TOWARDS SUSTAINABILITY IN THE RESIDENTIAL SECTOR

A Study of Future Energy Use in the Norwegian Dwelling Stock

by
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Norwegian Building Research Institute

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BY

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WITH A FOREWORD BY

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May 2000

THE THIRD GYULA SEBESTYEN YOUNG RESEARCHER'S FELLOWSHIP 1997

The Gyula Sebestyén CIB Young Researcher's Fellowship was established in permanent recognition of the distinctive contribution made to CIB by Gyula Sebestyén during his thirteen year tenure as Secretary General.

Its objective is to enable a young researcher from a CIB Full or Associate Member Institute to spend a period at another CIB Member Institute of his or her choice for the purpose of research.

This Report is the outcome of a research project which Lars Myhre was conducting at the Norwegian Building Research Institute (NBI) from 1997 to 1999. This project was originally financed by the Norwegian Research Council and NBI. In 1997, CIB awarded Lars Myhre the 3rd Gyula Sebestyén Young Researcher's Fellowship, which enabled him to stay for a longer period at the Center for Construction and Environment, University of Florida. The stay in Florida and the close contact with the staff at the Center, and especially with Prof. Charles Kibert proved extremely beneficial for Lars Myhre's research work. The Fellowship was therefore of major importance for the outcome of the project, and was a fundamental contribution to the final report.

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PREFACE

The work presented in this report has been funded by grants from the Norwegian Research Council, under the programme "Environment and Development".

During the work, I spent four months as a research scholar at the Center for Construction and Environment at the University of Florida, USA. The stay was partly financed by the Third Gyula Sebestyén CIB Young Researcher's Fellowship awarded by The International Council for Research and Innovation in Building and Construction (CIB). I want to thank CIB for generously awarding me the Fellowship. I also want to express my gratitude to the University of Florida, Professor Charles J. Kibert and the Staff at the Center for Construction and Environment for their warm hospitality during my stay in Florida.

Oslo, Norway
December 1999

Lars Myhre

BRIEF SUMMARY

This report studies future energy use in the Norwegian dwelling stock, and analyses how the total energy and electricity use will be affected by alternative energy efficiency measures carried out in the stock. The background for the work is the steadily growing energy and electricity use in Norwegian households, and the problems this causes for achieving sustainable development.

A calculation model is developed to estimate the total energy and electricity use in the dwelling stock up to 2030 for different scenarios. The total floor space in the stock is estimated to increase from 211 million m^2 in 1998 to 291 million m^2 in 2030. A reference scenario shows that the total energy use in the dwellings will increase from 49 TWh in 1998 to 60 TWh in 2030, and the electricity use from 35 TWh to 47 TWh, if appropriate energy efficiency measures are not carried out. An optimum scenario shows that it is fully possible to reduce the total energy use to 44 TWh in 2030, and the electricity use to 33 TWh.

It is recommended that the energy related requirements in the Building Regulations are tightened to ensure the construction of new, energy efficient houses. To improve the energy efficiency in the existing housing stock, it is recommended to increase the price of energy, to use the increased revenues to subsidise energy efficiency measures, and to conduct information campaigns to increase the energy awareness in the population and education programmes to increase the competence of the professionals.

TOWARDS SUSTAINABILITY IN THE RESIDENTIAL SECTOR

A STUDY OF FUTURE ENERGY USE IN THE NORWEGIAN DWELLING STOCK

FOREWORD BY

PROF.DR. CHARLES KIBERT
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USA

Lars Myhre visited the University of Florida during the Fall of 1997 as the winner of the 3rd CIB Gyula Sebestyén Young Researcher's Fellowship and, during his stay in Gainesville, he completed work on research he was conducting into energy issues and sustainability related to the housing stock in Norway. Energy issues are at the leading edge of what we now refer to as sustainable construction. The energy crises of the early 1970's were in fact the initial shock wave and stimulus that produced a widespread recognition that environmental, resource, and economic conditions were in a state of collision. Two decades later we have finally evolved to employing the systems approach and holistic thinking represented in approaching how to implement sustainability in the built environment. Energy is a strong indicator and even surrogate for many of the problems being addressed by sustainable development: land, air, and water emissions; global warming; human health; loss of biodiversity; negative impacts of extractive industries; and numerous others. Thus, two of the prime directives of sustainable construction are to reduce energy consumption in the building stock and shift from a fossil fuel based energy economy to one comprised entirely of renewable energy systems.

In his report, Lars comprehensively examines the problem of how to accomplish this energy system transformation for housing in Norway. His examination produced the startling conclusion, at least for an American, that per capita electricity consumption in Norway is the highest in the world. Fortunately the generation of electricity in Norway is largely from hydropower sources. However, due to an annual growth rate of 1.8% in electricity consumption, hydropower cannot keep up with the increasing consumption of electricity and fossil fuel power plants are taking up the slack in power production.

The Norwegian housing stock represents about two-thirds of all buildings in that country and, like most OECD countries, per capita floor space is increasing rapidly parallel to the rising affluence and consumption of the population. In the case of Norway, per capita floor space has increased 70% between 1967 and 1995, from 29 m^2 to 49 m^2. The implications of this rapid change in living space are obvious with respect to energy consumption patterns. More ominously, the trends in Norway combined with similar patterns in countries around the globe in energy consumption are clearly not sustainable without rapid changes in life style and consumption.

Dr. Myhre's work, however, does give a glimmer of hope with respect to energy consumption and provides a strategic plan for reversing the trend in energy consumption growth and the parallel growth in fossil fuel use. By shifting to renewables and heat pumping, he shows that even with a continued growth in dwelling floor area over the next three decades to 2030, Norwegian energy consumption can actually fall from 49 Twh in 1998 to 44 Twh in 2030. To accomplish this will take shifts in national policy that invest in renewable energy resources and systems as well as changes in Building Regulations that significantly tighten the energy performance requirements of new housing. He also suggest that although the Building Regulations do not apply to existing housing, incentives and education programs can help change the thermal performance of the large stock of existing residences.

The research represented by Dr. Myhre's project is transformative in nature and applicable to virtually every major industrial country. The approach and thinking he uses can be applied to the analysis of housing stocks worldwide and the result would be an overall reduction in worldwide energy consumption in this sector as well as a profound shift towards renewable energy sources. CIB's decision to award Lars the Gyula Sebestyén Fellowship was an excellent choice and is perhaps a precursor to effectively using the deep talent pool present in CIB organisations worldwide to help the cause of sustainable development in a real and profound manner. I have had the recent pleasure of working with Lars as Co-Coordinator of CIB Task Group 39 on Deconstruction and am always impressed by both his technical competence and leadership skills. I join with my colleagues from CIB member organisations in congratulating both CIB and Lars on his excellent research effort and wish him much success in his future endeavours.

LIST OF CONTENTS

SUMMARY

The report addresses the energy use and electricity use in the Norwegian dwelling stock towards year 2030 and the influence of alternative energy efficiency measures carried out in the stock.

Chapter 1 presents the background for the report which is the steadily growing energy use in Norwegian households. The annual growth was about 1.8 % per year as an average from 1976 to 1996, and the growth in the use of electricity was even higher due to more electric heating. Today, Norway has the highest electricity use per capita in the world, and the third highest total energy use per capita. The environmental burden connected to the production, transportation and use of energy use is one of the most important environmental problems. The power production in Norway has traditionally been based on hydropower, but the country is now facing a situation where hydropower can not cover the increasing power demand. Instead electric power produced from fossil fuels must be used to cover the demand, involving large emissions of CO_2. In a sustainable context, the growing energy use in Norwegian households conflicts with the need to reduce overall resource consumption and environmental load.

Chapter 2 introduces the concept of sustainable development. The concept emerged on the political agenda in 1987 when the World Commission on Environment and Development (WCED) presented the report “Our Common Future”. The report emphasised the need to see economic, ecological and social aspects in connection. A vast number of definitions of sustainable development have been proposed, comprising environmental, economic and social aspects. In most of these definitions, the time and space dimensions of sustainable development are important. The space dimension addresses how justice and equity can be achieved within the generations, and implies a need for a more fair distribution of wealth amongst poor and rich. Today, property, income and consumption are extremely unequally distributed within the world’s population. About 85 % of the total world’s income go to the richest 20 % of the population. The unequal distribution between developed and developing countries, and between rich and poor, has to be reduced to comply with the space dimension of sustainable development. The time dimension addresses how justice and equity can be achieved between the generations, and implies that decision making generally should be based on a long-term perspective, where the interests of future generations are taken fully into account.

Within the building sector, the concept of “Sustainable Construction” is put on the agenda by several central organisations such as CIB and IEA.

There is a need to halve the material turnovers (resource use) on a world-wide basis. The consumption pattern is however constantly increasing due to increasing purchasing power amongst people. The concept of Factor 4 has been introduced to show that by increasing the resource productivity fourfold, it is possible to double the wealth (in terms of consumption) while simultaneously halving the total resource use. The concept of Factor 10 has later been introduced as a more proactive alternative to Factor 4. Factor 10 is also based on the need to halve the resource use on a world-wide basis, but it also recognises that the per capita consumption is five times higher in the OECD countries than in the developing countries. Further increases in world population are unavoidable, and according to the Factor 10 concept

sustainable levels of material flows will not be reached unless the material intensity in the OECD countries is reduced by a factor ten.

Chapter 3 presents some basic data about the Norwegian dwelling stock. Dwellings represent about two-thirds of the total building stock in Norway. In February 1999, there were about 1.32 million residential buildings, including about 1.9 million dwelling units. The total floor space in the dwelling stock has grown strongly the last decades. The growth has been caused by increasing population, a significant shift towards smaller households, and larger average size of dwellings. Accounting for the increasing population, it is found that the average floor space per capita increased from 29 m^2 in 1967 to 49 m^2 in 1995. This increase of almost 70 % is alarming from a sustainable point of view since it may be assumed to have counterbalanced the effect of all energy and resource efficiency measures carried out in the dwelling stock during the same period.

Chapter 4 presents a calculation model for estimating the energy use in the dwelling stock towards year 2030. The model includes a number of stereotypes of houses assumed to be collectively representative for the total dwelling stock. The total energy use in the stock is estimated by calculating the annual energy use per square metre of each of the stereotypes, aggregating with the total floor space in the group of houses they are representative for.

Chapter 5 presents four scenarios on the energy and electricity use in the dwelling stock towards year 2030. These scenarios are a reference scenario based on today's requirements in the Building Regulations for new houses and limited improvement of the thermal performance of existing houses (Scenario 1), an improved energy efficiency scenario (Scenario 2), a high energy efficiency scenario (Scenario 3), and a heat pump scenario (Scenario 4). In all these scenarios, the total floor space in the stock is assumed to increase from 211 million m^2 in 1998, to 291 million m^2 in 2030. The total number of dwelling units is correspondingly estimated to increase from 1.88 million units to 2.36 million units, and the average dwelling size from 112 m^2 to 123 m^2.

The total energy use in the dwelling stock in 1998 is estimated to be 49 TWh and the total electricity use 35 TWh. The reference scenario shows that the total energy use in the stock will grow strongly to 60 TWh in 2030, and the use of electricity to 47 TWh. According to Scenario 2, the total energy use will be 52 TWh in year 2030, and the total electricity use 40 TWh. Scenario 3 shows a significant decrease in total energy and electricity use. The total energy use is estimated to be 36 TWh in 2030, and the total use of electricity 29 TWh. No conversion from direct electric heating to other types of heating is assumed in these three scenarios, and all new houses constructed towards year 2030 are assumed to have electric heating. For Scenario 4, the heat pump scenario, the total energy use is estimated to be 46 TWh in 2030 and the corresponding electricity use 39 TWh.

Based on the results from these four scenarios and the profitability of alternative energy efficiency measures, a fifth optimum scenario is defined. This scenario is in many ways similar to Scenario 2, but with a large share of heat pumps, especially in large houses. In the optimum scenario, the total energy use in the stock will reduce from today's 49 TWh to 44 TWh in year 2030, and the total electricity use from 35 TWh to 33 TWh.

The optimum scenario shows that the total energy and electricity in the dwelling stock can be lower in year 2030 than today if the right energy efficiency measures are being carried out. The calculations show that new houses constructed towards year 2030 will represent a significant share of the total energy use in year 2030. It is recommended to tighten the energy related requirements in the Building Regulations to ensure the construction of new energy efficient houses. The Building Regulations can not be used the same way to regulate the thermal performance of existing houses. Instead, a combination of economic instruments, information campaigns and education programmes should be used to influence the existing housing stock.

The growing energy and electricity use in Norwegian households conflicts with the need to reduce overall resource consumption and environmental load. A key task on the way towards sustainable development should therefore be to improve the energy efficiency in the dwelling stock.

1 INTRODUCTION

The phrases “Sustainable Development” and “Sustainability” include social, environmental and economic issues, as well as ethical and value based considerations where equity concerns within and between the generations are fundamental. The concept of sustainable development implies that decision making should based on a long-term perspective, and that we all should contribute to turn the current development into a more sustainable path. The slogan “Think globally, act locally” expresses this responsibility in a simple and elegant way.

The environmental burden connected to the production, transportation and use of energy is one of the most important environmental problems. The total the use of electricity per capita in Norway is the highest in the world, and the total energy use per capita is the third highest (NOU, 1998). The cold climate in Norway and the large share of power based industry are often used as explanations for the high energy use per capita, but the plentiful supply of energy resources (oil and hydro power) and low energy prices have certainly also contributed to reduce the focus on energy efficiency in Norway.

The growth in total energy use in Norwegian households was 1.8 % per year as an average for the period 1976 to 1996. The growth in the use of electricity was even higher due to increasing electric heating in houses. The power production in Norway has up to now been based on hydropower. But the country is now facing a situation where the production capacity of non-pollutive hydropower can not cover the increasing power demand. Power must instead be imported to cover the increasing demand. This imported power is to a large extent produced in coal fired power plants, involving large emissions of CO_2. This is used as a heavy argument for the construction of gas fired power plants in Norway. The reason is that the carbon content per energy unit is lower in gas than in coal. The production of power in gas fired power plants therefore involves less CO_2 emission than in coal fired plants.

But, also gas power involves large CO_2 emissions. In a sustainable context, it thus seems unacceptable that Norwegians, already using more electricity per capita than in any other country, actually wants to increase the use of electricity even more, and on top of it, to cover the increasing demand by CO_2 emitting production. Instead, the goal should have been to stabilise or even reduce the total use of electricity. The potential for making the electricity use more efficient should be obvious.

The scope of the work presented in this report is to analyse the energy use in the Norwegian dwelling stock towards year 2030, and to study how the total energy and electricity use will be affected by alternative energy efficiency measures. By focusing on the development of the future energy and electricity use in the residential sector, this report addresses a key issue on the way towards sustainable development.

2 SUSTAINABLE DEVELOPMENT

This chapter presents the background for the concept of sustainable development. The presentation is short, focusing on core issues.

2.1 Background[1]

An enormous economic growth has taken place in the industrialised world the last century. The growth in total production and consumption has been correspondingly large, causing large environmental problems and depletion of non-renewable resources.

