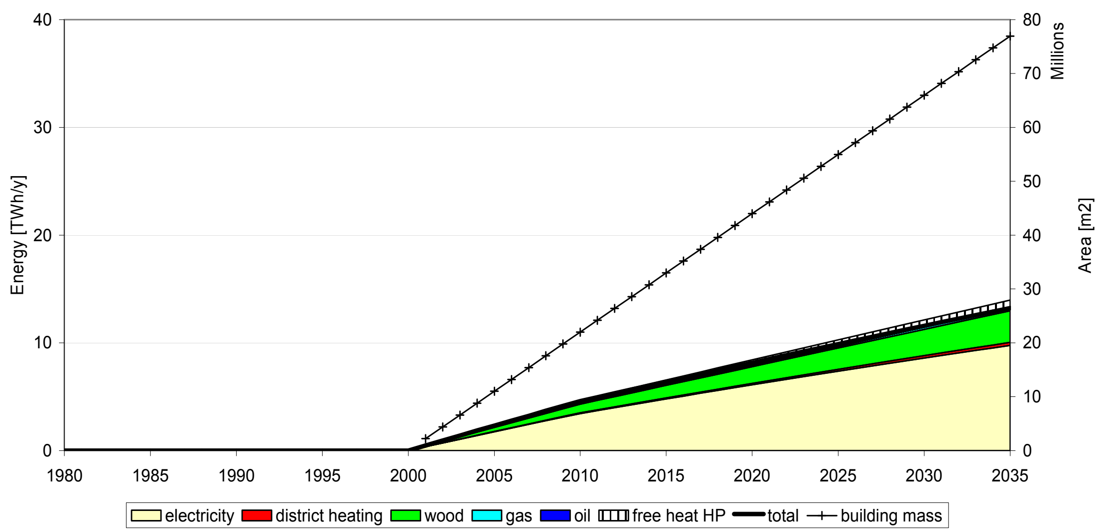



Figure 5-11 The energy demand and building mass for renovated residential buildings from 2000-2035 in the EPBD scenario.

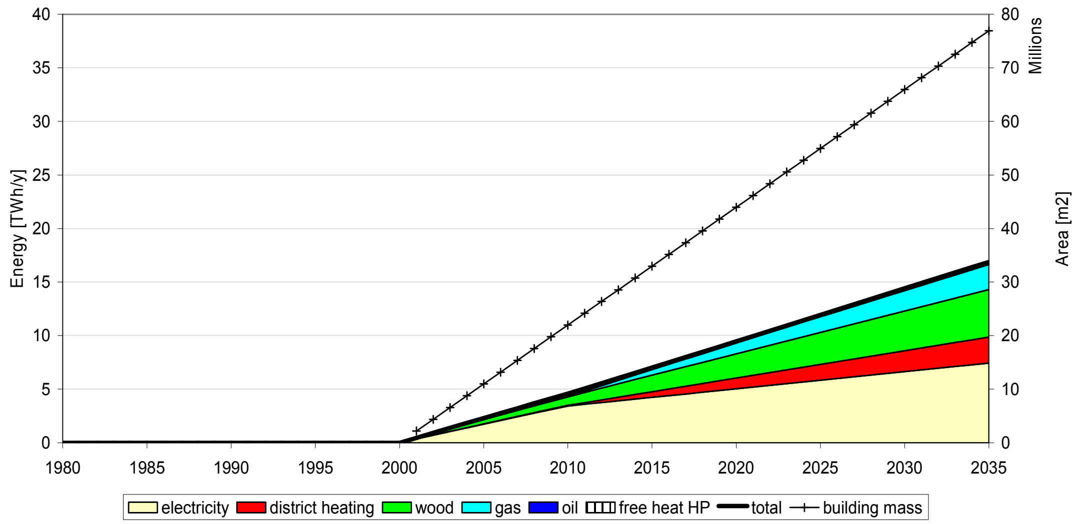



Figure 5-12 The energy demand and building mass for renovated residential buildings from 2000-2035 in the Substitution scenario.

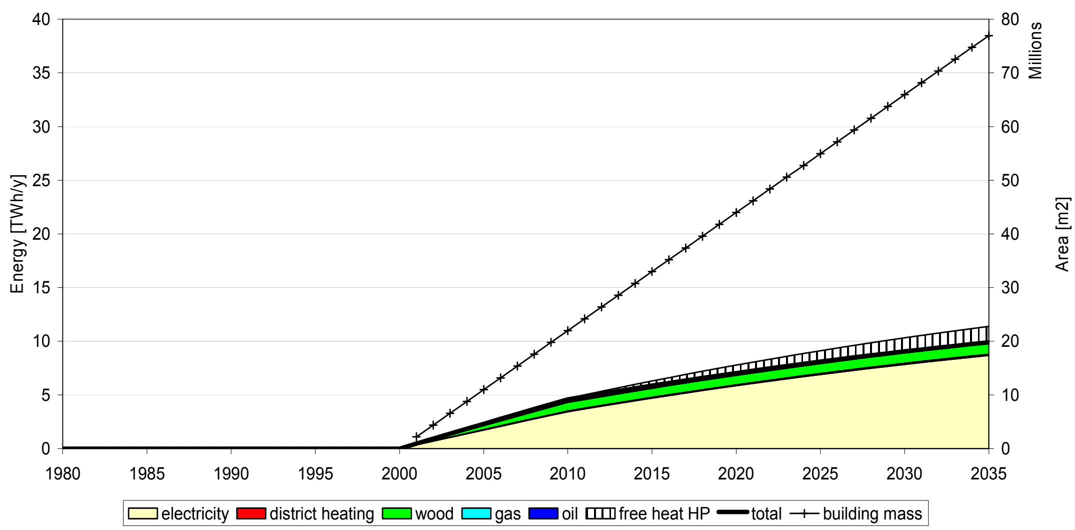



Figure 5-13 The energy demand and building mass for renovated residential buildings from 2000-2035 in the Conservation scenario.

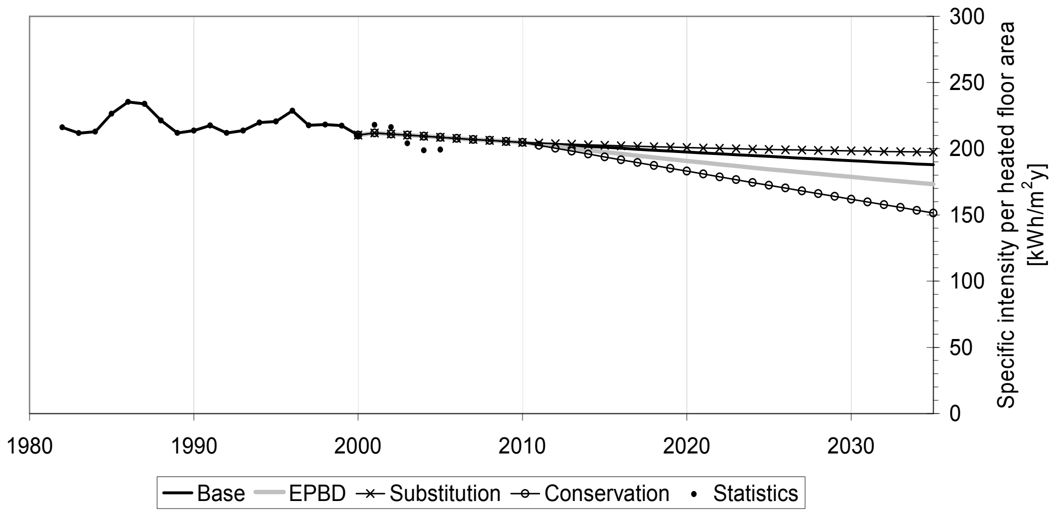



Figure 5-14 Intensity development for total dwelling stock for the different scenarios