Up to the 1950s, most industrialised countries considered nature as an inexhaustible source for resources that could be used for benefits of humans, and as an unlimited recipient for waste and pollution from human activities. The economy was further considered disconnected from the nature, and there where no economic reasons for managing the bio-physical environment. This basic view, focusing on human needs solely, has been called "Frontier Economics". Local pollution problems were somewhat recognised, and seeked solved by spreading the pollution over larger areas. This was done by extending the discharge pipes and smokestacks, leading waste water further out into the sea, and spreading the air pollution higher up into the atmosphere. As a reaction to the anthropogenic view of "Frontier Economics", a contrary view emerged called "Deep Ecology", focusing on a non-anthropogenic, bio centric view where nature and humans are in harmony, often implying a subordination of humans to nature.

By time, pollution became an important problem in many industrialised countries, and the dominance of "Frontier Economics" was gradually reduced as a result of this. A new basic view emerged in the 1960s called "Environmental Protection", recognising the need for considering environmental aspects and weigh between economy and ecology. In this view, it was focused on control and reductions of discharges and pollutants. Cleaning of flues was considered important, while preventive approaches to reduce the environmental load attained little attention. The amount of pollutants emitted to air and water was significantly reduced, however resulting in large amounts of waste material from the cleaning process needing special treatment. The maybe most important side of "Environmental Protection" was that this view legalised the environment as an economic externalty. Furthermore, the "Command-and-Control" approach was used to limit the pollution level and environmental damage, and optimum pollution levels were determined, predominantly based on short-termed economic judgements.

In many countries, environmental evaluation was carried out for large development projects as a supplement to the economic evaluation. Unfortunately, this environmental evaluation was often carried out late in the process, leading to large costs if changes had to be made for environmental reasons. As a result, the environmental evaluation had limited influence on the projects, as well as the impression arose that it was costly to take environmental considerations, and thus, that environmental considerations conflicted with growth and development.

In the late 60s and early 70s, a series of alarming studies on the global and environmental development had been published. Exponential population growth and availability of food were

[1] This section is mainly based on Colby (1990).

addressed in several of these studies, and especially the debate following the report "Limits to Growth" prepared for the Club of Rome (Meadows et al., 1972) increased the understanding of the need for changes in the global development. Based on computer simulations, the report postulated that the world would run out of non-renewable resources within 100 years, resulting in economic collapse, unemployment, shortage of food and increasing death rates (Hille, 1995).

In 1972, the United Nations Conference on the Human Environment was arranged in Stockholm. This conference, which was the first environmental conference organised by UN, included participants from 113 countries. The conference exposed the conflict between developed and developing countries, where the developed countries focus on environmental aspects and the need for reducing the environmental load, while the developing countries are more concerned about poverty and low efficient resource exploitation. Since the Stockholm conference, this conflict between the developed countries concern for "environment", and the developing countries need for "development", has been present in international collaboration on sustainable development (Mugaas, 1997).

2.2 The World Commission on Environment and Development

The broad concept of sustainable development, where the nature and economy are seen in conjunction, was first used in the report "World Conservation Strategy", prepared by the International Union for the Conservation of Nature (IUCN). The report was supported with funds from the World Wildlife Fund (WWF) and the United Nations Environment Programme (UNEP). The report has been criticised for identifying poor people's behaviour to be one of the main reasons for environmental degradation, without fully recognising that poverty is caused by the prevailing, economic system (Lafferty and Langhelle, 1997).

The concept of Sustainable Development, however, did not emerge on the political agenda until 1987 when the World Commission on Environment and Development (WCED) presented the report "Our Common Future" (WCED, 1987). The commission was established by the United Nations in 1984. The report emphasised the need to see economic, ecological and social aspects in connection, and defined sustainable development as:

> *"[development that] meets the needs of the present generation without compromising the ability of future generations to meet their own needs."*

According to WCED, the three main components in the concept of sustainable development are environment, growth and equity. These three components may further be accomplished at different levels (global/national/regional/local) as shown in Figure 2.1, increasing the complexity of the concept of sustainable development.

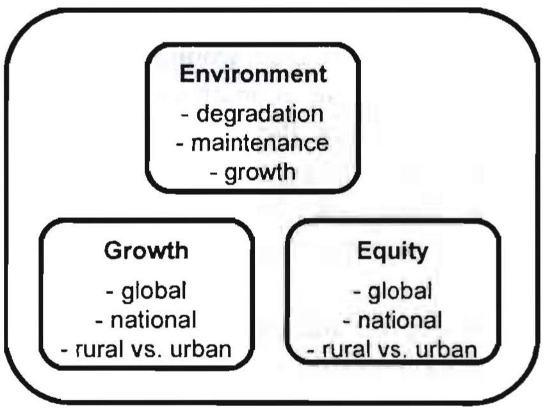

Figure 2.1 Three main components and complexity of sustainable development. (Kirkby et al., 1995).

Two key points underpin WCED's conception of "Sustainable Development" (Kirkby et al, 1995). The first key point is the overriding priority of achieving basic needs for all humankind. The second is the impression that technical, cultural and social factors are the constraints for development, and not environmental as earlier emphasised by the Club of Rome and others.

A vast number of definitions comprising environmental, economic and social aspects have been proposed for the concept of sustainable development since WCED launched their definition in 1987[2]. In most of these definitions, the time and space dimensions of sustainable development are important.

The space dimension addresses how justice and equity can be achieved within the generations (intra-generational equity), and implies a need for a more fair distribution of wealth amongst poor and rich. The WCED report emphasises that covering needs, especially the needs of the poor, has first priority (Lafferty and Langhelle, 1997). Today, property, income and consumption are extremely unequally distributed within the world's population, and these differences are increasing globally (St meld 58, 1997). In 1993 for instance, 85 % of the total income in the world went to the richest 20 % of the population. Consequently, the unequal distribution between developed and developing countries, and between rich and poor, have to be reduced to comply with the space dimension of sustainable development.

The time dimension addresses how justice and equity can be achieved between the generations (inter-generational equity). The time dimension implies that decision making generally should be based on a long-term perspective, where the interests of future generations are taken fully into account.

Figure 2.2 shows that inter-generational and intra-generational justice and equity should be considered both on a national level and on a global level.

		Space dimension	
		National level	Global level
Time dimension	Within the same generation	National justice within the same generation	Global justice within the same generation
	Between the generations	National justice between generations	Global justice between generations

Figure 2.2 Sustainable development in time and space (Lafferty and Langhelle, 1997).

It is generally accepted that meeting the needs of both present and future generations is important for a sustainable development (as stated by WCED). However, when discussing and determining how these needs can be met, there is a conflict and controversy between view points based on weak and strong sustainability. This controversy regards whether human made capital (economy)

[2] See Pearce at al. (1989) for a gallery of definitions.

can substitute natural capital. Human made capital includes human capital (technology, knowledge and state of health), production capital (infrastructure, buildings, machines, means of transport) and consumer capital (durable consumer goods). Natural capital is given by the supply of natural resources and the state of the environment (influenced by the pollution level in ground, water and air).

In weak sustainability, it is accepted that human made capital may substitute natural capital. In strong sustainability, however, such substitution is rejected. A reason for this rejection is that substitution implies a monetary valuation of the environment. At present, there is great controversy associated with monetary valuation of environmental effects, and monetization of the environment is being rejected for ethical, philosophical, political, methodological and technical reasons (Barde and Pearce, 1991). Further, by accepting that capital can substitute the environment, it is also presupposed that future generations will accept this. Moreover, by giving environmental effects a monetary value, these values will automatically be drawn into the economic system where they will be used in cost-benefit analyses being a part of the decision making. The discounting process in such cost-benefit analyses significantly reduces the weight of future costs and benefits, implying that less weight is given future environmental effects.

The concept of sustainable development includes environmental, economic and social issues, as well as fundamental aspects related to intra-generational and inter-generational equity. The variety of aspects that are included in the concept of sustainable development, whereof many are conflicting, and the controversy associated with the evaluation of each of these aspects, makes it a fundamental problem to evaluate whether sustainability is achieved or not in practise.

2.3 Follow up of the WCED report

The work of WCED was followed up by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. This conference was the largest environmental conference ever, and about 30,000 persons attended (Kirkby et al., 1995).

Five documents were signed during the Rio Conference, off which the three first as a direct result of the UNCED process (Mugaas, 1997):

1. The Rio-statement on Environment and development, which is 27 general principles defining the rights and obligations individual countries have in the work to promote development and human behaviour.
2. Agenda 21, which is the main document from the conference, describing in 40 chapters different issues which are important to make the development socially, economic and ecologically sustainable. The document, however, does not prioritise between the different issues.
3. The Forest Principles, which describes principles for the management of forests.
4. The Convention on Biological Diversity, which states that the biological diversity must be managed and harvested in a sustainable way, and that the yield should be distributed in justifiable way.
5. The Climate Convention, which ultimate goal is to stabilise the greenhouse gases on a level that does not harm the global climate in a substantial way.

The content of these documents was rather general and controversy issues were not included. In addition, a shift of focus had taken place. Where the WCED had focused on the need for environmental, social and economic improvements in the developing countries, and the need for closing the gap between the developed and developing nations, the UNCED focused more narrowly on environmental or "green" aspects, without emphasising the need for development in the South. An important reason for this shift of focus was the self-interest of the Northern countries in keeping trade, economy and foreign policy at status quo. Kirkby et al. (1995) states the outcome of Rio as: *"The North turned green, and the South was turned away"*. Consequently, as a follow up and a continuation of the work initiated by the WCED report, the Rio Conference may be said to have failed.

The Commission on Sustainable Development (CSD) was established during the Rio Conference to encourage the follow up of Agenda 21. It was also decided to organise a new conference in 1997 to evaluate the follow up of UNCED and the need for new initiatives. This new conference, Earth Summit +5, was arranged as a UN General Assembly Session in New York. During Earth Summit +5, it turned out impossible to agree on a common political statement, and the conference did not result in a comprehensive final document. Neither in size, nor in political importance, was Earth Summit +5 comparable with the Rio Conference (PROSUS, 1997).

In Norway, having prime minister Gro Harlem Brundtland chairing the World Commission, sustainable development gained large attention and was included in most political agendas. In 1992, the Constitution of the Kingdom of Norway was supplemented with §110b, stating that:

> *"Every person has a right to an environment that is conducive to health and to natural surroundings whose productivity and diversity are preserved. Natural resources should be made use of on the basis of comprehensive long-term considerations whereby this right will be safeguarded for future generations as well. (...)"*

2.4 Local Agenda 21

Agenda 21 was the main document from the Rio Conference. Chapter 28 in Agenda 21 encouraged municipalities to develop a Local Agenda 21 within 1996 in co-operation with local trade and industry, organisations and inhabitants.

In 1992, the same year as the Rio Conference was arranged, the government in Norway had initiated an environmental reform in the municipalities called "Miljøvern i kommunene (MIK)". In many ways, this MIK reform was a "light version" of the Local Agenda 21 process described in Agenda 21 (Agenda21.no, 1999). The government did not want to start LA 21 as a parallel process to the MIK reform, and MIK therefore continued for some years before LA21 was implemented. It therefore took more than three years after the Rio Conference before the first municipality in Norway invited for a Local Agenda 21 process. In 1998, a national conference on LA21 was arranged in Fredrikstad, gathering more than 700 participants from the government, local and regional authorities and organisation. A statement was formulated during this conference, committing the municipalities to follow up the Local Agenda 21work. By January 1999, more than 100 of Norway's 435 municipalities had signed the statement.

2.5 Factor 4 and 10

The concept of Factor 4 was introduced in the report "Factor Four. Doubling wealth, halving resource use" in 1997 (Weizsäcker et al., 1997). This report was prepared for the Club of Rome, the same organisation that stood behind the report "Limits to Growth" in 1972. The background for the Factor 4 concept is the understanding that the material turnovers (resource use) need to be halved on a world-wide basis. At the same time, it is necessary to account for the constantly increasing consumption pattern, caused by increasing purchasing power amongst people. Factor 4 therefore means that by increasing the resource productivity fourfold, it is possible to double the wealth (in terms of consumption) while simultaneously halving the total resource use. The concept of Factor 4 is also relevant with regard to climate change. The recommendations from the International Panel on Climate Change (IPCC) say that the emissions of CO_2 emissions have to be reduced by 60 % to stabilise the concentration of CO_2 in the atmosphere on today's level. The global energy use is very carbon dependent. By assuming that the need for energy related services will double in the future, the efficiency of these services have to be increased fourfold to reach the recommendation of almost halved CO_2 emissions.

The concept of Factor 10 has later been introduced by Friedrich Scmidt-Bleek as a more proactive alternative to Factor 4. The concept of Factor 10 is also based on the conclusion that the resource use should be halved on a world-wide basis. But it also recognises that the per capita consumption is five times higher in the OECD countries than in the developing countries. Further increases in world population are unavoidable, and Scmidt-Bleek postulates that sustainable levels of material flows will not be reached unless the material intensity in the OECD countries is reduced by a factor ten (Weizsäcker et al., 1997). However, while it might be attainable to increase the material productivity fourfold according to the Factor 4 concept within the current socio-economic system, it more a question whether a tenfold increase is feasible without dramatically changes in resource handling. Depositing and waste incineration, for instance, are not in accordance with the Factor 10 concept.

2.6 Sustainable development and the building sector

Buildings are of large environmental, economic and social importance. These aspects are all considered important in the concept of "Sustainable Development". World Watch Institute has estimated that 40 % of the world's materials and energy is used for buildings (Roodman and Lenssen, 1995). For Western Europe, it has been estimated that buildings account for about 50 % of total primary energy use (Baldwin, 1997). In the US, buildings contribute from 12 % to 42 % of the total environmental burden for each of eight major environmental categories (Levin et al., 1997). Securing a healthy indoor environment is further important, especially when considering that people in Northern Europe spend most of their time indoors.

The economic importance of the building sector is immense. More than one-third of the total investments in Norway goes to buildings and constructions, and buildings and constructions represent almost 70 % of the total real capital in Norway (St meld 28, 1998) The operation and management costs further represent a large share of the annual spending for buildings owners. Insufficient management of the built environment may lead to degradation and early obsolescence, representing large economic loss for the individual owner and for the whole society. Improvements and measures to reduce construction costs, as well as running and management costs, may therefore yield enormous savings for the society.

In a sustainable context, economic aspects are not only about economic efficiency, but also about affordability and the possibility for low-income households to get a decent place to live. This aspect, which relates directly to the intra-generational equity principle of sustainable development, is emphasised in for instance the Austin Green Builder Programme (Doxsey, 1997).

Affordability is also important for the social aspects of sustainable development. By increasing the building costs in an area, groups of people are excluded from living and working in this area. Equity concern and social aspects should be included when considering the sustainability of buildings and communities. Many of the sustainable community programmes ongoing in the US, for instance, emphasises local participation, education and crime preventive measures.

2.6.1 "Sustainable Construction"

The concept of "Sustainable Construction" has been introduced for sustainable development efforts in the construction industry. A widely cited definition of sustainable construction originates from the First International Conference on Sustainable Construction in Tampa, USA, 1994, where sustainable construction was defined as (Kibert et al., 1994):

> *"creating and maintaining a healthy built environment based on ecologically sound principles and resource efficiency."*

Figure 2.3 shows a conceptual model for implementing sustainable construction presented in Kibert et al. (1996).

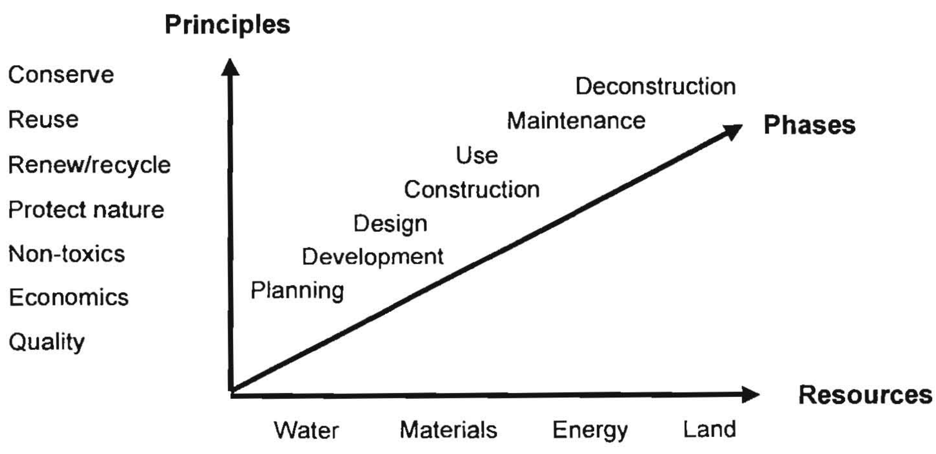

Figure 2.3 A model for implementing sustainable construction (Kibert et al., 1996).

The model is based on four resource categories (land, energy, water and materials) and seven principles for sustainable construction:

1. Minimise resource consumption (Conserve)
2. Maximise resource reuse (Reuse)
3. Use renewable or recyclable resources (Renew/recycle)
4. Protect the natural environment (Protect nature)
5. Eliminate manmade toxics in both the natural and human environments (Non-toxics)
6. Account for environmental costs in all analyses (Economics)
7. Pursue excellent quality in creating the built environment (Quality)

Even though the principles for sustainable construction and the conceptual model focus on "green" and environmental aspects, it is recognised that also economic and social aspects should be included in a sustainable context. Many non-technical, subjective, non-quantitative issues of how people choose to live have to be considered when studying sustainable construction, and a more global approach to sustainable construction has been considered in for example Bourdeau (1997).

The International Council for Research and Innovation in Building and Construction (CIB) has defined Sustainable Construction as a priority theme. CIB is a world wide network of over 5,000 experts from about 500 member organisations. The CIB World Building Congress in 1998 included more than 200 presentations on the theme of Sustainable Construction. CIB has worked out the report "Agenda 21 on Sustainable Construction" in co-operation with other international associations and organisations such as CERF[3], RILEM[4], IEA ECBCS[5] and ISIAQ[6] (Bourdeau (ed.), 1999). The report analyses optimal ways to engage the international collaboration on research and innovation in building and construction.

Several Task Groups (TG) and Working Commissions (W) within CIB focus on themes related to Sustainable Construction. Examples are:

- TG16 "Best Practise for Sustainable Construction" was established in 1994 to present examples on best practise for sustainable construction in an international best practise report. This report is expected end 1999.
- TG22 "Environmental Design Methods in Materials and Structural Engineering" focuses on methods and methodologies for structural design to meet the requirements of sustainable development during the entire life of a structure. The environmental design will be presented as a part of integral structural design, which includes the mechanical, physical, economic, energy, health and environmental aspects.
- TG38 "Urban Sustainability" focuses on the interrelations between the many issues influencing the quality of urban development, and how these issues impact on the whole construction chain and on quality of the urban landscape.
- TG39 "Deconstruction" is a new task group that will focus on the disassembly of the built environment and the reuse and recycling of building components and materials. The task group is the successor of TG16.

3 The Construction Engineering Research Foundation (CERF)
4 The International Union of Testing and Research Laboratories for Materials and Structures (RILEM)
5 The International Energy Agency Implementing Agreement on Energy Conservation in Buildings and Community Systems (IEA ECBCS),
6 The International Society for Indoor quality and Climate (ISIAQ)

- W82 "Future Studies in Construction" presented an international state of the art report titled "Sustainable Development and the Future of Construction" in 1998. This report included national papers about the consequences of sustainable development on the construction industry by the year 2010. W82 has now established a project on developing performance indicators for sustainable built environment.
- W100 "Environmental Assessment of Buildings" was established in 1998 as the successor of the former TG08 "Buildings and the Environment" which functioned from 1994 to 1997. W100 focuses on issues related to the implementation of environmental performance assessment systems for buildings.

Another organisation that has put sustainability on the agenda is the International Energy Agency (IEA). IEA is an independent agency with 24 member countries linked with the Organisation for Economic Co-operation and Development (OECD). In 1993, the IEA ministers adopted a number of shared goals, including a statement that the environmentally sustainable provision and use of energy is central to the achievement of the goals (IEA, 1999).

With regard to the built environment, IEA established a clear focus on sustainable issues by organising the workshop "Towards Sustainable Buildings" in 1998. The aim of this workshop was to define collaborative research and development needs, and fifteen concept papers for high priority activities related to sustainable buildings were outlined during the workshop (Morse, 1998). During the workshop, there was a general understanding amongst the participants that there already exists a lot of energy efficient and environmentally favourable technology. A main challenge in the building sector to contribute towards sustainable development is therefore to make such technology commonly used in the market.

2.6.2 Factor 4 and 10 in the building sector

The possibility of achieving factor 4 and 10 in four different sectors was studied in a recent report to the Nordic Council of Ministers (Nordic Council of Ministers, 1999). The Norwegian building and real estate sector was one of the sectors studied. This study concluded that it is realistic to reduce the environmental impact caused by energy use and material consumption in the building and real estate sector by a factor of 10 within 30 to 50 years, but that it is not realistic or necessary, to reduce the overall energy use in the sector by a factor of 10.

3 The Norwegian dwelling stock

The Norwegian population of 4.3 million people is spread over a total land area of 324,000 square kilometres. The corresponding population density is 13 persons per square kilometre, which is close to 20 times lower than in for instance Germany and United Kingdom (Statistics Norway, 1997). Not only sparsely populated, Norway is also a very long, relatively narrow country. The total distance (direct line) from the south (58°N degree latitude) to the north (71°N) of the country is more than 1,600 kilometres. The majority of the population lives in the southern part of the country where the major cities are found. These cities are Oslo with 500,000 inhabitants, Bergen with 220,000 inhabitants and Trondheim with 140,000 inhabitants. In a European scale, the cities are small, and traffic and space problems are not as prominent as in the larger European cities.

The climate is rather cold in Norway, even though large variations are found between the different parts of the country. The energy required to heat a house in the inland of the Northern Norway is for instance more than twice the energy required to heat a similar house in the coastal area in the south-west of Norway. The largest population concentration is found around the capital Oslo in the south-east of Norway, and the climate in Oslo may be taken to be representative as an average for the entire dwelling stock in Norway (Myhre, 1995). The average temperature in Oslo is 5.9°C on a yearly basis, ranging from -4.7°C as average in January, to 17.3°C in July.

Because of the cold climate, heating represents a large share of the energy use in Norwegian buildings. In 1990, for example, space heating, ventilation and hot water production represented about 75 % of the total energy use in the dwelling stock (Ljones et al, 1992). Cooling is negligible in dwellings, but in commercial buildings, an increasing amount of energy is used for cooling due to large internal heat loads from lighting and electric appliances. A general trend amongst many architects to use large glazed façades in commercial buildings has also contributed to increase the need for cooling during sunny days (Aftenposten, 1999).

3.1 Number of dwellings

The statistical information about the total dwelling stock in Norway is rather limited. The GAB-register organised by Norwegian Mapping Authority (Statens kartverk) provides information about the total number of buildings in Norway. For buildings constructed after 1982, the register contains some information about e.g. the type of building, the size and the main construction material.

Table 3.1 shows the total number of buildings in Norway according to the information in the GAB-register. Totally, there were 3.35 million buildings 1 February 1999, whereof 1.32 million residential buildings and 2.03 million non-residential buildings. A total number of 343,000 leisure buildings (huts, cabins etc.) is included in the group of "other buildings" amongst the non-residential buildings.

Table 3.1 Total number of buildings in Norway per 1 February 1999 according to the GAB-register, by type of building.

Type of building	Number	Share
Residential buildings		
Detached one-family houses	1,020,980	77 %
Vert. divided two-family houses	57,369	4 %
Row houses and terraced houses	76,915	6 %
Horiz. divided houses with less than 5 dwellings	103,596	8 %
Block of flats	18,726	1 %
Other house types	42,221	3 %
Total	1,319,807	100 %
Non-residential buildings		
Buildings for agriculture, forestry and fishing	488,184	24 %
Production buildings for minery and industry	41,132	2 %
Offices, commercial buildings etc.	820,703	40 %
Hotels and restaurants	24,024	1 %
Education and research	13,970	1 %
Buildings for health care	8,986	0 %
Meeting halls	14,958	1 %
Other buildings 1)	619,723	31 %
Total	2,031,680	100 %
Total	3,351,487	

1) Including 343,366 leisure buildings (huts, cabins etc.)

The GAB-register does not provide information about the number of dwellings found in the buildings[7]. Instead, such information has to be based on estimates from sample surveys and other sources.

Table 3.2 shows the estimated number of dwelling units the last decades according to three different sources. The first source is the surveys of housing conditions regularly conducted by Statistics Norway. Based on these surveys, the total number of registered dwelling units[8] is estimated to have increased from 1.24 million in 1967, to 1.85 million in 1995. The second source is the population and housing censuses conducted by Statistics Norway every tenth year. According to these censuses, the estimated number of registered dwellings increased from 1.08 million in 1960, to 1.75 million in 1990. The third source is a long-term simulation model of the Norwegian housing market developed by the University of Oslo, Department of Economics, and the Norwegian Building Research Institute (Rødseth et. al., 1997). According to this model, BUMOD, the total number of dwelling units increased from 1.65 million in 1981, to 1.94 million in 1998. The BUMOD estimates include unregistered dwellings, and are therefore a little higher than the two other sources.

[7] It has been proposed to establish a register with information about dwellings and households in Norway by connecting the information in the GAB-register with the information in the National Register.

[8] A dwelling is only registered if a person has the place of residence registered on the same address.

Table 3.2 Estimated number of households and dwellings in Norway according to three sources.

Year	Surveys of housing condition	Population and housing census	BUMOD *
1960	-	1.08	-
1967	1.24	-	-
1970	-	1.30	-
1973	1.38	-	-
1980	-	1.52	-
1981	1.52	-	1.65
1988	1.65	-	1.81
1990	-	1.75	1.85
1995	1.85	-	1.90
1998	-	-	1.94

* BUMOD is a long-term simulation model of the Norwegian housing market (Rødseth et. al, 1997).

Figure 3.1 figure shows that a varying number of new dwellings has been completed in Norway each year between 1951 and 1998. The construction of new dwellings reached a bottom in 1993 with only 15,900 completed dwellings, as compared to more than 40,000 dwellings per year during the mid-70s. The number of new dwellings has been slowly increasing since 1993, reaching more than 20,000 units in 1998.

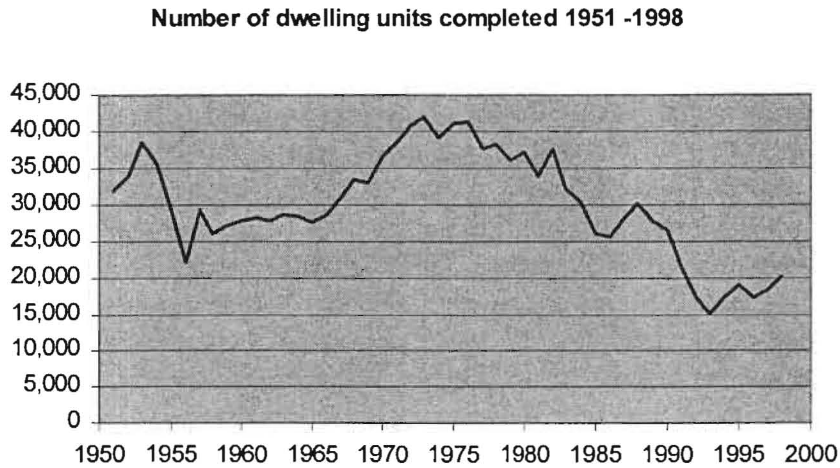

Figure 3.1 Number of dwelling units in buildings completed between 1951 to 1998. Source: Statistics Norway.

The recession during the end of the 1980s and beginning of the 1990s influenced the average size of the dwellings completed as seen from Figure 3.2. The average size of dwellings in detached houses fell from more than 210 m^2 in 1988, to less than 170 m^2 in 1993. The share of dwellings in detached houses also fell; from 60 % in 1985, to close to 30 % in 1991. Dwellings in detached houses are normally much larger than dwellings in other types of houses. The reduced share of dwellings in detached houses therefore significantly contributed to reduce the average size of all dwellings from 166 m^2 in 1985, to 116 m^2 in 1991.

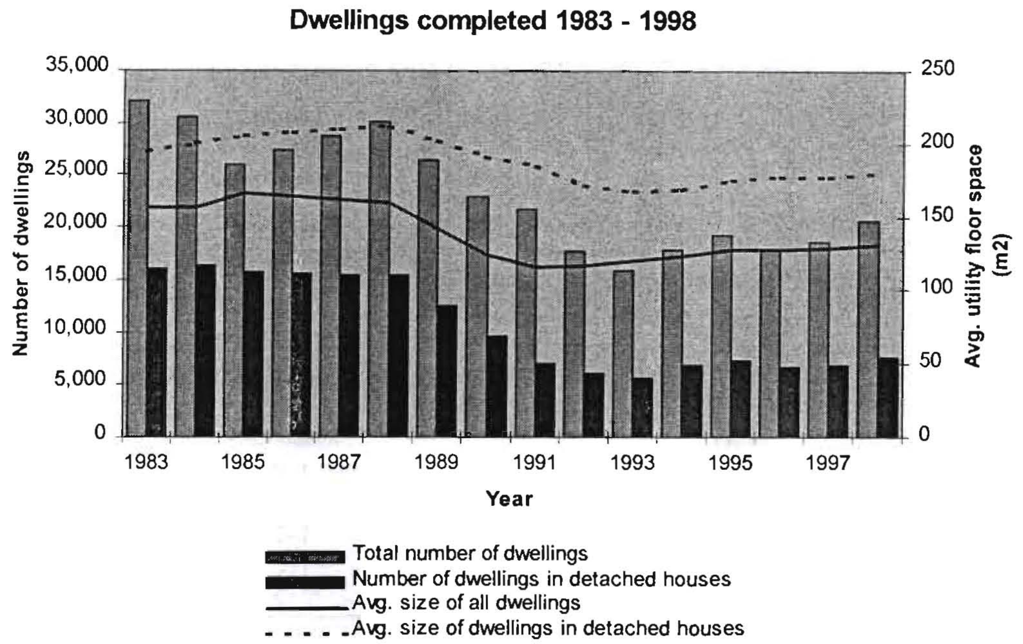

Figure 3.2 Dwellings completed between 1983 and 1998. Total number of dwellings, total number of dwellings in detached houses, average size (utility floor space) of all dwellings and average size of dwellings in detached houses. Based on information from Statistics Norway (1999).