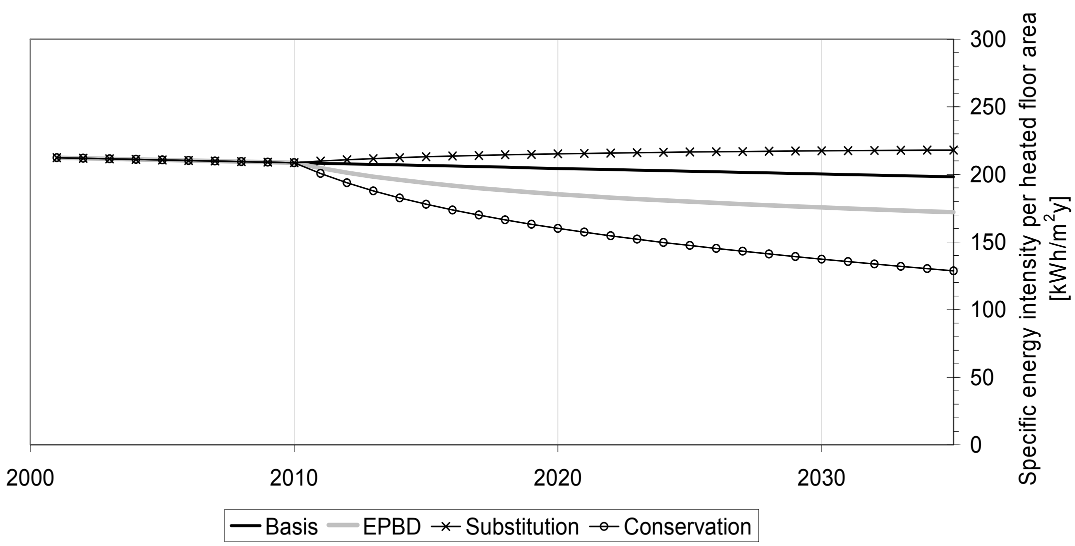



Figure 5-15 The intensity development for the dwelling stock renovated after year 2001 for the different scenarios.

Table 5-4 The energy demand for the dwelling stock renovated after year 2001 for the base scenario compared with the three alternative scenarios

| Scenario | | Basis | | | EPBD | | | Substitution | | | Conservation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total [GWh] | Change from base scenario [GWh] | Change from base scenario [%] | Total [GWh] | Change from base scenario [GWh] | Change from base scenario [%] | Total [GWh] | Change from base scenario [GWh] | Change from base scenario [%] | Total [GWh] | Change from base scenario [GWh] | Change from base scenario [%] |
| 2005 | Electricity | 1.750 | 0 | 0,0 % | 1.750 | 0 | 0,0 % | 1.750 | 0 | 0,0 % | 1.750 | 0 | 0,0 % |
| | District heat | 22 | 0 | 0,0 % | 22 | 0 | 0,0 % | 22 | 0 | 0,0 % | 22 | 0 | 0,0 % |
| | Biobrensel | 384 | 0 | 0,0 % | 384 | 0 | 0,0 % | 384 | 0 | 0,0 % | 384 | 0 | 0,0 % |
| | Gas | 12 | 0 | 0,0 % | 12 | 0 | 0,0 % | 12 | 0 | 0,0 % | 12 | 0 | 0,0 % |
| | Oil | 148 | 0 | 0,0 % | 148 | 0 | 0,0 % | 148 | 0 | 0,0 % | 148 | 0 | 0,0 % |
| | **Total consumption** | **2.316** | **0** | **0,0 %** | **2.316** | **0** | **0,0 %** | **2.316** | **0** | **0,0 %** | **2.316** | **0** | **0,0 %** |
| | Renewable via heat pumps | 27 | 0 | 0,0 % | 27 | 0 | 0,0 % | 27 | 0 | 0,0 % | 27 | 0 | 0,0 % |
| 2010 | Electricity | 3.441 | 0 | 0,0 % | 3.441 | 0 | 0,0 % | 3.441 | 0 | 0,0 % | 3.441 | 0 | 0,0 % |
| | District heat | 54 | 0 | 0,0 % | 54 | 0 | 0,0 % | 54 | 0 | 0,0 % | 54 | 0 | 0,0 % |
| | Biobrensel | 810 | 0 | 0,0 % | 810 | 0 | 0,0 % | 810 | 0 | 0,0 % | 810 | 0 | 0,0 % |
| | Gas | 36 | 0 | 0,0 % | 36 | 0 | 0,0 % | 36 | 0 | 0,0 % | 36 | 0 | 0,0 % |
| | Oil | 246 | 0 | 0,0 % | 246 | 0 | 0,0 % | 246 | 0 | 0,0 % | 246 | 0 | 0,0 % |
| | **Total consumption** | **4.587** | **0** | **0,0 %** | **4.587** | **0** | **0,0 %** | **4.587** | **0** | **0,0 %** | **4.587** | **0** | **0,0 %** |
| | Renewable via heat pumps | 87 | 0 | 0,0 % | 87 | 0 | 0,0 % | 87 | 0 | 0,0 % | 87 | 0 | 0,0 % |
| 2035 | Electricity | 10.995 | 0 | 0,0 % | 9.759 | -1.236 | -11,2 % | 7.442 | -3.553 | -32,3 % | 8.685 | -2.310 | -21,0 % |
| | District heat | 351 | 0 | 0,0 % | 287 | -64 | -18,2 % | 2.427 | 2.076 | 592,1 % | 100 | -250 | -71,4 % |
| | Biobrensel | 3.574 | 0 | 0,0 % | 2.923 | -651 | -18,2 % | 4.433 | 859 | 24,0 % | 1.021 | -2.553 | -71,4 % |
| | Gas | 329 | 0 | 0,0 % | 269 | -60 | -18,2 % | 2.474 | 2.146 | 653,1 % | 94 | -235 | -71,4 % |
| | Oil | 0 | 0 | 0,0 % | 0 | 0 | 0,0 % | 0 | 0 | 0,0 % | 0 | 0 | 0,0 % |
| | **Total consumption** | **15.248** | **0** | **0,0 %** | **13.238** | **-2.011** | **-13,2 %** | **16.776** | **1.528** | **10,0 %** | **9.901** | **-5.348** | **-35,1 %** |
| | Renewable via heat pumps | 889 | 0 | 0,0 % | 727 | -162 | -18,2 % | 254 | -635 | -71,4 % | 1.477 | 588 | 66,2 % |

As can be seen from the graphs and tables presented above, the results are identical for all scenarios until year 2010. The reason is that we assume that changes caused by new energy requirements in revised building code not will come into effect before 2011.

Thus we do not expect any break of the business as usual trend until 2011, even in the case of immediate political consensus for a policy in accordance with one of the alternative scenarios.