Due to the departure of existing dwellings, the net increase in the number of dwellings in the dwelling stock is lower than the number of dwellings completed each year. Existing dwellings depart because of demolishing, fire or accidents. Two dwelling units may also be merged into one larger unit, resulting in a loss of one dwelling unit. Dwellings may further be left empty in the sparsely populated areas when people leave to more densely populated areas. Since dwellings are only registered when persons are registered at the address, these empty dwellings are ignored in the statistics.

According to the population and housing censuses conducted by Statistics Norway in 1960, 1970, 1980 and 1990, the total departure of dwellings was just below 9,000 units per year in average between 1960 and 1970, increasing to almost 15,000 units per year between 1970 and 1980. The departure of dwellings decreased again between 1980 and 1990, to an average of less than 7,000 units per year. The average departure of dwellings was about 10,000 units per year for the whole period from 1960 to 1990.

Population growth contributes to increase the need for new dwellings. The population growth has in average been close to 20,000 person per year the last two decades. A significant shift towards smaller households (fewer persons per household) has also strongly contributed to increase the need for new dwellings[9]. A presentation of factors that have influenced the need for dwellings is given in Appendix 1. Table 3.3 shows that the average household size went down from 3.1 persons per household in 1967 to 2.3 persons in 1995. Smaller families and more people living in single households can explain the reduction. In addition, the share of elderly is increasing, and most elderly live in one or two person households. It may be worth noting that a reduction in average household size has been a general trend in other Nordic countries as well, however not as significant as in Norway (Euromonitor, 1995).

Table 3.3 Population in Norway in 1967, 1973, 1981, 1988 and 1995. Total number of dwellings and average floor space per dwelling from household censuses conducted by Statistics Norway. Estimated total floor space and average floor space per capita.

Year	Population	Number of dwellings	Average size of dwellings	Total floor space	Average floor space per capita
	Million	Million	m^2	Million m^2	m^2
1967	3.79	1.23	89	110	29
1973	3.96	1.38	89	123	31
1981	4.10	1.52	98	149	36
1988	4.21	1.65	108	178	42
1995	4.36	1.89	112	212	49

Simultaneously as the average household size declined, the average floor space went up from 89 m^2 to 112 m^2. The average floor space per capita consequently increased from 29 m^2 in 1967 to 49 m^2 in 1995. This increase of almost 70 % is alarming from a sustainable point of view since it may be assumed to have counterbalanced the effect of all energy and resource efficiency measures carried out in the dwelling stock during the same period.

3.2 Energy use

The total, gross floor space in the Norwegian building stock has been estimated as 320 million m^2 in 1998 by the Norwegian Water Resources and Energy Directorate (NVE), whereof 204 million m^2 (65 %) in dwellings and 114 million m^2 (34 %) in non-residential buildings (NVE, 1999). The total energy use in the building stock the same year was estimated as 76 TWh, which is about one-third of the total energy use in Norway. Table 3.4 shows that 44 TWh (58 %) is used in dwellings and 33 TWh (42 %) in non-residential buildings. NVE has also estimated that heating of dwellings represented about 27 TWh in 1998, whereof 19 TWh electric heating (NVE, 1999).

9 Appendix 1 shows that decreasing household size in fact has been a stronger factor for the increasing number of dwellings than increasing population.

Table 3.4 Estimated total energy use and total floor space in the building stock in 1998, with corresponding specific energy use as kWh/m² (NVE, 1999).

Type of building	Total energy use		Estimated (gross) floor space		Specific energy use
	TWh	%	mill. m²	%	kWh/m²
Dwellings	**44**	**58**	**206**	**64**	**214**
Detached houses	33	43	141	44	234
Row houses	7	9	40	13	175
Block of flats	4	5	25	8	160
Non-residential buildings	**32**	**42**	**114**	**36**	**281**
Offices, commercial buildings etc.	16	21	56	18	286
Education and research	5	7	19	6	263
Buildings for health care	4	5	8	3	500
Industry buildings	7	9	31	10	226
Total	**76**	**100**	**320**	**100**	**238**

In addition to the 76 TWh annually used to operate buildings, about 5 TWh are used to produce building materials, and 3 TWh are used for transportation of materials and construction (Søgnen et al., 1998). About 84 TWh may therefore in total be ascribed buildings.

The evolution of the total energy use and floor space in the building stock from 1950 to 1990 have been analysed in Bartlett (1993). Figure 3.3 shows that the total energy use is estimated to have increased from less than 40 TWh in 1970, to close to 70 TWh in 1990. This increase was covered by more use of electricity, while the consumption of fuel oil and bio energy decreased. The figure also shows the development of total heated floor space in the building stock. It can be seen that the increase in total energy use has been proportional with the increase in floor space. This indicates that increasing floor space has been a very important reason for the increasing energy use in the building stock.

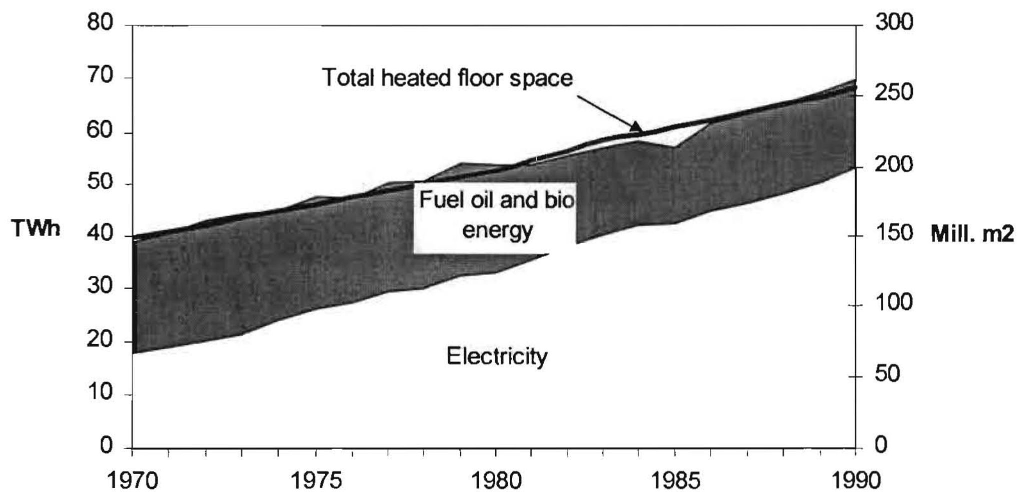

Figure 3.3 Development in total, climate corrected energy use in the building stock from 1970 to 1990 by type of energy (electricity, and fuel oil and bio energy), with corresponding development in total heated floor space in buildings (Bartlett, 1993).

Statistics Norway has estimated that the total, heated floor space in the entire building stock increased from 149 million m^2 in 1970, to 257 million m^2 in 1990 (Bartlett, 1993). During the same period, the total energy use in the stock is estimated to have increased from 39 TWh to 70 TWh, and the electricity use from 18 TWh to 53 TWh. Figure 3.4 shows the calculated, average energy and electricity use per square metre in the building stock based on these estimates from Statistics Norway. The figure shows that the specific energy use (kWh/m^2) was rather constant during the period[10]. This is rather surprising since the thermal insulation level of new buildings has been steadily improving due to tightened requirements in the building regulations, and various energy efficiency measures have been carried out in a large number of the existing buildings. A reduction in the specific energy use should therefore be expected.

Increasing comfort demands is probably one important reason for why the specific energy use has not improved. The space heating demand increases by approximately 5 % per degree Celsius the indoor temperature is changed during the heating season. It is likely to believe that the average indoor temperature has been raised for comfort reasons, and that more rooms in the buildings have been kept fully heated. For non-residential buildings, increased ventilation rates can furthermore be expected to have contributed increase the total energy use.

Finally, more electric appliances have most likely contributed to the increased energy use. Electric appliances like dishwashers, tumble dryers and PCs are today commonly found in dwellings, as well as many electric devices (TV, stereo, video players, telephones) with an energy consuming stand-by function. When there is no need for space heating in the building, which is a large part of the year, the heat load from all these electric appliances is not utilised for space heating useful purpose, but only contributes to increase the overall energy use.

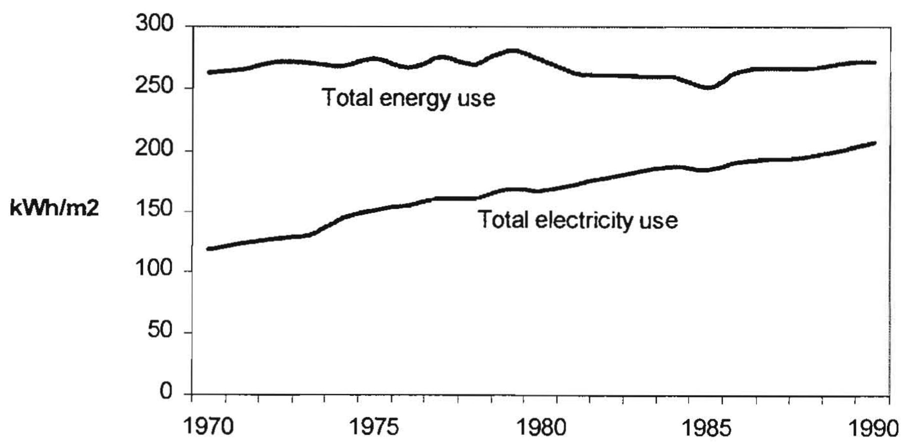

Figure 3.4 Development of specific energy and electricity use (kWh/m^2) in the building stock from 1970 to 1990. Based on Bartlett (1993).

Figure 3.4 also shows that the use of electricity increased very strongly from 1970 to 1990, and today, the use of electricity is exceptionally high in Norwegian buildings. In 1996, about 58 TWh

[10] When studying the underlying data, a slight improvement in specific energy use is found for the dwelling stock.

of electricity were used in buildings, corresponding to 50 % of the total electricity production in Norway in a standard year (Søgnen et al., 1998). Electric heating alone represented 29 TWh, which is close to 70 % of the total heating demand in the building stock. Furthermore, 29 TWh is close to 25 % of the annual production of electricity in Norway.

The price of electricity has been low in Norway due to good supply of hydro electric power. For many years, the price was even lower than for fuel oil. Since direct electric heating involves very low installation costs, easy operation and control, and almost no need for maintenance, it has been preferred when constructing or renovating buildings. Today, however, Norway is facing a situation where the production of "clean" and cheap hydropower can not meet the increasing demand for electricity. Instead, electricity must be produced in gas-fired power plants, or imported as coal or nuclear power. The price of electricity is expected to increase in the future because of increased environmental taxes, and there is a strong need to reduce the electricity demand in buildings by installing central heating systems that can utilise other energy sources than electricity. Such systems include radiator and floor-heating systems.

To significantly influence the total electricity demand in the building stock, it is not sufficient to install central heating systems in new buildings. It is also necessary to convert from direct electric heating to non-electric heating in existing buildings. These types of conversions are very expensive, and therefore not likely to carried out at large scale without a significant reduction in the installation costs, increase in the price on electricity, or massive subsidies from the Government.

3.3 Type of construction

Most large buildings are constructed using concrete or brick as main construction material, while wood is dominating as the main construction material in smaller buildings. Surveys conducted by Statistics Norway, for example, show that more than 90 % of all detached and divided small houses in Norway have wood as main construction material (Statistics Norway, 1983).

Light timber framed constructions with mineral wool have been dominating from around 1955 onwards. Initially, 100 mm studs were used in the walls. In the early 1980s, there was a shift towards 150 mm studs and 150 mm thermal insulation. Increasing oil prices and tightening of the Building Regulations drove this shift. The thermal insulation level of floors and roofs was also improved during the same period. New Building Regulations were enforced 1 July 1997, involving tightened requirements for the energy demand for space heating and ventilation of new buildings. The regulations may therefore be expected to have contributed to a new shift in the thermal insulation level.

3.4 Type of ownership

Most buildings in the residential sector in Norway are privately owned. In total, privately owned detached houses and divided small houses represent 57 % of the total floor area in the Norwegian building stock (Søgnen et al., 1998). It may therefore be difficult to realise the total potential for environmental improvements in the building sector since a huge number of owners have to be persuaded to carry out improvements.

4 DWELLING STOCK MODEL FOR TOTAL ENERGY USE TOWARDS 2030

This chapter presents a dwelling stock model that is developed to estimate the total energy use for operation in the entire dwelling stock in Norway towards year 2030. The model is based on a stereotype of house approach, where a number of carefully defined stereotypes of houses are taken to be representative for the entire stock. The total energy use in the stock is estimated by calculating the specific energy use (kWh per square metre) of each stereotype of house, aggregating with the total floor space in the group of dwellings each stereotype is representative for.

For simplicity reasons, the model addresses the energy use for operation (space heating and ventilation, domestic hot water production, lighting and household electricity). The energy use required to for instance produce the building materials, construct the houses and deconstruct them at the end of the service life, is not included. The operation phase represents around 80 to 90 % of the total energy use during a buildings life cycle according to Fossdal (1995), Winther (1997), and Adalberth (1999). The construction phase, including production and transportation of building materials, represents 10 % – 15 %, while the deconstruction phase only represents a few percent of the total energy use. The dominating share of the total energy use during a building's life cycle is therefore connected to the operation phase. The model further enables calculations of the energy savings obtained for various energy efficiency measures. The amount of energy used to produce energy efficiency measures, such as additional thermal wall insulation and high-insulating windows, has been shown by Myhre (1995) and Fossdal (1996) to be small as compared to the total energy savings obtained by the measure.

By focusing on the energy use for operation, the dwelling stock model covers the dominating share of the energy use connected to the dwelling stock. To include the production and removal phases based on a life cycle perspective, would not influence the calculated total energy savings obtained for the alternative energy efficiency measures.

4.1 Dwelling stock model per December 1998.

An estimation model for total energy and electricity use in the dwelling stock is presented in the following. The model is based on a similar model developed for the dwelling stock in 1990 (Myhre, 1995). In this model, the dwelling stock per 1990 was divided into twelve groups according to type of house (detached houses, divided small houses and large houses), and year of construction (before 1956, 1956 - 1970, 1971 - 1980, and 1981 - 1990). A stereotype of house was defined for each group, assumed to be representative for all the dwellings within the group. Climate data (monthly mean value) for a standard year for Oslo, taken to be representative as average for entire dwelling stock in Norway, was used to estimate the energy use of the stereotypes of houses. The total energy use in the stock was calculated by multiplying the calculated specific energy use of the stereotypes (kWh/m^2) with the total floor space each house was representative for.

The dwelling stock model per 1990 is updated to 1998 level by defining new stereotypes of houses for the dwellings constructed between 1991 and 1998. The definition of these new stereotypes of houses is described in Appendix 2. A detailed description of all the stereotypes of houses in the dwelling stock model is also given in Appendix 3.

4.1.1 Calculated energy use in the dwelling stock per 31 December 1998

Table 4.1 shows the estimated, annual energy use per dwelling and per square metre of the fifteen stereotypes of houses, as well as the aggregated annual energy use per 1998 in the stock. The total energy use is calculated as 48.5 TWh, whereof 33.1 TWh in detached houses, 9.2 TWh in divided small houses and 6.2 TWh in large houses.

In numbers, detached houses is estimated to represent 57 % of all dwellings in Norway, divided small houses 23 % and large houses 20 %. Dwellings in detached houses are generally larger and have a slightly higher specific energy use (kWh per square metre) than dwellings in divided small houses and large houses. The importance of detached houses therefore increase when considering total floor space and energy use. Table 4.1 shows that 67 % of the total floor space and 68 % of the total energy use are connected to detached houses. Consequently, energy efficiency measures have to be directed towards detached houses to significantly influence the overall energy use in the dwelling stock.

Table 4.1 Dwelling stock model per 31 December 1998. Number of dwelling units, size of dwellings and total floor space. Calculated annual energy use per dwelling and per square metre, and aggregated annual energy use for the entire dwelling stock.

Sub-group	Dwelling units		Average size of dwellings[1]	Total floor space[1]		Calculated energy use		Aggregated energy use	
	1,000		m^2	Mill. m^2		kWh/ dwelling	kWh/m^2	TWh	
Detached houses	**1,076**	**57%**	**130**	**140**	**67%**	**30,801**	**236**	**33.1**	**68%**
Before 1956	375	20%	124	46	22%	37,037	299	13.9	29%
1956 – 1970	231	12%	121	28	13%	30,008	248	6.9	14%
1971 – 1980	215	11%	137	29	14%	30,297	222	6.5	13%
1981 – 1990	184	10%	136	25	12%	22,727	167	4.2	9%
1991 – 1998	72	4%	161	12	5%	23,050	143	1.7	3%
Div. small houses	**431**	**23%**	**99**	**43**	**20%**	**21,257**	**214**	**9.2**	**19%**
Before 1956	118	6%	94	11	5%	26,568	281	3.1	6%
1956 – 1970	92	5%	103	10	5%	22,694	220	2.1	4%
1971 – 1980	87	5%	103	9	4%	20,289	196	1.8	4%
1981 – 1990	78	4%	103	8	4%	16,865	163	1.3	3%
1991 – 1998	56	3%	91	5	2%	15,231	168	0.8	2%
Large houses	**370**	**20%**	**74**	**28**	**13%**	**16,805**	**226**	**6.2**	**13%**
Before 1956	138	7%	75	10	5%	22,013	294	3.0	6%
1956 – 1970	105	6%	68	7	3%	14,071	207	1.5	3%
1971 – 1980	72	4%	79	6	3%	14,444	183	1.0	2%
1981 – 1990	32	2%	78	2	1%	12,641	162	0.4	1%
1991 – 1998	22	1%	81	2	1%	10,954	136	0.2	1%
Total stock	**1,877**	**100%**	**112**	**211**	**100%**	**25,851**	**230**	**48.5**	**100%**

1 Heated floor space for dwellings constructed before 1991. Utility floor space for dwellings constructed between 1991 and 1998.

It should be noted that the average size of the dwellings constructed before 1991 is based on information about heated floor space (space heated above 15°C), while utility floor space is used for houses constructed between 1991 and 1998. For many old, poorly insulated houses, parts of the building are not heated. The heated floor space can therefore be significantly smaller than the utility floor space in these buildings. For modern, well-insulated buildings, however, heated floor space can be considered to correspond with utility floor space.

4.1.2 Discussion of the accuracy of the dwelling stock model per 1998

No exact data are available with regard to the number of dwelling units, the total floor space and the total energy use in the dwelling stock in Norway. It is therefore difficult to evaluate the accuracy of the dwelling stock model presented in this report. The model estimates the annual energy use as 48.5 TWh (see Table 4.1). In comparison, the Norwegian Water Resources and Energy Directorate (NVE) has estimated the total, climate corrected energy use in dwellings in 1998 to be 44 TWh (NVE, 1999), while NOU (1998) states the total, stationary energy use in private households as 47.4 TWh in 1996.

In Table 4.2, the results from the dwelling stock model are compared to the NVE estimates. The estimate of 48.5 TWh from the model is based on 15 stereotypes of houses, collectively taken to be representative for 1.88 million dwelling units having a total heated floor space of 211 million square metres. The NVE estimate of 44 TWh, in contrast, is stated to correspond to a total gross floor space of 206 million square metres. Total gross floor space includes external walls and unheated space, which is not included in heated floor space. The heated floor space used in the dwelling stock model should therefore be smaller than the gross floor space used by NVE. The larger floor space used in the model may therefore be one reason for the estimated higher energy use.

Table 4.2 Comparison of estimated total floor space, annual energy use for heating (space heating and hot water production), and total energy use in the dwelling stock by type of houses.

Type of building	Dwelling stock model per 1998			NVE, 1998		
	Heated floor space	Heating	Total energy use	Gross floor space	Heating	Total energy use
	Mill. m^2	TWh	TWh	Mill. m^2	TWh	TWh
Detached houses	140	26	33	141	-	33
Div. small houses	43	7	9	40	-	7
Large houses	28	5	6	25	-	4
Total stock	211	38	49	206	27	44

Another reason might be that the model over-estimates the energy use for heating (space heating and hot water production). According to the model, the annual energy use for heating is 38 TWh, or 78 % of the total energy use. NVE, in contrast, states the total energy use for heating as 27 TWh (61 % of total energy use). This, however, seems to be a too low estimate.

The model estimates the total use of electricity as 34.7 TWh. The actual use of electricity in private households was 35.2 TWh in 1996 and 33.9 TWh in 1997 according to Statistics Norway (not climate corrected). The lower use in 1997 was to a large extent caused by increasing prices of electric power for households that year due to low production of hydro electric power (dry year with little rainfall).

The scope of the dwelling stock model is to estimate the overall energy use in the dwelling stock and indicate how and where the energy is used. The 48.5 TWh of the model is only 2.3 % higher than the 47.4 TWh stated in NOU (1998), and 10 % higher than the NVE estimate of 44 TWh. The estimated total use of electric power corresponds well with the data from SSB. Taking into account that the NVE estimates might be a little low, the accuracy of the dwelling stock model per December 1998 may be said to be acceptable.

4.2 Description of the dwelling stock model towards year 2030

Many factors influence the total energy use in the dwelling stock towards year 2030, such as the total volume of the stock, the energy performance of the dwellings and the user habits of the occupants. A clear distinction must be drawn between the dwellings already constructed (the existing stock), and the dwellings that will be constructed towards year 2030. We know fairly well the total number of dwellings today and the corresponding energy performance of these dwellings, while large uncertainties are involved in the prognostication of the total energy use in the future stock.

The development of the dwelling stock is closely linked to the general development in the society, and many social, political, economic and environmental issues will in practise influence the number of dwellings constructed and the thermal performance of these dwellings. Some factors influencing the total energy use in the dwelling stock may be predicted with a relatively high degree of certainty, such as the population growth and the general development towards smaller households (NOU, 1998). The prediction of other important factors, such as type of heating, thermal insulation level of the houses and behaviour of the occupants, are more uncertain.

In the following, the total energy use in the dwelling stock is expressed as the total floor space in the stock multiplied with the average energy intensity (energy use per square metre) of the dwellings:

$$Q_{tot\ i} = A_{tot\ i} \cdot q_{avg\ i} = a_{avg\ i} \cdot n_{tot\ i} \cdot q_{avg\ i}$$

where:

$Q_{tot\ i}$ = total energy use in the stock in year i,
$A_{tot\ i}$ = total floor space in the stock in year i,
$q_{avg\ i}$ = average energy intensity in the stock in year i,
$a_{avg\ i}$ = average size of dwellings in year i,
$n_{tot\ i}$ = total number of dwellings in year i.

Four scenarios will be applied when using the dwelling stock model to estimate the total energy use in the dwelling stock towards 2030. These scenarios include alternative developments in the average energy intensity of the dwellings ($q_{avg\ i}$), while the development in total floor space in the stock ($A_{tot\ i}$) is assumed to be the same for all four scenarios.

4.2.1 Total floor space in the dwelling stock towards 2030

The population growth and the general development towards smaller households can be predicted with a relatively high degree of certainty (NOU, 1998). The total number of dwellings (i.e. households) in the future can therefore also be predicted with a relatively high degree of certainty. The development of the average dwelling size is more uncertain. Table 3.3 showed that the average size steadily increased from 89 m² in 1967, to 112 m² in 1995[11], despite the fact that the average household size went down during this period. The construction of new large dwellings and the extension of existing dwellings have probably been main reasons for the increasing average dwelling size. In addition, the merging of two smaller apartments into one larger unit in blocks of flats and the conversion of horizontally divided two-family houses into single family houses have contributed to increase the average dwelling size.

The increasing dwelling size is a consequence of our prosperous society, where people tend to prefer more space if they can afford it. All prognoses indicate that Norwegians will increase their purchasing power in the future. The average size of dwellings will therefore probably continue to increase in the future, even though the increase will be somewhat dampened by the trend towards smaller households, more elderly living alone and pressure on urban areas with lack of space.

Statistics Norway has prognosticated the population size towards 2050 for three different scenarios (Low, Medium and High) as seen from Figure 4.1. For the medium scenario, the population growth is expected to decline and the population to stabilise close to 5.1 million people from year 2040 onwards.

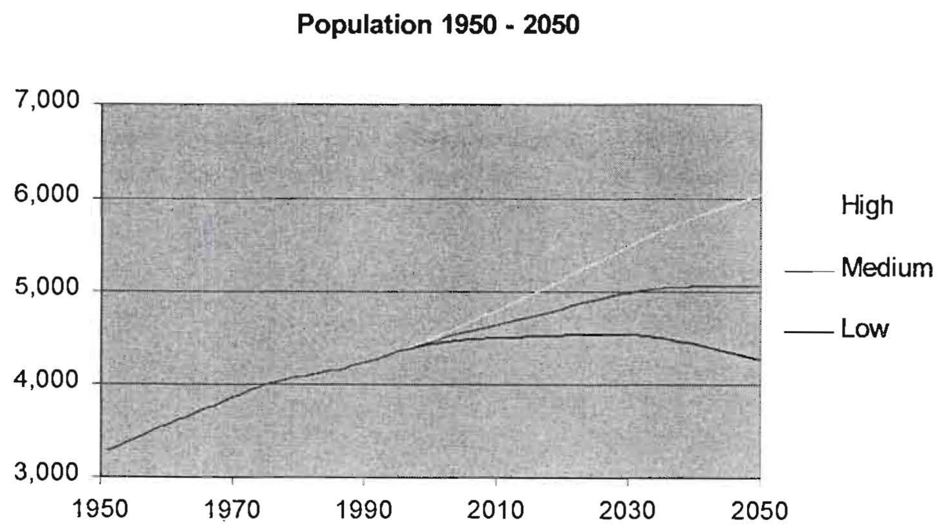

Figure 4.1 Registered population in Norway 1 January 1951 - 1999, and prognosticated population 1 January 2000 - 2050. Source: Statistics Norway.

[11] The average size of dwellings (boligareal) was as high as 122 m² in 1997 according to the Survey of Living Conditions 1997. The questions about dwelling size were however formulated differently in this survey than in previous surveys conducted by Statistics Norway. The respondents may have misunderstood the questions, and it is therefore a question whether the estimated average dwelling size from Survey of Living Conditions 1997 is comparable with the estimates from the previous surveys conducted by Statistics Norway.

Statistics Norway (SSB) has developed a combined macro-micro model for the simulation of households and family dynamics. The model does not consider the type of building or dwelling the households are located into. In Keilman and Brunborg (1995), the SSB-model has been used to estimate the total number of households towards year 2020 for three different scenarios. Table 4.3 shows that the total number of household is prognosticated to be between 2.37 million and 2.62 million in year 2020, with a basic (medium) estimate of 2.50 million households.

The BUMOD model has been used to prognosticate the number of dwelling units towards year 2015. BUMOD is a long-term simulation model of the Norwegian housing market developed by the University of Oslo, Department of Economics, and the Norwegian Building Research Institute (Rødseth et. al., 1997). Based on information about for example the predicted demographic and economic development, and the number of dwellings departing the stock, the model estimates the development in future prices of dwellings and the net increase in the total number of households. The departure of dwellings is estimated to be 7,000 units per year towards 2015 in the model. BUMOD classifies the number of households by the following types of building and number of rooms (kitchen and bathroom excluded):

B.1: Large house, 1-2 rooms
B.3: Large house, 3 rooms
B.5: Large house, 4 rooms or more
B.7: Small house, 1-2 rooms
B.9: Small house, 3-4 rooms,
B.11: Small house, 5 rooms or more

Table 4.3 shows that the total number of households is estimated to increase from 1.845 million in 1990 to 2.139 million in year 2015. The estimated number of dwellings based on BUMOD is a little lower than the estimated number of households in the basic scenario of the SSB model. One reason for this is that the SSB model accounts a larger number of unregistered households than the number of unregistered dwellings accounted in BUMOD. This may also be the reason for why a stronger growth is expected in the number of households towards 2015 (SSB model), than in the number of dwelling units (BUMOD).

Table 4.3 Prognosticated number of households and dwelling units from 1990 to 2020 for two different models; SSB model (Keilman and Brunborg, 1995) and BUMOD (Rødseth et. al., 1997).

Year	SSB-model (1,000 households)			BUMOD (1,000 dwelling units)						
	Low	Basic	High	B.1	B.3	B.5	B.7	B.9	B.11	Total
1990		1,923		171	132	80	226	650	586	1,845
1995		1,995		173	136	83	230	649	630	1,900
2000	2,072	2,093	2,113	173	142	87	228	648	681	1,958
2005	2,143	2,185	2,224	171	147	90	223	643	742	2,015
2010	2,215	2,281	2,343	167	150	92	219	636	810	2,073
2015	2,293	2,387	2,478	162	152	93	215	630	886	2,139
2020	2,367	2,495	2,623	-	-	-	-	-	-	-
1990-2015		+ 464		- 9	+ 20	+ 13	- 9	- 20	+ 300	+ 294

When studying the underlying data, it is striking to see that the number of one-person households is expected to grow strongly in the SSB estimates; from 0.740 million units in 1990, to between 1.037 and 1.369 million in 2020. The average household size is further expected to be as low as 1.9 persons per household in year 2020. The BUMOD estimates shows that there will be a strong increase in the number of dwelling units within the B.11 group, which is small houses with five rooms or more. The smallest dwelling types (B.1 and B.7) are expected to reduce in numbers. The SSB-prognoses of reduced, average households size together with the BUMOD estimates of increased number of rooms in the dwellings (thus larger dwellings), indicate a strong increase in the average space per person in the dwelling stock in the future.

To enable prognostication of the energy use in the dwelling stock towards 2030, stereotypes of houses are defined for the detached houses, divided small houses and large houses that will be constructed towards 2030. For detached houses, three different types of houses are defined, and the calculated average energy use per dwelling used in the model:

A. Detached house in 1 ½ storey with one dwelling unit, representing 25 % of all dwelling units in detached houses. Total utility floor space of 142 m^2.
B. Detached house in 2 ½ storeys with one dwelling unit, representing 25 % of all dwelling units in detached houses. Total utility floor space of 236 m^2.
C. Detached house in 2 ½ storeys with two dwelling units, representing 50 % of all dwelling units in detached houses. Total utility floor space of 236 m^2 (118 m^2 per dwelling).