In the base-scenario, the distribution with respect to energy carriers is based on a linear projection of the trend for the end user preference for heating from 1995-2005, see Figure 5-5. Further it is assumed that the energy efficiency for new buildings will not change in the analysis period, and that renovation does not affect the energy efficiency. We observe that this results in a gradual increase of the consumption for all carriers except for oil, which will be completely phased out in 2035.

The part of the stock that has been renovated in the period 2005-2035 constitutes 28 % of the total dwelling stock. The final consumption in 2035 for this part of the stock is shown in Table 5-4. In total this stock consumes 15.2 TWh.

In the EPBD scenario, it is assumed that the introduction of the buildings energy directive works as intended, which results in an improvement of the energy standard for buildings built and renovated after year 2011. From Figure 5-7 it can be observed that this results in a flattening of the increase in electricity consumption.

The total consumption in 2035 for the renovated part of the stock is 13.2 TWh, i.e. 2 TWh lower than in the base scenario.

In the substitution scenario, electricity consumption is reduced at the expense of increased use of firewood, district heat and gas, see Figure 5-8. When looking only at renovated dwellings, the total consumption in 2035 increases by 1.5 TWh from the base scenario, although the electricity consumption decreases by 3.6 TWh. The increase in the total is due to reduced system efficiencies for alternative energy systems compared to direct use of electricity, and reduced renewable energy provided via heat pumps.

In the conservation scenario, the total consumption in 2035 for the renovated part of the stock is 9.9 TWh, i.e. 5.3 TWh lower than in the base scenario. Electricity consumption is reduced by 2.3 TWh compared to the base scenario.

# 6. Ownership and decision processes

## 6.1 Ownership of the Norwegian building stock

The occupants of the approximately two million dwellings may be categorised in these groups:

- Homeowner (alone or joint ownership)
- Homeowner through membership in housing cooperative
- Tenants of:
  - Private owners
  - Housing companies
  - Municipal bodies
  - Other landlords

The distribution between these groups is as follows:

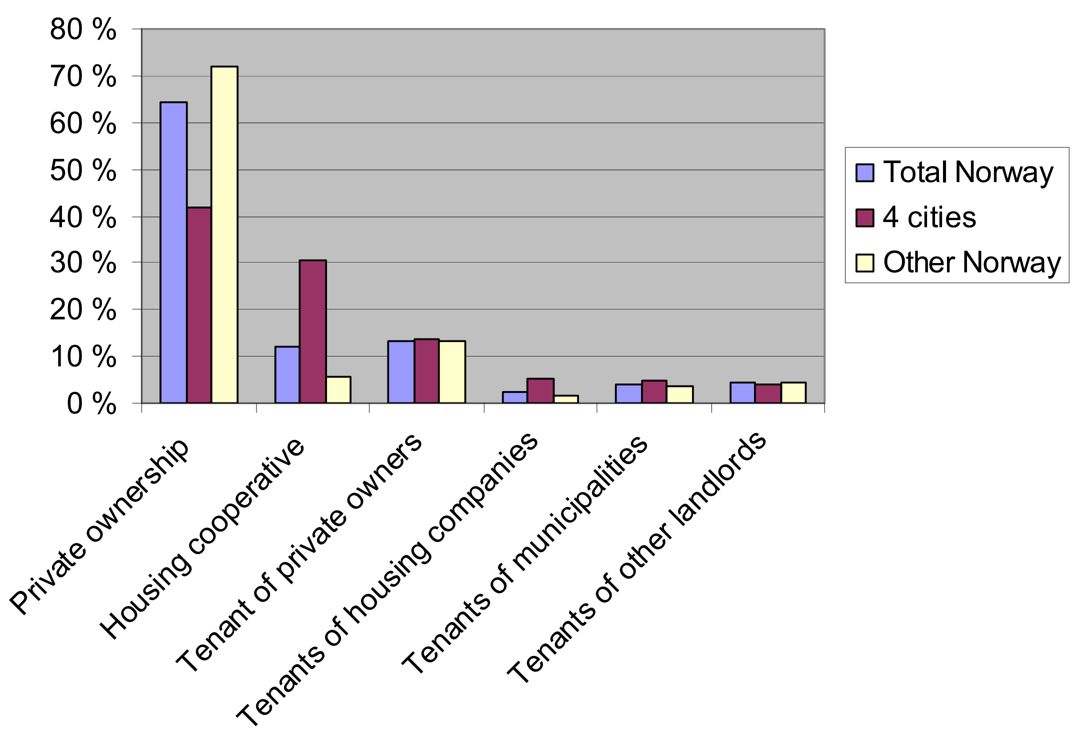



Figure 6-1 Ownership of Norwegian homes in 2001 *

* “4 cities” includes the four biggest cities in Norway (Oslo, Bergen, Trondheim and Stavanger). These cities count alone for 26 % of the total Norwegian building stock (Oslo half of this).

As the graph indicates, private homeowners are the predominant owners of the Norwegian building stock. If we include housing co-operatives, the total proportion of homeowners is 76%.

However, there are big regional differences between urban and rural areas. In the cities, the housing co-operatives have a much higher share of the housing stock market than elsewhere in Norway. In the next sub-chapters, we will discuss the decision-making processes for these different market segments.

## 6.2 Private homeowners

Private homeowners are either single persons or families with or without children. Regarding decisions connected to renovation of their homes, we can compare it with any other decision-making of purchases involving high expenditure.

### 6.2.1 Segments of homeowner

Private homeowners can be segmented by different criteria. In this case, demographic data and family life cycle may be useful criteria. Each stage creates different consumer demands:

- bachelor stage
- newly married, young, no children
- full nest 1, youngest child < 6 years
- full nest 2, youngest child 6 or over
- full nest 3, older married couple with dependent children
- empty nest 1, older married couple with no children living with them
- etc.

In this context, it is important to recognize that the family unit makes several decisions. Other relevant segment criteria may be social class and culture/sub culture.

In the REEP (Residential Energy Efficiency Project) undertaken in the Waterloo Region in Canada, they started with a GIS (geographical information system) analysis where data on type of building and year built for the building stock were combined with demographic data. Based on the analysis, neighbourhoods were classified as being highly suitable, suitable, somewhat suitable or not suitable for the project. The result was used when marketing where conducted, and it was concluded that the GIS-analysis was very useful to identify neighbourhoods that were more likely to respond [10].

### 6.2.2 Decision-making process

Consumer behaviour and the decision making process is the study of how people buy, what they buy, when they buy and why they buy. It includes elements as psychology, sociology, sociopsychology, anthropology and economics. We try to understand the consumer's decision-making process, both individually and in groups and study characteristics of individual consumers such as psychographics, demographics, and behavioural variables in an attempt to understand their wants. The decision making process will differ for different products, but market researchers have developed a common step-by-step model for the consumer decision-making process [11]:

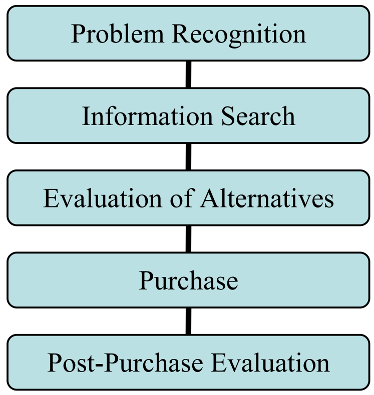



Figure 6-2 The decision making process [11]

#### *6.2.2.1 Problem recognition*

The consumer perceives a need and becomes motivated to solve a problem.