This division indicates that every third detached house constructed in the future will include a supplementary dwelling like for instance a basement flat.

For divided small houses, a two-storey row house including four dwelling units is defined as stereotype. The total utility floor space of each dwelling is assumed to be 94 m^2.

For large houses, a four-storey block of flats including 16 dwelling units is defined as stereotype. Each dwelling is assumed to be 79 m^2.

Many of today's dwellings will depart the stock towards year 2030 because of demolition, vacation, merging, fire etc. A great number of today's dwellings will further be extended. The existing dwellings will consequently be reduced in numbers due to departure, while the average size will increase due to extensions. Table 4.4 shows the estimated annual departure and extensions of existing dwellings, and the estimated number of new dwellings being constructed towards year 2030.

Table 4.4 Input data for the dwelling stock model. Annual percentage of dwellings departing the stock and corresponding floor space and number of dwelling units (reference year 1998). Annual share of dwellings being extended and corresponding floor space (reference year 1998). Annual construction of new dwellings in number of units and corresponding share of the existing stock per 1998.

Sub-group	Departure			Extensions		New construction	
	%	Mill m^2	Units	%	Mill m^2	Units	%
Detached houses	**-0.25%**	**-0.35**	**-2,804**	**0.30%**	**0.42**	**11,000**	**1.0%**
Before 1956	-0.40%	-0.19	-1,499	0.30%	0.14		
1956 – 1970	-0.30%	-0.08	-692	0.30%	0.08		
1971 – 1980	-0.20%	-0.06	-429	0.30%	0.09		
1981 – 1990	-0.10%	-0.03	-184	0.30%	0.08		
1991 – 1998				0.30%	0.03		
1999 – 2030						11,000	
Div. small houses	**-0.23%**	**-0.10**	**-1,001**	**0.30%**	**0.13**	**6,000**	**1.4%**
Before 1956	-0.40%	-0.04	-472	0.30%	0.03		
1956 – 1970	-0.30%	-0.03	-277	0.30%	0.03		
1971 – 1980	-0.20%	-0.02	-174	0.30%	0.03		
1981 – 1990	-0.10%	-0.01	-78	0.30%	0.02		
1991 – 1998				0.30%	0.02		
1999 – 2030						6,000	
Large houses	**-0.28%**	**-0.08**	**-1,046**			**3,000**	**0.8%**
Before 1956	-0.40%	-0.04	-554				
1956 – 1970	-0.30%	-0.02	-315				
1971 – 1980	-0.20%	-0.01	-145				
1981 – 1990	-0.10%	0.00	-32				
1991 – 1998							
1999 – 2030						3,000	
Total stock	**-0.25%**	**-0.53**	**-4,851**	**0.26%**	**0.55**	**20,000**	**1.1%**

The estimated percentages of dwellings departing the stock in Table 4.4 correspond with a total departure of close to 5,000 units per year. The estimated extension of existing dwellings corresponds with a total floor space of 0.55 million m^2 per year, or an annual increase in the existing dwelling stock of 0.26 % (reference year 1998). The construction of new dwellings is predicted to be constant 20,000 dwellings per year towards 2030, whereof 11,000 in detached houses, 6,000 in divided small houses and 3,000 in large houses.

Table 4.5 shows the total number of dwelling units and total floor space towards year 2030 by type of dwelling. From 1998 to 2030, the total number of dwellings is estimated to increase from 1.88 million to 2.36 million units, and the average size of the dwellings from 112 m^2 to 123 m^2. The total floor space in the dwelling stock is estimated to increase 40 %; from 211 million m^2 in 1998 to 291 million m^2 in 2030. The distribution of the dwellings by type of house is predicted to be rather constant during the period. In numbers, about 57 % of the dwellings will be in detached houses, 23-25 % in divided small houses and around 20 % in large houses. Accounted as total floor space, close to 70 % will be in detached houses throughout the period, about 20 % in divided small houses, and around 12 % in large houses.

Table 4.5 Prognosticated number of dwelling units towards year 2030 by type of dwelling and year of construction (1,000 units).

Year	Detached houses			Divided small houses			Large houses			Total stock		
	Units	Floor space		Units	Floor space		Units	Floor space		Units	Floor space	
		Avg.	Total		Avg.	Total		Avg.	Total		Avg.	Total
	1,000	m^2	Mill m^2	1,000	m^2	Mill m^2	1,000	m^2	Mill m^2	1,000	m^2	Mill m^2
1998	1,076	130	140	431	99	43	370	74	28	1,877	112	211
2000	1,093	132	144	441	100	44	374	74	28	1,907	113	216
2010	1,174	137	161	491	102	50	394	75	29	2,059	117	241
2020	1,256	142	179	541	103	56	413	75	31	2,210	120	266
2030	1,338	147	196	591	104	62	433	75	33	2,362	123	291
Constructed before 1999	986 74%		142 73%	399 67%		44 71%	337 78%		25 77%	1,722 73%		211 73%

The prognosticated number of dwelling units towards 2015 according to the dwelling stock model correspond rather well with the estimates from BUMOD (see Table 4.3), but are lower than the estimated number of households towards 2020 of Keilman and Brunborg (1995). They prognosticate close to 2.5 million households in year 2020 for the medium scenario, whereas the dwelling stock model estimates 2.2 million dwelling units.

The prognosticated total floor space of 291 million m^2 in year 2030 corresponds with an average floor space per capita of 58 m^2 according to the medium scenario on population growth shown in Figure 4.1, 64 m^2 for the low scenario, and 53 m^2 for the high scenario.

The replacement of existing dwellings will be slow, and the dwellings already constructed will dominate the dwelling stock in the future. Table 4.5 shows that dwellings constructed before 1999 are estimated to represent as much as 73 % of the total stock in year 2030. The existing houses are more energy consuming than the more energy efficient houses that will be constructed in the future. This indicates that even thirty to forty years from now, the main part of the total energy use in Norwegian dwellings will be in dwellings constructed before 1999, and not in dwellings constructed from 1999 onwards.

4.2.2 Four scenarios on future energy use in dwellings

Four scenarios on the development of the energy use in dwellings will be applied when using the dwelling stock model to estimate the future total energy use in the dwelling stock. The energy efficiency in the dwellings are different in these scenarios, while the evolution of the stock in terms of total floor space and distribution by type of house is assumed to be the same for all scenarios. The scenarios are:

- Scenario 1 – reference scenario. This scenario represents a slow development in the energy performance of existing houses. For houses constructed before 1991, it is assumed that windows and doors have been replaced in 50% of the houses by 2030. The energy efficiency of houses constructed between 1991 and 1998 is assumed not to be improved towards 2030. The minimum requirements in today's Building Regulations are assumed representative for the new houses constructed towards 2030.

- Scenario 2 – improved energy efficiency scenario. This scenario involves a gradual improvement of the energy standard of existing houses, and a slightly improved standard of new houses compared to the standard in the reference scenario. It is assumed that 50 % of the houses constructed before 1999 have been upgraded to the medium standard by year 2030.

- Scenario 3 – high energy efficiency scenario. This scenario implies that energy efficient products and construction alternatives are used for all new dwellings, and that the whole stock of existing houses is gradually upgraded with energy efficient solutions. It is assumed that all houses constructed before 1999 are converted to highly energy efficient houses by year 2030.

- Scenario 4 – heat pump scenario. This scenario implies that heat pumps are installed in all new houses constructed, and that heat pumps are gradually being introduced in existing houses also. By year 2030, it is assumed that heat pumps are installed in 50 % of the existing dwellings (constructed before 1999). The thermal performance (heat loss) of the houses is assumed to be similar to the performance of the houses in the reference scenario.

Within each scenario, the existing dwelling stock (constructed before 1999) is composed of houses with different thermal performance, depending on how they have been upgraded. The following five energy standards are used to express the thermal performance of the houses (U-values, internal heat load, heat recovery of ventilation exhaust air etc.) within the scenarios:

- Unimproved standard: similar to the thermal performance of today's houses.

- Low standard: the same as unimproved standard, but with new windows and doors.

- Medium standard: Depending on the unimproved standard of the house, the walls, floors and ceilings are assumed additionally insulated. No additional insulation for houses constructed between 1991 and 1998. New, energy efficient windows and doors for houses constructed before 1991. The internal heat load from lighting and electric equipment is slightly lower than for the unimproved and low standard.

- High standard: Additional thermal insulation of walls, floors and ceilings (not for houses constructed between 1991 and 1998). New, super insulating windows and doors for houses constructed before 1991. Energy efficient lighting systems and electric appliances, and lower internal heat load than for the medium standard.

- Heat pump standard: The houses have installed heat pumps, but otherwise similar to the low standard houses.

Figure 4.2 shows the evolution of the energy standard of the existing houses towards year 2030 for the four scenarios. The evolution is the same for all year classes in the dwelling stock model (Before 1956, 1956-1970, 1971-1980, 1981-1990). The existing dwelling stock in Scenario 1 is a combination of unimproved dwellings and low standard dwellings. It is assumed that 50 % of the existing dwellings will have low standard by year 2030, while the remaining dwellings will be unimproved. In Scenario 2, 50 % of the dwellings will be upgraded to medium standard in year

2030, while low standard and unimproved dwellings will represent 25 % each. In Scenario 3, all dwellings will be upgraded to high standard by year 2030. In Scenario 4, 50 % of the dwellings will have heat pump standard in year 2030, the remaining 50 % will have unimproved standard.

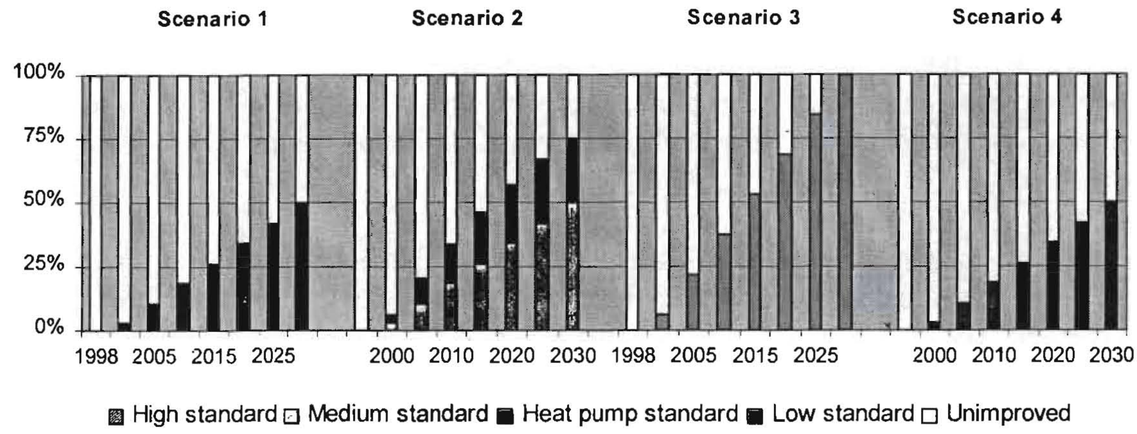

Figure 4.2 Dwellings constructed before 1991. Four scenarios on the evolution of the energy standard towards year 2030. The energy standard of unimproved dwellings is the same for all scenarios. Low standard dwellings have improved windows and doors, otherwise equal to the unimproved alternative. Unimproved and low standard are identical for dwellings constructed between 1991 and 1998.

4.3 Input data for the dwelling stock model

The specific energy use in the dwelling stock (kWh per square metre) is influenced by many factors, such as the size and shape of the building, the thermal insulation level of the external constructions, the heat recovery of the ventilation exhaust air, the energy efficiency of the lighting systems, and the amount and energy efficiency of the electric appliances. In addition to these physical factors, the energy behaviour of the occupants will strongly influence the energy use.

The most important input parameters used to characterise the energy standard of the houses in the dwelling stock model are more thoroughly presented in the following. All relevant input data are also summarised in Appendix 3.

4.3.1 U-values

Table 4.6 shows the U-values for dwellings constructed after 1998 for the four scenarios, and the U-values stated in the prevailing Building Regulations (introduced in July 1997, in force from July 1998). The construction alternatives indicated for the Scenario 1 are similar to the alternatives commonly used for new houses today.

Table 4.6 Input data for the dwelling stock model. U-values for dwellings constructed after 1998 and the corresponding U-values in today's Building Regulations.

Construction	New dwellings 1999-2030 (W/m^2K)	Examples of construction
Walls		
Scenario 1 and 4	0.27	150 mm thermal insulation, 36 × 148 mm studs.
Scenario 2	0.20	200 mm thermal insulation, I-profiled studs
Scenario 3	0.14	300 mm thermal insulation, I-profiled studs
Building Regulations	0.22	
Ceiling		
Scenario 1 and 4	0.15	250 – 300 mm thermal insulation.
Scenario 2	0.12	325 – 350 mm thermal insulation.
Scenario 3	0.08	Approx. 500 mm thermal insulation.
Building Regulations	0.15	
Floors		
Scenario 1 and 4	0.15	Tier of beams: 250 – 275 mm thermal insulation. Slab-on-grade: approx. 170 mm thermal insulation.
Scenario 2	0.12	Tier of beams: approx. 300 mm thermal insulation. Slab-on-grade: approx. 240 mm thermal insulation.
Scenario 3	0.10	Tier of beams: approx. 400 mm thermal insulation. Slab-on-grade: approx. 300 mm thermal insulation.
Building Regulations	0.15	
Windows		
Scenario 1 and 4	1.6	2 pane window, 1 layer of low-emissive coating.
Scenario 2	1.2	3 pane window, 2 layers of low-emissive coating and Argon gas filling.
Scenario 3	1.0	2 + 1 pane window, 2 layers of low-emissive coating and Argon gas filling between the inner two panes.
Building Regulations	1.6	

The energy savings that can be obtained by carrying out additional thermal insulation measures depend on the initial thermal insulation level. The better insulated, the less is gained by improving the U-value. The energy saving potential is therefore normally larger in the old houses. Additional thermal insulation measures should be carried out in connection with general refurbishment works to reduce the investment costs. The need for renovation and refurbishment will grow in the future. Many of the older houses have already been renovated, while less has been done with the stock of houses constructed during the 1960s, 1970s and 1980s.

Table 4.7 shows the U-values of walls, ceiling and floors used in the four scenarios for dwellings constructed before 1991. Relatively large improvements of the U-values are assumed for the oldest houses, while only the walls are assumed improved for houses constructed between 1981 and 1990.

No additional thermal insulation is assumed for houses constructed between 1991 and 1998. The reason is that these houses already are relatively well insulated, and have a limited need for general renovation and refurbishment towards year 2030.

Table 4.7 Input data for the dwelling stock model. U-values (W/m^2K) of walls, ceiling and floors for dwellings constructed before 1991 for unimproved, medium and high standard.