For the renovation, market sources of problem recognition may include:

- Dissatisfaction with a current product (house)
- Consumer needs and wants
- New products available

#### *6.2.2.2 Information Search*

When the consumer has recognised a problem (or a need), he/she searches for information on products and services that can solve that problem.

Sources of information normally include:

- Personal sources (family, friends, neighbours, etc)
- Commercial sources (salespeople, advertising, etc)
- Public sources (radio, television, newspapers, magazines, etc)
- Personal experience (i.e. using the product)

#### *6.2.2.3 Alternative evaluation*

At this stage, the consumer compares the products that are available. Both functional and psychological benefits are evaluated. Renovation of a building is a "high involvement purchase". It is therefore likely that the consumer will carry out an extensive evaluation.

#### *6.2.2.4 Purchase decision*

When the alternatives have been evaluated, the consumer makes the purchase decision.

#### *6.2.2.5 Post purchase evaluation*

When the consumer has purchased the product, they will start evaluating their decision. The product's performance will be compared with their expectations.

When consumer has purchased a “high-involvement” products (i.e. a house), they usually experience some level of discomfort after the purchase. They experience some level of doubt that they made the right choice.

### 6.2.3 Communication challenges with the private homeowner

Let us now limit this question to projects where the house is fully renovated, i.e. a large investment, and where the consumer will hire professionals to conduct the work i.e. a carpenter or a contractor.

Renovating a house is a high-involvement purchase decision. This implies that the customer will carry out an extensive evaluation of alternatives and the marketer needs to provide lots of information about the positive consequences of buying.

Some of the main communication challenges are related to:

- the customer is an individual; there are many potential customers
- it’s not a “standard” product – it is difficult to give a fixed price
- it can be difficult to define the positive consequences relative to the extent of the investment

If a thorough segmentation job is done, it should be possible to define a manageable target group of potential customers. However, it will probably not be sufficient if only the carpenter/contractor communicate the message to start sustainable renovation project. To build strong motivation by sufficient numbers of consumers, organisations and opinion leaders supporting the environmental and energy-efficiency aspects of renovating a house should also communicate this message. There will also be a demand for telling success stories in magazine articles, etc.

When sufficient motivation is built up, and there are adequate information, the question of who will get the job, will be a function of the skills, reputation and offers of the suppliers.

## 6.3 Members of housing cooperatives

People who own their homes through housing cooperatives, represent the same categories as described in §6.2. However, as Figure 5-1 illustrates, the majority of them live in the urban areas of Norway.

Most cities in Norway have a housing cooperative company, which provides management and support services to several housing co-operatives in the city and its surroundings. Each co-operative elects a board of representatives of the members (i.e. the occupants).

### 6.3.1 Segments of housing co-operatives

Norway has a total of 89 housing co-operative companies, which give services to a total of approximately 5000 housing co-operatives [source: the Norwegian Federation of Co-operative Housing Associations (NBBL)].

We may therefore segment this market on two main levels:

- The housing co-operative companies (size, geography and their focus/interest)
- The co-operatives (same as described in 5.2.1)

Due to the limited number of housing co-operative companies, it is relatively easy to segment this substantial part of the total market.

### 6.3.2 Decision-making process

Within a family/household, the decision-making process is the same irrespective of whether they live in a housing co-operative or in an ordinary private dwelling.

As renovation of a building is a major investment, it has to be decided by a majority of 2/3 of the general assembly of the housing co-operative.

In 1996 the housing co-operative company in the municipality of Hamar started a project to motivate the housing co-operatives in the city to execute substantial renovation project with the main focus of installing lifts in the buildings. By 2005 15 housing co-operatives had completed extensive renovation projects. A study [12] of why this became a success, describes the steps in the decision-making process as follows:

1. Launching of the idea to renovate (either by a single member, the board or the housing co-operative company).
2. Formal discussion between the board and the housing co-operative company with the aim to identify the complete picture of the real need for renovation (not only lift)

3. Informal hearing among members in order to find out degree of interest
4. Decision by the general assembly to start a pre-project or not. The decision also included a definition of the scope of an eventual pre-project.
5. Execution of pre-project with a strong focus on bringing up all relevant pieces of information, including financing and consequences for future payments.
6. Informal information campaign where each of the occupants were informed in their own dwelling. This was done in order to demonstrate how the proposed renovations would impact on their own flat.
7. Final decision to start the project was made by the general assembly. 2/3 majority was needed for approving the project.
8. During the renovation phase it was a strong focus on informing the occupants about the proceeding and eventual unexpected problems which occurred. In some of the projects the occupants had to move out of their flats for a few days.

During the whole process, the board members played a very important role in informal information to the occupants. Especially elderly people had difficulties to understand the consequences of the planned renovation. For these persons it was important to talk personally to someone they knew and trusted (board members).

Some of the occupants who opposed to the renovation project started counter-actions in order to stop the plan. The most successful boards met these actions with open discussions in plenary, and based their arguments on facts.

### 6.3.3 Communication challenges with housing co-operatives

As it is easy to identify the housing co-operative companies in Norway, it simplifies the communication towards this segment. Further, each housing co-operative company has detailed information about every single housing co-operative. This includes information about the buildings as well as about the occupants. Therefore, it is possible together with the housing co-operative company to identify the housing co-operatives that are more likely to be interested in sustainable renovation or not.

The fact that the occupants already have an established relationship with the housing co-operative company, they pay more attention and respect to ideas being launched by the company. The housing co-operative company will normally be recognised as “independent” and not having an interest in itself to sell renovation solutions. By this, they have stronger credibility than an entrepreneur company.

The experiences from Hamar, however demonstrated that the decision-making process in itself should not be underestimated. It is very important that the occupants get ownership of the idea at an early stage. A good example demonstrating this important issue was a housing co-operative with buildings that were identical to another housing co-operative that had successfully renovated their buildings. The board found the solution chosen by the other housing co-operative to be so brilliant that it was decided to present a copy of the other project directly to the general assembly, which rejected the proposal. Several years later this housing co-operative started their own renovation project. The main findings from Hamar in order to succeed in the decision-making process were:

- Written information must be combined with oral information.
- Repeating the message several times.
- Known persons (board members) disseminated the information.

## 6.4 Owners of homes for rent

As it is not the tenant who makes the decision whether the building should be renovated or not, we will in this sub-chapter focus on the property owners and their behaviour regarding investing in renovation of their existing building(s).

### 6.4.1 Segments of owners

As shown in the figure in subchapter 5.1, approximately 50% of all tenants in Norway rent their homes from private persons. A very high proportion of these flats are located in the same house as the owner. This means that a decision of eventual renovation of this part of the market will be done as part of the renovation of the whole house.

Municipalities or municipal bodies own approximately 4 % of the total homes in Norway. These flats are a part of the social security system, and are normally financed by the Norwegian Housing Bank.

Professionals having renting as a business, own approximately 8 % of Norwegian homes. These companies are easy to identify through the national company register. All financial data are available on the internet. It is therefore possible to categorise this market by size, for example by total revenues or in total capital investments.

### 6.4.2 Decision-making process

**For private owners**, the decision process is close to identical as described in subchapter 5.2.2. There is however, two important questions which additionally having to be taken into account:

1. How will the renovation influence on the tenant, during the renovation phase and afterwards? Should this have an impact on the rent?
2. If the standard of the flat is too bad for being rented out, this could be the initial “need” (problem) to start considering renovating the whole building.