Type of house	Before 1956			1956-1970			1971-1980			1981-1990		
	Walls	Ceil.	Floors	Walls	Ceil.	Floors	Walls	Ceil.	Floors	Walls	Ceil.	Floors
Detached houses												
Unimproved*	0.55	0.38	0.53	0.39	0.32	0.27	0.38	0.20	0.36	0.26	0.18	0.20
Medium	0.25	0.20	0.20	0.22	0.20	0.20	0.22	0.20	0.20	0.18	0.18	0.20
High	0.20	0.15	0.20	0.18	0.15	0.20	0.18	0.15	0.20	0.18	0.18	0.20
Divided small houses												
Unimproved*	0.55	0.38	0.51	0.39	0.32	0.26	0.38	0.20	0.20	0.26	0.18	0.17
Medium	0.25	0.20	0.20	0.22	0.20	0.20	0.22	0.20	0.20	0.18	0.18	0.17
High	0.20	0.15	0.20	0.18	0.15	0.20	0.18	0.15	0.20	0.18	0.18	0.17
Large houses												
Unimproved*	0.82	0.36	0.39	0.67	0.28	0.34	0.49	0.20	0.24	0.35	0.20	0.17
Medium	0.30	0.20	0.20	0.30	0.20	0.20	0.30	0.20	0.24	0.25	0.20	0.17
High	0.25	0.15	0.20	0.20	0.15	0.20	0.20	0.15	0.24	0.20	0.20	0.17

* U-values of low standard and heat pump standard are identical to the unimproved standard

Many of the existing houses will need new windows and external doors before year 2030. Sealed windows for instance, often punctuate after 30 to 40 years and have to be replaced. A large share of the houses constructed during the 1970s and 1980s may therefore be expected to need new windows before 2030. New windows and doors are also more difficult to open for burglars. Safety reasons may therefore contribute to the installations of new windows and doors in existing houses.

For low standard and heat pump standard houses, the U-values of windows and doors are assumed to be 1.6 W/m^2K and 1.2 W/m^2K, respectively,. For medium standard houses (Scenario 2), the U-values are 1.2 W/m^2K for windows and 1.0 W/m^2K for doors. For high standard houses (Scenario 3), U-values are 1.0 W/m^2K for windows and 0.8 W/m^2K for doors.

4.3.2 Ventilation and infiltration

The ventilation air-exchange rate is assumed to be 0.5 air-changes per hour for all new dwellings in all four scenarios, and for all high standard dwellings in Scenario 3. This rate is identical to the basic requirement prescribed in the Building Regulations. The infiltration rate is set to be 0.1 air-change per hour. It should be noted that many existing dwellings with natural ventilation have poor ventilation, and a total air-exchange rate that is lower than the 0.5 air-changes per hour recommended from an indoor climate point of view. Natural ventilation does often not provide the required driving forces to distribute the necessary air volume, or the occupants have closed the ventilation inlets to reduce cold draught.

Only a very few Norwegian dwellings have balanced mechanical ventilation system with heat recovery of the exhaust air. Heat recovery of the ventilation air is neither required in the Building Regulations. The annual energy use of well-insulated houses is approximately 20 % higher without heat recovery than with heat recovery (60 % heat recovery rate). The heat recovery rate depends on the type of heat recover installed. A rate of 60 % is typical for the heat recovers used in dwellings. A higher rate (up to 75 %) is possible for rotation heat recovers, but they are seldom used in dwellings due to higher investment costs.

Heat recovery of the ventilation exhaust air (60 % heat recovery rate) is assumed for all new dwellings in Scenario 2 and 3, and for all existing dwellings upgraded to high standard in Scenario 3. In scenario 1 and 4, 25 % of all new dwellings are assumed to have heat recovery of the ventilation exhaust air.

4.3.3 Indoor air temperature

The indoor temperature used in the calculation of the energy demand of the stereotypes of houses is a crucial parameter for the estimated total energy use in the dwelling stock. The total energy use in the stock will reduce by approximately 5-6 % per degree Celsius the indoor air temperature is reduced in the calculations. The influence of altered indoor temperature is larger for houses with poor thermal performance than for new, well-insulated houses.

An indoor temperature of 22 °C is used when calculating the energy demand of houses according to Norwegian Standard NS 3031. But the indoor temperature actually found in existing dwellings is often lower. The reason is that it is rather common in Norway to have chilly bedrooms, and it is also rather common to reduce the indoor temperature during night or when the house is not in use. Furthermore, rooms that are not in daily use are often not kept fully heated. This is typical for many large detached houses.

A lower indoor temperature than 22 °C is therefore used for houses constructed before 1999 in the dwelling stock model. The temperatures used is mainly based on information from the energy use survey 1990 conducted by Statistics Norway (see Myhre (1995) for more information). For the stereotypes of houses constructed after 1999, it is assumed an indoor temperature of 22 °C. A higher, average indoor temperature is assumed for new houses since the improved energy performance makes it cheaper for the occupants to keep a higher indoor temperature. In well-insulated buildings, it also takes longer time before the temperature falls when the heating is turned off (long time constant). This reduces the possibility of decreasing the energy use by turning off the heat during shorter periods (e.g. during night).

It should be noted that the indoor temperature is commonly raised for comfort reasons after for instance an additional thermal insulation measure has been carried out. The theoretical energy saving potential calculated before the measure was carried out is therefore often not achieved in practise. It should also be noted that it is possible to keep a lower indoor air temperature without loss of thermal comfort in rooms with radiant heating (floor or ceiling). The indoor air temperature can theoretically be reduced by 1 - 2 degrees Celsius, as compared to an alternative with other type of heating (panel heaters or radiators). This effect of radiant heating is not taken into account in the calculations in the dwelling stock model, even though hydronic low temperature floor heating is an interesting alternative with regard to effective utilisation of new, renewable energy sources.

4.3.4 Hot water production

The annual energy use for hot water production is assumed to be 4,500 kWh per dwelling for detached houses, 4,000 kWh for divided small houses, and 3,500 kWh for large houses for all houses in Scenario 1, 2 and 4. These values are also used for houses constructed before 1999 in Scenario 3. For the new houses in the Scenario 3, the values are reduced by 50 % since it assumed that the houses have energy efficient sanitary equipment and heat recovery of the grey wastewater.

4.3.5 Internal heat loads

The internal heat load from persons, lighting and equipment contributes to useful heating and thereby reduces the need for heating from the heating system. The share of the internal loads that is utilised for useful heating purpose depends on the building's heating demand. The lower heating demand, the lower share is utilised for useful heating purpose.

According to NS 3031, the internal heat loads are 3.0 W/m^2 for lighting, 1.4 W/m^2 for persons and 2.7 W/m^2 for electric appliances. The value for lighting is increased by 40 % during the winter (January, February, November and December), and reduced by 40 % during the summer (May, June, July and August). The internal heat load from persons is similarly increased by 10 % during winter and reduced by 10 % during summer.

The internal heat load from persons of 1.4 W/m^2 taken from NS 3031 is used in all four scenarios in the dwelling stock model. It is not distinguished between small and large dwellings, nor is it taken into account that the internal heat load from persons (W/m^2) will be slightly reduced in the future due to reduced average household size and increased average size of dwellings.

The internal heat load of 2.7 kWh/m^2 from electric appliances in NS 3031 corresponds to an annual energy of 2,650 kWh for an average dwelling with a floor space of 112 m^2. The European Union has a system for energy labelling of large household appliances (freezers, refrigerators, washing machines). The energy efficiency of the best products (class A) can be significantly better than for the worst (G). The annual energy use of an A-class freezer is for instance less than half of the energy use of an F-class freezer[12]. A lot would consequently be gained with regard to the electricity use in dwellings if the consumers chose A-classed products. The problem is that the energy efficient products often are more technically advanced, and therefore costs more to produce. In the long run, however, the higher quality and the lower energy use of the A-class products may pay off.

Electric equipment and appliances will probably be more energy efficient in the future. The corresponding energy savings may however be counterbalanced by an increasing number of such equipment in the dwellings. For Scenario 1 and 4, it is assumed that the heat load from electric equipment will be constant 2.7 W/m^{2}K throughout the period. It is assumed that an increasing number of electric appliances will counterbalance the effect of slightly more energy efficient appliances.

In Scenario 2, it is assumed that more energy efficient products will reduce the internal loads from electric equipment and appliances. An internal load of 2.35 W/m^{2}K is therefore used for all new houses and all existing houses upgraded to medium standard. In Scenario 3, it is assumed

[12] A-class: GRAM FBL 350-01E (333 litre net), annual energy demand 266 kWh.
F-class: Electrolux EC 3203N (297 litre net), annual energy demand 579 kWh.

widespread use of energy efficient technology. The internal load from electric appliances is therefore set to 2.00 W/m^2 for all new houses and all existing houses upgraded to high standard.

The internal heat load from lighting is stated as 3.0 W/m^{2}K in NS 3031. This standard value is used for Scenario 1 and 4. The possibility of reducing the energy use for lighting is large. Energy saving light bulbs, for instance, need 80 to 85 % less energy than ordinary light bulbs. In Scenario 2, an internal load of 2.0 W/m^{2}K from lighting is used for all new houses and all existing houses upgraded to medium standard. In Scenario 3, an internal load of 1.0 W/m^{2}K is similarly used for all new and all upgraded houses.

4.3.6 Type of heating and energy source

Direct electric heating dominates in dwellings today, representing about 70 % of the total energy use for heating. It is a political goal to reduce the dependency on electric heating in Norway and to increase the use of hydronic heating. The present government (Bondevik) has established a goal of increasing the use of hydronic heating based on new, renewable energy sources, heat pumps and waste energy by 4 TWh within year 2010 (St meld 29, 1999). But it is a fundamental problem that the environmentally favourable alternatives to direct electric heating in smaller houses currently involve too high investment costs to be economic profitable. It is therefore a question whether the government's aim of increased hydronic heating will be achieved in practise, at least for smaller, residential houses. Thus, it may be assumed that direct electric heating will be of large importance in new houses also in the future.

Table 4.8 shows the distribution of the energy use for heating and hot water production by type of energy. The same distribution is used for Scenario 1, 2 and 3. All dwellings constructed from 1999 onwards are assumed to have electric heating and domestic hot water production. For dwellings constructed before 1991, the distribution of energy use for space heating and ventilation is based on information from Ljones et al. (1992). All detached and divided small houses are assumed to have electric production of domestic hot water. In large houses, the domestic hot water is assumed to be produced the same way as heat for space heating and ventilation, with the exception that no bio-energy is assumed for hot water production.

In Scenario 4, heat pumps are assumed to cover 80 % of the total heating demand (space heating, ventilation and hot water production) for all new dwellings and upgraded dwellings. The rest is assumed covered by electric heating. The dwellings not being upgraded are assumed to have heating as shown in Table 4.8.

Table 4.8 Input data for the dwelling stock model. Distribution of energy use for heating and domestic hot water production by type of energy for Scenario 1, 2 and 3.

Type of house	Space heating and ventilation				Domestic hot water production			
	El	Oil	Bio	Total	El	Oil	Bio	Total
Detached houses								
Bef 56	50 %	17 %	33 %	100 %	100 %			100 %
56-70	47 %	18 %	35 %	100 %	100 %			100 %
71-80	47 %	18 %	35 %	100 %	100 %			100 %
81-90	61 %	13 %	26 %	100 %	100 %			100 %
91-98	90 %		10 %	100 %	100 %			100 %
99-30	100 %			100 %	100 %			100 %
Divided small houses								
Bef 56	64 %	16 %	20 %	100 %	100 %			100 %
56-70	59 %	18 %	23 %	100 %	100 %			100 %
71-80	59 %	18 %	23 %	100 %	100 %			100 %
81-90	71 %	13 %	16 %	100 %	100 %			100 %
91-98	90 %		10 %	100 %	100 %			100 %
99-30	100 %			100 %	100 %			100 %
Large houses								
Bef 56	56 %	35 %	9 %	100 %	56 %	35 %		91 %
56-70	69 %	24 %	7 %	100 %	69 %	24 %		93 %
71-80	69 %	24 %	7 %	100 %	69 %	24 %		93 %
81-90	78 %	17 %	5 %	100 %	78 %	17 %		95 %
91-98	90 %	5 %	5 %	100 %	90 %	5 %		95 %
99-30	100 %			100 %	100 %			100 %

Energy sources like district heating, heat pumps and solar energy are currently of minor importance in the dwelling stock. The government's aim to increase the use of hydronic heating and new renewable energy sources may change this picture. Such a possible trend towards other energy sources is however not considered in Scenario 1, 2 and 3, and only heat pumps are considered in Scenario 4.

5 ESTIMATED ENERGY USE IN THE DWELLING STOCK TOWARDS 2030

This chapter presents the estimated energy use in the dwelling stock towards year 2030 based on the four energy efficiency scenarios described in the previous chapter.

5.1 Estimated total energy and electricity use in the dwelling stock towards year 2030 for four scenarios

Table 5.1 shows the estimated total energy and electricity use in the dwelling stock towards year 2030 for the four scenarios. Scenario 1, the reference scenario, shows that the total energy use in the stock will grow strongly from today's 49 TWh, to 60 TWh in 2030, and the use of electricity from 35 TWh to 47 TWh. But, the average specific use of energy and electricity (kWh/m^2) will in fact be slightly improved since the total floor space increases even more (from 211 million m^2 in 1998 to 291 million m^2 in 2030). The construction of new, more energy efficient houses, departure of existing dwellings, and replacement of windows and doors in 50 % of the houses constructed before 1991, contribute to improve the average energy performance in stock.

According to Scenario 2, the total energy use will be 52 TWh in year 2030, while the use of electricity increases to 40 TWh. Scenario 3 shows a significant decrease in total energy and electricity use. The total energy use is estimated to be 36 TWh in 2030, significantly lower than the 60 TWh of the reference scenario. The total use of electricity is estimated to decrease to 29 TWh. To obtain these reductions while the total floor space simultaneously increases as much as it does, the average specific energy and electricity use has to be almost halved. For Scenario 4, the heat pump scenario, the total energy use is estimated to be 46 TWh in 2030 and the corresponding electricity use 39 TWh.

Table 5.1 Dwelling stock model. Total energy use and total electricity use in the dwelling stock towards year 2030 for the four scenarios.

Year	Total energy use				Total electricity use			
	S1	S2	S3	S4	S1	S2	S3	S4
	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh
1998	49	49	49	49	35	35	35	35
2000	49	49	48	48	35	35	34	35
2005	51	49	46	48	37	36	33	36
2010	53	50	44	48	39	37	32	36
2015	54	50	42	47	41	37	31	37
2020	56	51	40	47	43	38	31	38
2025	58	51	38	47	45	39	30	39
2030	60	52	36	46	47	40	29	39

Figure 5.1 shows the total energy use in the dwelling stock in year 2030 for the four scenarios by type of house and year of construction. In all four scenarios, close to 70 % of the total energy use are used in detached houses. The group of detached houses constructed before 1956, for instance, uses just as much energy alone, as all divided small houses together. It is also worth noting that detached houses constructed from 1999 onwards will represent a significant share of the total energy use in year 2030. The annual energy use of this group is several TWh lower for Scenario

2, 3 and 4 than for the reference scenario (Scenario 1). Large energy savings may therefore be achieved by constructing more energy efficient detached houses than common today.