For heavy renovation projects of **municipal** owned homes, this will have to be included in the yearly budget. This means that it will need political approval, which means that the decision process is more complex and takes normally more time than by private owners.

**Professional homeowners** can make rather quick decisions on whether it is profitable to renovate. Normally, the tenant pays the heating of the flat. This means that the owner has little incentive to invest in passive measures. As long as the homes are in normal condition compared with the alternatives, the owner will have little interest in starting renovation. If the building is in a poor condition, a heavy renovation project may be profitable, as the owner can attract tenants who are willing to pay higher rent for better quality.

### 6.4.3 Communication challenges with the owners

For the private owner we refer to subchapter 5.2.3.

As a municipality has decided to start a heavy renovation project, it will publish the project for tendering. This means there will be a strong focus on lowest price. As there are limited resources in the public sector, often simpler solutions are chosen even though the consequences are poorer economy in the long run.

Professional private investors' main focus is to choose the most profitable solution. This means that they are not as open for emotional and moral arguments as a private owner. Only when the owner can see how he can use the same arguments to achieve a higher rent, this may be relevant for the communication.

# 7. Building codes

This chapter describes the energy requirements for housing from different construction periods. This overview may be useful when assessing the energy saving potential in the existing dwelling stock.

## 7.1 Building code from 1928

The first building code in Norway came into force in 1928 as a supplement to the Building act of 1924. The code was valid only for the cities. In this code there were no quantified requirements for thermal insulation or air-tightness, but the external walls should be performed in such a way that they would protect against coldness and moisture.

## 7.2 Building code from 1949

The first quantified requirement to thermal insulation came in the building code from 1949. The code was still in force only for the cities, and it distinguished between buildings in wood (light construction) and brick (heavy construction). The code had also different requirements for four climate zones, see Table 7-1.

Table 7-1 U-value requirements. Climate zone I to IV (Oslo in climate zone II)

| Construction type | U-values, kcal/m²h°C (W/m²K) [1] | | | |
|---|---|---|---|---|
| | *Climate zone* | | | |
| | *I* | *II* | *III* | *IV* |
| External walls in buildings of brick or other inflammable materials, more than 200 m² floor area | 1.1 (1.0) | 1.0 (0.9) | 0.9 (0.8) | 0.8 (0.7) |
| External walls in buildings of brick or other inflammable materials, less than 200 m² floor area | 1.1 (1.0) | 0.9 (0.8) | 0.8 (0.7) | 0.7 (0.6) |
| External walls in wooden buildings | 0.9 (0.8) | 0.8 (0.7) | 0.7 (0.6) | 0.6 (0.5) |
| External roof above heated rooms | 0.9 (0.8) | 0.8 (0.7) | 0.7 (0.6) | 0.6 (0.5) |
| Floor above heated rooms | 1.0 (0.9) | 0.9 (0.8) | 0.8 (0.7) | 0.7 (0.6) |
| External wall in basements | 1.6 (1.4) | 1.4 (1.2) | 1.2 (1.0) | 1.0 (0.9) |

[1] Conversion factor from [kcal/ m$^2$hºC] to [W/m$^2$K]: multiply by 0.87

Additional requirements:

- Floors above unheated room should not have a U-value higher than 0.8 kcal/m$^2$hºC (0.7 W/m$^2$K)
- If the window area measured more than 1/8 of the floor area, double glazed windows were required.

## 7.3 Building code from 1969

With the building code from 1969, the thermal insulation, and now also air-tightness requirement, became in force for the whole country. In accordance with the code, all parts of the external envelope should, as a general rule, by sufficiently airtight to prevent airflow through the insulation.

The new and stricter requirements from 1969 are shown in tables 7-2 and 7-3.

Table 7-2 U-value requirements for walls, floor and roof. Climate zone I to IV (Oslo climate zone II)

| Construction type | U-values [W/m²K] | | | |
|---|---|---|---|---|
| | Climate zone | | | |
| | I | II | III | IV |
| External walls, mass less than 100 kg/m² | 0.70 | 0.81 | 1.04 | 1.04 |
| External walls, mass more than 100 kg/m² | 0.46 | 0.46 | 0.58 | 0.58 |
| External roof, non-wooden structure | 0.46 | 0.46 | 0.58 | 0.58 |
| External roof, wooden structure | 0.41 | 0.41 | 0.46 | 0.46 |
| Floor above basement | 0.58 | 0.58 | 0.70 | 0.70 |
| Floor towards outdoor air | 0.41 | 0.41 | 0.46 | 0.46 |

Table 7-3 U-value requirements for external windows and doors. The *F* is the total area of external walls, measured from the inside of the walls and including window and door area. The *f* is the total window and door area.

| Ratio window/floor area to wall area | U-values [W/m²K] | | | |
|---|---|---|---|---|
| | Climate zone | | | |
| | I | II | III | IV |
| f/F ≤ 0.3 | 3.14 | 3.14 | 3.60 | 3.60 |
| 0.3 ≤ f/F ≤ 0.6 | 3.14 | 3.14 | 3.14 | 3.60 |
| f/F ≥ 0.6 | 2.44 | 2.44 | 2.44 | 3.14 |

## 7.4 Building code from 1980

From 1980 the thermal insulation requirements became independent on construction weight. However, the new code distinguished between small houses (with up to two dwelling units) and other heated buildings. In order to simplify the regulations, the climate zones were removed. From 1980 there were therefore similar requirements for the whole country. The requirements for thermal insulation in small houses and other buildings are shown in tables 7-4 and 7-5 respectively.

Table 7-4 U-value requirements (W/m²K) for *small houses*

| Façade alternatives | Construction element | U-value [W/m²K] |
|---|---|---|
| Alternative 1 | External walls | 0.35 |
| | Windows and balcony doors | 2.10 |
| Alternative 2 | External walls | 0.25 |
| | Windows and balcony doors | 2.70 |
| (Common to both alternatives) | External roof | 0.23 |
| | Floor towards outdoor air | 0.23 |
| | Floor towards non-heated room | 0.30 |
| | Floor on the ground | 0.30 |
| | External door | 2.00 |

Table 7-5 U-value requirements, *other buildings than small houses*, and with room temperatures above 10 ºC

| Construction element | U-value [W/m²K] |
|---|---|
| Facades, including windows and doors | 0.45* |
| External roof | 0.23 |
| Floor towards outdoor air | 0.23 |
| Floor towards non-heated rooms | 0.30 |
| Floor on the ground | 0.30 |

* ”Equivalent U-value”, i.e. solar radiation could be taken into consideration

**All buildings**

New in this code was that the window area should not exceed 15 % of the heated floor area. If 15 % was exceeded, the thermal insulation of the windows and/or the walls should compensate for the increased thermal loss.

For the first time, the building code got quantified requirements for the air-tightness. The air-tightness should not exceed 3 air changes per hour at 50 Pa pressure difference for buildings with maximum two stories, and 1.5 air changes per hour for higher buildings.

## 7.5 Building code from 1987

In the building code from 1987 the thermal insulation requirements became similar for all heated buildings. The air-tightness requirement remained unchanged, except that the requirement for “small houses” and row houses was now 4 air changes per hour at 50 Pa.

Table 7-6 U-value requirements for heated buildings/rooms (above 18 ºC)

| Construction element | U-value [W/m²K] |
|---|---|
| External walls | 0.30 |
| Windows | 2.40 |
| Doors | 2.00 |
| External roof | 0.20 |
| Floor towards outdoor air | 0.20 |
| Floor towards non-heated room | 0.30 |
| Floor on the ground | 0.30 |

Window area should not exceed 15 % of the heated floor area. If 15 % was exceeded, the thermal insulation of window and/or walls should compensate the increased thermal loss. Other U-values than listed in the table could be used, but the overall thermal insulation standard should not be less than if the listed values were satisfied.

## 7.6 Building code from 1997

This code gives several documentation methods for documentation of the energy efficiency of the building. However, they are all based on a base set of U-values. These U-values are listed in Table 7-7.

Table 7-7 U-value requirements for heated buildings/rooms (above 18 ºC)

| Construction element | U-value [W/m²K] |
|---|---|
| External walls | 0.22 |
| Windows | 1.60 |
| Windows in non-residential buildings | 2.00 |
| Doors | 1.60 |
| External roof | 0.15 |
| Floor towards outdoor air | 0.15 |
| Floor towards non-heated room | 0.30 |
| Floor on the ground | 0.15 |

The total window and door area should not exceed 20 % of the heated floor area. If 20 % was exceeded, or some of the building envelope constructions had higher U-values than listed in the table, the increased thermal losses had to be compensated by means of better thermal insulation of the other constructions. However, a maximum level for U-values, described in the code, should still be kept.

## 7.7 Building code from 2007

This code gives two different methods for documentation of the energy efficiency of the buildings. Similarly as for the code from 1997, also these methods are based on a base set of requirements, shown in Table 7.8. Individual requirements may be breached so long as compensating measures are taken to ensure that the building's total thermal loss does not exceed the permitted total loss if all listed requirements were satisfied. This code also dictates maximum permissible U-values and air-tightness that can not be exceeded, even with compensating measures.

Table 7-8 Energy requirements for heated buildings (above 15 ºC)

| **Construction element, utility** | **Requirement** |
|---|---|
| Total area of glass, windows and doors: | Maximum 20 % of the total heated floor area |
| U-value for external walls | 0,18 W/m²K |
| U-value for external roofs | 0,13 W/m²K |
| U-value for floor on the ground or towards outdoor air | 0,15 W/m²K |
| U-value for glass/windows/doors | 1,2 W/m²K |
| Thermal brides (per m² heated floor area) | 0,03 W/m²K for small houses,<br>0,06 W/m²K for apartment blocks |
| Air-tightness (@ 50 Pa) | 2,5 $h^{-1}$ for small houses,<br>1,5 $h^{-1}$ for apartment blocks |
| Annual average efficiency of heat exchanger in ventilation systems | 70 % |
| Specific fan power (SFP) for ventilation fans | 2,5 kW/(m³/s) for residential buildings |

## References

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# Appendix A – NS 3457 Building classification

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**Residential building**

**Detached house**
111 Detached house
112 Detached house with 2 dwelling units, including one bed-sit, basement flat etc.
113 Farmhouse

**House with 2 dwellings**
121 Part of semi-detached house
122 House with 2 dwellings
123 Part of semi-detached farmhouse
124 Farmhouse with 2 dwellings

**Row house, linked house and house with 3 or 4 dwellings**
131 Part of row house with 3 or 4 dwellings
132 Part of row house with 5 or more dwellings
133 Part of linked house incl. atrium with up to 4 dwellings
134 Part of linked house incl. atrium with 5 or more dwellings
135 Terraced house
136 House with 3 or 4 dwellings

**Multi-dwelling building**
141 Multi-dwelling building, 2 storeys
142 Multi-dwelling building, 3 and 4 storeys
143 Multi-dwelling building, 5 or more storeys
144 Linked multi-dwelling building, 2 storeys
145 Linked multi-dwelling building, 3 and 4 storeys
146 Linked multi-dwelling building, 5 or more storeys

**Residence for communities**
151 Residence and service residence for the elderly and other social groups
152 Student home
159 Other residential building for communities

**Non-residential building, holiday house, residential garage etc.**

**Holiday house, residential garage etc.**

**Holiday house**
161 Holiday house (chalet, summerhouse etc.)
162 Detached house used as holiday house
163 Farmhouse used as holiday house

**Cabin, mountain farm hut etc.**
171 Mountain farm hut, fishermen's shack etc.
172 Cabin, turf hut

**Residential garage and outhouse**
181 Garage, outhouse, annex linked to dwelling
182 Garage, outhouse, annex linked to holiday house
183 Boat-house, wharfside shed

**Other residential building**
193 Workmen's hut
199 Other residential building

**Non-residential building**

**Industrial building and warehouse**

**Industrial building**
211 Factory building
212 Workshop
213 Production building
214 Building for treatment plant
215 Building for waste treatment
216 Building for water supply including pumping station
219 Other industrial building

**Power supply building**
221 Power station (<15 000 kVA )
222 Smaller power station
223 Transformer station (>10 000 kVA )
224 Smaller transformer station, transformer box
229 Other building for power supply

**Warehouse**
231 Warehouse
232 Cold storage warehouse
233 Silo building
239 Other warehouse

290 Other industrial buildings and warehouses

**Agricultural and fishery building**
241 Building for animals, granary, fruit and vegetable storage, agricultural silo, building for hay/grain drying
242 Agricultural garage/implement shed
243 Greenhouse
244 Works building used for fishery and hunting, incl. fish farm
245 Fishery boat-house and shed
248 Other fishery and hunting building
249 Other agricultural building

**Office and business building**

**Office building**
311 Office and administration building, town hall
312 Bank building, post office
313 Media building
319 Other office building

**Wholesale and retail trade building**
321 Shopping centre, department store
322 Detached shops
323 Service station

21

329 Other wholesale and retail trade building

330 Fair and congress building

390 Other office and wholesale and retail trade building

**Transport and communications building**

**Service and terminal building**
411 Service building, airport terminal, air traffic control tower
412 Railway station and underground station
413 Bus station
414 Harbour terminal
415 Goods terminal
416 Post terminal
419 Other service and terminal building

**Telecommunication building**
421 Telephone building, public call box
422 Radio link station
423 Radio and television broadcast building, transformer station
424 AM station
429 Other telecommunication building

**Garage and hangar building**
431 Parking garage
432 Bus garage, tram and engine shed
433 Airplane hangar
439 Other garage and hangar building

**Road, driving and motor vehicle examiners building**
441 Driving and motor vehicle examiners building
442 Public Roads Administration Centre
443 Toll bar building, customs station and weigh station
449 Other road, motor vehicle and driving examiners building

490 Other transport and communication building

**Hotel and restaurant building**

**Hotel building**
511 Hotel building
512 Motel building
519 Other hotel building

**Short-stay accommodation building**
521 Pension and similar accommodation building
522 Youth hostel, holiday camp, tourist chalet
523 Apartment lodging building
524 Camping hut, holiday bungalow
529 Other short-stay accommodation building

**Restaurant building**
531 Restaurant building, café building
532 Food service kitchen, canteen building
533 Snack bar, kiosk
539 Other restaurant building

590 Other hotel and restaurant building

**Building used for education, research, public entertainment and religious activities**

**School building**
611 Playground
612 Kindergarten
613 Primary school
614 Lower secondary school
615 Combined primary and lower secondary school
616 Upper secondary school
619 Other school building

**University and research building**
621 University and higher technical education building
622 Special education building
629 Other university and research building
630 Laboratory building

**Museum and library building**
641 Museum and art gallery
642 Library
643 Zoological and botanical garden
649 Other museum and library building

**Sports building**
651 Sports hall
652 Ice arena
653 Indoor swimming pool
654 Stand and building for shower and changing rooms
655 Fitness centre
659 Other sports building

**Public entertainment building**
661 Cinema, theatre, concert hall, opera house
662 Community centre, local meeting hall used for public entertainment
663 Discotheque
669 Other public entertainment building

**Building used for religious activities**
671 Church, chapel
672 House of worship, parish house
673 Crematorium, cemetery chapel, chapel of repose
674 Synagogue, mosque
675 Convent, monastery
679 Other building used for religious activities

690 Other building used for education, research, public entertainment and religious activities

*Noregs offisielle statistikk*

**Hospital and institutional care building**

**Hospital**
711 Local hospital
712 Central hospital
713 Regional hospital, university hospital
714 Specialized hospital
719 Other hospital

**Long-stay hospital and nursing home**
721 Nursing home
722 Residence and home with nursing and medical care
723 Building for rehabilitation, sanatorium
729 Other long-stay hospital and nursing home

**Primary health building**
731 Clinic, doctor's office, medical centre, emergency clinic
732 Health and social services centre, health station
739 Other primary health building

790 Other hospital and institutional care building

**Prison, building for emergency preparedness etc.**

**Prison building**
811 Central prison
812 Auxiliary prison, regional prison
813 Open prison
819 Other prison building

**Emergency preparedness building**
821 Police station
822 Fire station, ambulance station
823 Lighthouse building, pilot station
824 Radar surveillance station for aircraft and/or ships
825 Air-raid shelter, bunker
829 Other building for emergency preparedness

830 Monument

840 Public toilet

890 Other prison, building for emergency preparedness etc.

# Appendix B – Archetypes

## Year 2001

| class E, Rs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 190,00 | | | | | | | | | 212,82 | |
| electric | **41,00** | 21,6 % | | | | 1,00 | electricity | 41,00 | electricity | 161,95 | 76,1 % |
| cooling | **0,00** | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | **149,00** | 78,4 % | electricity direct | 80,65 % | 120,17 | 1,00 | electricity direct | 120,17 | | | |
| | | | district heating | 0,94 % | 1,39 | 0,88 | district heating | 1,58 | district heating | 1,58 | 0,7 % |
| | | | wood | 8,87 % | 13,21 | 0,40 | wood | 33,04 | wood | 33,04 | 15,5 % |
| | | | gas | 0,31 % | 0,45 | 0,81 | gas | 0,56 | gas | 0,56 | 0,3 % |
| | | | oil | 8,11 % | 12,08 | 0,77 | oil | 15,69 | oil | 15,69 | 7,4 % |
| | | | heat from HP | 1,13 % | 1,69 | 2,16 | ele. to drive HP | 0,78 | | | |
| | | | | | | | free heat HP | 0,91 | free heat HP | 0,91 | --- |

| class D, (Rs+Rr)/2 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 155,50 | | | | | | | | | 172,50 | |
| electric | 44,50 | 28,6 % | | | | 1,00 | electricity | 44,50 | electricity | 134,60 | 78,0 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 111,00 | 71,4 % | electricity direct | 80,65 % | 89,52 | 1,00 | electricity direct | 89,52 | | | |
| | | | district heating | 0,94 % | 1,04 | 0,88 | district heating | 1,18 | district heating | 1,18 | 0,7 % |
| | | | wood | 8,87 % | 9,84 | 0,40 | wood | 24,61 | wood | 24,61 | 14,3 % |
| | | | gas | 0,31 % | 0,34 | 0,81 | gas | 0,42 | gas | 0,42 | 0,2 % |
| | | | oil | 8,11 % | 9,00 | 0,77 | oil | 11,69 | oil | 11,69 | 6,8 % |
| | | | heat from HP | 1,13 % | 1,26 | 2,16 | ele. to drive HP | 0,58 | | | |
| | | | | | | | free heat HP | 0,67 | free heat HP | 0,67 | --- |

| class C, Rr | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 121,00 | | | | | | | | | 132,18 | |
| electric | **48,00** | 39,7 % | | | | 1,00 | electricity | 48,00 | electricity | 107,26 | 81,1 % |
| cooling | **0,00** | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | **73,00** | 60,3 % | electricity direct | 80,65 % | 58,88 | 1,00 | electricity direct | 58,88 | | | |
| | | | district heating | 0,94 % | 0,68 | 0,88 | district heating | 0,78 | district heating | 0,78 | 0,6 % |
| | | | wood | 8,87 % | 6,47 | 0,40 | wood | 16,19 | wood | 16,19 | 12,2 % |
| | | | gas | 0,31 % | 0,22 | 0,81 | gas | 0,27 | gas | 0,27 | 0,2 % |
| | | | oil | 8,11 % | 5,92 | 0,77 | oil | 7,69 | oil | 7,69 | 5,8 % |
| | | | heat from HP | 1,13 % | 0,83 | 2,16 | ele. to drive HP | 0,38 | | | |
| | | | | | | | free heat HP | 0,44 | free heat HP | 0,44 | --- |

## Year 2035

| class E, Rs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 190,00 | | | | | | | | | 198,17 | |
| electric | 41,00 | 21,6 % | | | | 1,00 | electricity | 41,00 | electricity | 142,90 | 72,1 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 149,00 | 78,4 % | electricity direct | 61,71 % | 91,94 | 1,00 | electricity direct | 91,94 | | | |
| | | | district heating | 2,69 % | 4,01 | 0,88 | district heating | 4,56 | district heating | 4,56 | 2,3 % |
| | | | wood | 18,70 % | 27,87 | 0,60 | wood | 46,45 | wood | 46,45 | 23,4 % |
| | | | gas | 2,46 % | 3,67 | 0,86 | gas | 4,27 | gas | 4,27 | 2,2 % |
| | | | oil | 0,00 % | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | 14,43 % | 21,51 | 2,16 | ele. to drive HP | 9,96 | | | |
| | | | | | | | free heat HP | 11,55 | free heat HP | 11,55 | --- |

| class D, (Rs+Rr)/2 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 155,50 | | | | | | | | | 161,59 | |
| electric | 44,50 | 28,6 % | | | | 1,00 | electricity | 44,50 | electricity | 120,41 | 74,5 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 111,00 | 71,4 % | electricity direct | 61,71 % | 68,49 | 1,00 | electricity direct | 68,49 | | | |
| | | | district heating | 2,69 % | 2,99 | 0,88 | district heating | 3,39 | district heating | 3,39 | 2,1 % |
| | | | wood | 18,70 % | 20,76 | 0,60 | wood | 34,60 | wood | 34,60 | 21,4 % |
| | | | gas | 2,46 % | 2,74 | 0,86 | gas | 3,18 | gas | 3,18 | 2,0 % |
| | | | oil | 0,00 % | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | 14,43 % | 16,02 | 2,16 | ele. to drive HP | 7,42 | | | |
| | | | | | | | free heat HP | 8,60 | free heat HP | 8,60 | --- |

| class C, Rr | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 121,00 | | | | | | | | | 125,00 | |
| electric | 48,00 | 39,7 % | | | | 1,00 | electricity | 48,00 | electricity | 97,92 | 78,3 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 73,00 | 60,3 % | electricity direct | 61,71 % | 45,05 | 1,00 | electricity direct | 45,05 | | | |
| | | | district heating | 2,69 % | 1,96 | 0,88 | district heating | 2,23 | district heating | 2,23 | 1,8 % |
| | | | wood | 18,70 % | 13,65 | 0,60 | wood | 22,76 | wood | 22,76 | 18,2 % |
| | | | gas | 2,46 % | 1,80 | 0,86 | gas | 2,09 | gas | 2,09 | 1,7 % |
| | | | oil | 0,00 % | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | 14,43 % | 10,54 | 2,16 | ele. to drive HP | 4,88 | | | |
| | | | | | | | free heat HP | 5,66 | free heat HP | 5,66 | --- |

# Substitution

| class E, Rs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 190,00 | | | | | | | | | 225,98 | |
| electric | 41,00 | 21,6 % | | | | 1,00 | electricity | 41,00 | electricity | 78,25 | 34,6 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 149,00 | 78,4 % | electricity direct | **25,00 %** | 37,25 | 1,00 | electricity direct | 37,25 | | | |
| | | | district heating | **25,00 %** | 37,25 | 0,88 | district heating | 42,33 | district heating | 42,33 | 18,7 % |
| | | | wood | **25,00 %** | 37,25 | 0,60 | wood | 62,08 | wood | 62,08 | 27,5 % |
| | | | gas | **25,00 %** | 37,25 | 0,86 | gas | 43,31 | gas | 43,31 | 19,2 % |
| | | | oil | **0,00 %** | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | **0,00 %** | 0,00 | 2,16 | ele. to drive HP | 0,00 | | | |
| | | | | | | | free heat HP | 0,00 | free heat HP | 0,00 | --- |

| class D, (Rs+Rr)/2 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 155,50 | | | | | | | | | 182,30 | |
| electric | 44,50 | 28,6 % | | | | 1,00 | electricity | 44,50 | electricity | 72,25 | 39,6 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 111,00 | 71,4 % | electricity direct | **25,00 %** | 27,75 | 1,00 | electricity direct | 27,75 | | | |
| | | | district heating | **25,00 %** | 27,75 | 0,88 | district heating | 31,53 | district heating | 31,53 | 17,3 % |
| | | | wood | **25,00 %** | 27,75 | 0,60 | wood | 46,25 | wood | 46,25 | 25,4 % |
| | | | gas | **25,00 %** | 27,75 | 0,86 | gas | 32,27 | gas | 32,27 | 17,7 % |
| | | | oil | **0,00 %** | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | **0,00 %** | 0,00 | 2,16 | ele. to drive HP | 0,00 | | | |
| | | | | | | | free heat HP | 0,00 | free heat HP | 0,00 | --- |

# Conservation

| class D, (Rs+Rr)/2 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 155,50 | | | | | | | | | 125,69 | |
| electric | 44,50 | 28,6 % | | | | 1,00 | electricity | 44,50 | electricity | 125,69 | 100,0 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 111,00 | 71,4 % | electricity direct | **50,00 %** | 55,50 | 1,00 | electricity direct | 55,50 | | | |
| | | | district heating | **0,00 %** | 0,00 | 0,88 | district heating | 0,00 | district heating | 0,00 | 0,0 % |
| | | | wood | **0,00 %** | 0,00 | 0,60 | wood | 0,00 | wood | 0,00 | 0,0 % |
| | | | gas | **0,00 %** | 0,00 | 0,86 | gas | 0,00 | gas | 0,00 | 0,0 % |
| | | | oil | **0,00 %** | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | **50,00 %** | 55,50 | 2,16 | ele. to drive HP | 25,69 | | | |
| | | | | | | | free heat HP | 29,81 | free heat HP | 29,81 | --- |

| class C, Rr | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 121,00 | | | | | | | | | 101,40 | |
| electric | 48,00 | 39,7 % | | | | 1,00 | electricity | 48,00 | electricity | 101,40 | 100,0 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 73,00 | 60,3 % | electricity direct | **50,00 %** | 36,50 | 1,00 | electricity direct | 36,50 | | | |
| | | | district heating | **0,00 %** | 0,00 | 0,88 | district heating | 0,00 | district heating | 0,00 | 0,0 % |
| | | | wood | **0,00 %** | 0,00 | 0,60 | wood | 0,00 | wood | 0,00 | 0,0 % |
| | | | gas | **0,00 %** | 0,00 | 0,86 | gas | 0,00 | gas | 0,00 | 0,0 % |
| | | | oil | **0,00 %** | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | **50,00 %** | 36,50 | 2,16 | ele. to drive HP | 16,90 | | | |
| | | | | | | | free heat HP | 19,60 | free heat HP | 19,60 | --- |

| class B, 0.75*Rr | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 90,75 | | | | | | | | | 76,05 | |
| electric | 36,00 | 39,7 % | | | | 1,00 | electricity | 36,00 | electricity | 76,05 | 100,0 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 54,75 | 60,3 % | electricity direct | **50,00 %** | 27,38 | 1,00 | electricity direct | 27,38 | | | |
| | | | district heating | **0,00 %** | 0,00 | 0,88 | district heating | 0,00 | district heating | 0,00 | 0,0 % |
| | | | wood | **0,00 %** | 0,00 | 0,60 | wood | 0,00 | wood | 0,00 | 0,0 % |
| | | | gas | **0,00 %** | 0,00 | 0,86 | gas | 0,00 | gas | 0,00 | 0,0 % |
| | | | oil | **0,00 %** | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | **50,00 %** | 27,38 | 2,16 | ele. to drive HP | 12,67 | | | |
| | | | | | | | free heat HP | 14,70 | free heat HP | 14,70 | --- |

| class A, 0.5*Rr | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| net energy | | | | | | delivered energy | | | | | |
| energy use | kWh/m2y | share | carrier | user preference | kWh/m2y | efficiency or COP | carrier | kWh/m2y | energy carrier | kWh/m2y | share |
| | 60,50 | | | | | | | | | 50,70 | |
| electric | 24,00 | 39,7 % | | | | 1,00 | electricity | 24,00 | electricity | 50,70 | 100,0 % |
| cooling | 0,00 | 0,0 % | | | | 1,40 | electricity | 0,00 | | | |
| heating | 36,50 | 60,3 % | electricity direct | **50,00 %** | 18,25 | 1,00 | electricity direct | 18,25 | | | |
| | | | district heating | **0,00 %** | 0,00 | 0,88 | district heating | 0,00 | district heating | 0,00 | 0,0 % |
| | | | wood | **0,00 %** | 0,00 | 0,60 | wood | 0,00 | wood | 0,00 | 0,0 % |
| | | | gas | **0,00 %** | 0,00 | 0,86 | gas | 0,00 | gas | 0,00 | 0,0 % |
| | | | oil | **0,00 %** | 0,00 | 0,77 | oil | 0,00 | oil | 0,00 | 0,0 % |
| | | | heat from HP | **50,00 %** | 18,25 | 2,16 | ele. to drive HP | 8,45 | | | |
| | | | | | | | free heat HP | 9,80 | free heat HP | 9,80 | --- |