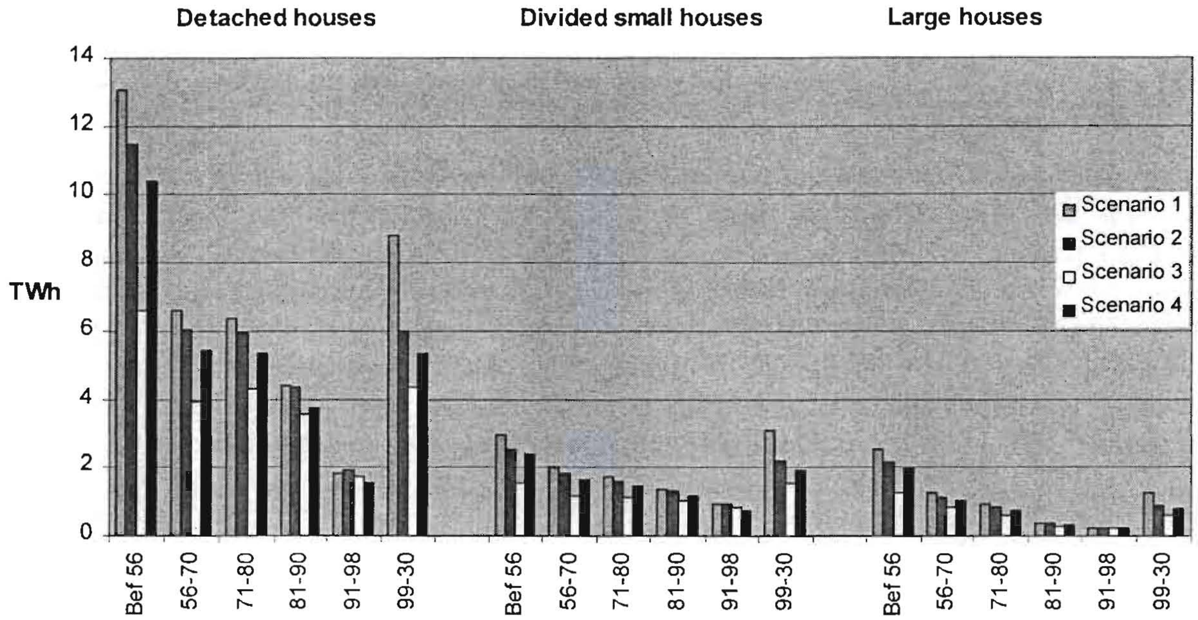

Figure 5.1 Total energy use in the dwelling stock in year 2030 by type of house and scenario. S1 = reference scenario, S2 = medium energy efficiency scenario, S3 = high energy efficiency scenario, S4 = heat pump scenario.

Table 5.2 shows the energy and electricity use in year 2030 by type of house and year of construction for the four scenarios, and the reductions obtained for Scenario 2, 3 and 4 relative to Scenario 1. The reductions vary significantly for the different house types. Large reductions are obtained for the oldest houses, due to the poor standard of the unimproved houses, while less is gained for the younger year classes.

Table 5.2 Total energy and electricity use in the dwelling stock in year 2030 by type of house and scenario, and reductions obtained for scenario 2, 3 and 4 relative to the reference scenario. S1 = reference scenario, S2 = medium energy efficiency scenario, S3 = high energy efficiency scenario, S4 = heat pump scenario. DH = detached houses, DSH = divided small houses, and LH = large houses.

Type of house	Energy							Electricity						
	Total use				Reductions compared to reference scenario (S1)			Total use				Reductions compared to reference scenario (S1)		
	S1	S2	S3	S4	S2	S3	S4	S1	S2	S3	S4	S2	S3	S4
	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh	TWh
DH	**41.1**	**35.7**	**24.5**	**31.8**	**-5.4**	**-16.6**	**-9.3**	**31.3**	**26.9**	**19.3**	**26.7**	**-4.4**	**-12.1**	**-4.7**
Bef 56	13.1	11.5	6.6	10.4	-1.6	-6.4	-2.7	8.5	7.6	4.7	8.0	-0.9	-3.8	-0.5
56-70	6.6	6.0	3.9	5.4	-0.6	-2.7	-1.2	4.4	4.1	2.8	4.3	-0.3	-1.6	-0.1
71-80	6.4	5.9	4.3	5.3	-0.4	-2.0	-1.0	4.3	4.0	3.0	4.2	-0.3	-1.3	-0.1
81-90	4.4	4.4	3.5	3.7	0.0	-0.8	-0.7	3.6	3.5	2.8	3.3	-0.1	-0.8	-0.2
91-98	1.8	1.9	1.7	1.6	0.1	-0.1	-0.3	1.8	1.8	1.6	1.5	0.1	-0.1	-0.2
99-30	8.8	6.0	4.3	5.3	-2.8	-4.5	-3.5	8.8	6.0	4.3	5.3	-2.8	-4.5	-3.5
DSH	**12.1**	**10.4**	**7.3**	**9.4**	**-1.7**	**-4.8**	**-2.7**	**10.3**	**8.9**	**6.4**	**8.4**	**-1.5**	**-4.0**	**-1.9**
Bef 56	2.9	2.5	1.5	2.4	-0.4	-1.4	-0.5	2.2	2.0	1.2	2.0	-0.3	-1.0	-0.2
56-70	2.0	1.8	1.2	1.7	-0.2	-0.8	-0.3	1.5	1.4	1.0	1.4	-0.1	-0.6	-0.1
71-80	1.7	1.6	1.1	1.5	-0.1	-0.6	-0.3	1.4	1.3	0.9	1.2	-0.1	-0.4	-0.1
81-90	1.4	1.3	1.0	1.2	-0.1	-0.3	-0.2	1.2	1.1	0.9	1.1	-0.1	-0.3	-0.1
91-98	0.9	0.9	0.9	0.8	0.0	-0.1	-0.2	0.9	0.9	0.8	0.7	0.0	-0.1	-0.1
99-30	3.1	2.2	1.5	1.9	-0.9	-1.6	-1.2	3.1	2.2	1.5	1.9	-0.9	-1.6	-1.2
LH	**6.6**	**5.6**	**3.9**	**5.1**	**-1.0**	**-2.7**	**-1.5**	**5.2**	**4.4**	**3.1**	**4.3**	**-0.8**	**-2.1**	**-0.9**
Bef 56	2.5	2.2	1.3	2.0	-0.3	-1.2	-0.6	1.6	1.4	0.9	1.5	-0.2	-0.8	-0.1
56-70	1.3	1.1	0.8	1.0	-0.2	-0.4	-0.2	1.0	0.9	0.7	0.9	-0.1	-0.3	-0.1
71-80	0.9	0.8	0.6	0.8	-0.1	-0.3	-0.2	0.7	0.7	0.5	0.7	-0.1	-0.2	-0.1
81-90	0.4	0.4	0.3	0.3	0.0	-0.1	-0.1	0.3	0.3	0.2	0.3	0.0	-0.1	0.0
91-98	0.3	0.3	0.2	0.2	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.0	0.0	0.0
99-30	1.3	0.9	0.6	0.8	-0.4	-0.7	-0.5	1.3	0.9	0.6	0.8	-0.4	-0.7	-0.5
Total	**59.8**	**51.8**	**35.7**	**46.3**	**-8.0**	**-24.1**	**-13.5**	**46.9**	**40.2**	**28.7**	**39.4**	**-6.7**	**-18.1**	**-7.5**
Bef 99	46.6	42.7	29.2	38.2	-3.9	-17.4	-8.4	33.7	31.1	22.2	31.4	-2.6	-11.5	-2.3
99-30	13.2	9.1	6.5	8.1	-4.1	-6.7	-5.1	13.2	9.1	6.5	8.1	-4.1	-6.7	-5.1

The potential for reducing the energy use in Norway towards year 2030 has also been studied in Hille and Malvik (1997). Table 5.3 shows that they estimated the total number of dwelling units in Norway to increase from about 1.80 million units in 1995, to 2.18 million units in 2030. They further estimated that the total energy use in dwellings could be as low as 28.7 TWh in 2030, whereof 6.6 TWh for lighting and electric equipment, and 22.1 TWh for heating. These estimates were based on rough assumptions about the average energy use per dwelling and how this energy use could be reduced.

Table 5.3 Number of dwellings in 1995, 2010 and 2030, total corresponding total energy use distributed on el-specific energy use (lighting and electric appliances and equipment), and heat (Hille and Malvik, 1997).

Year	Constructed before 1996				Constructed 1996-2003				Total stock			
	Units Million	Total	El.	Heat	Units Million	Total TWh	El. TWh	Heat TWh	Units Million	Total TWh	El.. TWh	Heat TWh
1995	1.80	41.9	11.5	30.4					1.80	41.9	11.5	30.4
2010	1.62	31.8	7.8	24	0.30	3.7	1.4	2.3	1.92	35.5	9.2	26.3
2030	1.38	20.8	4.4	16.4	0.70	7.9	2.2	5.7	2.18	28.7	6.6	22.1

Hille and Malvik's estimate of 28.7 TWh in dwellings in year 2030 is much lower than the estimates based on the four scenarios of the dwelling stock model. The estimate of Hille and Malvik is however based on 2.18 million dwelling units in year 2030, whereas the dwelling stock model prognosticates the total number of dwellings to be 2.36 million units (see Table 4.5). The estimate of 28.7 TWh of Hille and Malvik is therefore not directly comparable to the estimates from the dwelling stock model, but supports the findings that the future energy use in the dwelling stock could be stabilised and even lowered in the future.

5.2 Optimum solutions for energy efficiency in the dwelling stock

Optimum solutions for energy efficiency in new and existing dwellings towards year 2030 are presented in the following, based on the results from the four scenarios shown in the previous section.

The profitability of alternative energy efficiency measures is a relative issue, where many factors influence. One factor is the investment costs for the measure. The costs normally decline when a certain measure gets common or a product is being mass-produced. The current price of the most energy effective solutions therefore does not have to reflect the price of these solutions if they were standardised solutions. A second factor is the price of energy used in the calculations. The average price of electric power was for instance NOK 0.59 per kWh including all taxes for households in Norway in 1997, whereas it was about twice as high in Denmark. Higher energy prices in Norway will improve the profitability of energy efficiency measures and increase the energy saving potential in the stock. A third factor is the discount rate or real rate of interest used in the calculations. The higher rate, the lower weight is given future savings and costs. Energy efficiency measures in houses normally involve high initial investment costs and savings that are evenly distributed over a long time period. The effect of discounting significantly reduces the profitability of these measures. A fourth factor is the time period used in the calculations. Many energy efficiency measures have a predicted service life of 30 years or more. The longer time period used in the calculations, the more weight is given future savings and costs (even though the effect of longer calculation periods is reduced in the discounting process). But many house owners have a relatively short time-horizon and demand profitability within a few years. Energy efficiency measures that are profitable in a long-term perspective are therefore not carried out in practise since the house owner has a shorter time-horizon. A fifth factor is the comfort-increase that is often observed after energy efficiency measures have been carried out. The indoor air temperature is for instance often raised after the measures have been carried out since it is cheaper for the occupants to keep a higher indoor temperature.

Table 5.4 shows the estimated annual energy saving per dwelling for alternative energy efficiency measures assumed carried out on the stereotypes of houses in the dwelling stock model, and corresponding maximum investment costs (1,000 NOK) for profitability of the measures. The unimproved standard is used as reference for dwellings constructed before 1999, and Scenario 1 standard as reference for dwellings constructed in the future (1999-2030). A calculation period of 30 years is used for all measures, even though the alternative measures in practise will have different service lives. The real rate of interest is assumed to be 7 %, which is similar to the discount rate used by the Norwegian Government when calculating the profitability of public investments. The energy price is assumed to be NOK 0.55 per kWh throughout the period. This is similar to the current price of electricity for households, including taxes. It is not taken into account that the energy prices may increase in the future, even though this is probable, especially for the price of electric power.

Other parameters that influence the energy use in the houses are kept constant when calculating the profitability of the alternative measures. The indoor air temperature is for instance assumed not to be affected by improved thermal insulation.

5.2.1 Lighting and electric equipment

The total energy savings are estimated to be very small, if any, for energy efficient lighting system (1.0 W/m^2 instead of 3.0 W/m^2) and electric equipment (2.0 W/m^2 instead of 2.7 W/m^2). The reason is that a large share of the waste heat from the lighting system and electric equipment is utilised for useful heating purpose, reducing the need for additional heat from the heating system. For electric heated houses, the total benefit of using energy efficient lighting and electric equipment will be very small since the need for electric heating will increase. For houses with other types of heating, in contrast, energy efficient lighting system and appliances will significantly contribute to reduce the need for electric power. The share of the waste heat that is utilised for useful heating purpose decreases the lower the heating demand of the house. The total benefit of energy efficient installations therefore increases for the new, well-insulated houses.

5.2.2 Heat recovery of the ventilation exhaust air

Relatively large energy savings are calculated for heat recovery of the ventilation exhaust air. The costs of installing balanced, mechanical ventilation system with heat recovery of the exhaust air can vary significantly. It is normally more expensive to install such systems in existing houses than in new houses, but also the design of the house influences the costs. If the house has a rational lay out, the costs of installing a balanced mechanical ventilation system with heat recovery in a new detached house can be less than NOK 20,000. As seen from Table 5.4, this makes the installation absolutely profitable. For existing houses, the installation costs may be assumed to be much higher, and the reduced energy costs not enough to cover the investments. But balanced mechanical ventilation has several benefits that are normally not included into the economic account. Balanced ventilation makes it easier to control the ventilation and obtain the required volume of fresh air. Many houses with natural ventilation are under-ventilated. Balanced ventilation also makes it possible to filter the inlet air, thereby improving the indoor climate. And finally, balanced ventilation with heat recovery makes it possible to pre-heat the inlet air, eliminating cold draught as a problem when it is cold outside. The installation of balanced mechanical ventilation system therefore improves the indoor climate in the house.

Table 5.4 Estimated annual energy saving (MWh) per dwelling for alternative energy efficiency measures compared to the reference standard (Scenario 1) for different house types, and corresponding maximum investment costs (1,000 NOK) for profitability of the measures (30 years calculation period, 7 % real rate of interest and energy price NOK 0.55 per kWh). WFC = additional thermal insulation of walls, floors and ceiling.

Energy efficiency measure	Before 1956		1956-1970		1971-1980		1981-1990		1991-1998		1999-2030	
	MWh	1,000 NOK	MWh	1,000 NOK	MWh	1,000 NOK	MWh	1,000 NOK	MWh	1,000 NOK	MWh	1,000 NOK
Detached houses												
Internal heat load												
Lighting (1.0 W/m^2)	0	-1	0	0	0	0	0	2	1	5	0	2
El-equipment (2.0 W/m^2)	0	0	0	0	0	1	0	2	0	3	0	1
Heat recovery												
Ventilation exhaust air	6	41	5	33	4	28	3	23	3	23	5	33
Domestic hot water	2	15	2	15	2	15	2	15	2	15	2	15
Heat pump	20	139	16	108	15	105	10	69	9	63	10	67
Thermal insulation												
Windows - 1.6 W/m^{2}K	2	13	3	17	3	21	1	4	0	3	0	0
Windows - 1.2 W/m^{2}K	3	23	4	25	4	29	2	12	2	11	1	8
Windows - 1.0 W/m^{2}K	4	25	4	26	5	31	2	14	2	13	2	10
WFC – Scenario 2	11	76	6	38	4	29	1	7	0	0	2	11
WFC – Scenario 3	13	86	7	47	5	36	1	7	0	0	3	22
Divided small houses												
Internal heat load												
Lighting (1.0 W/m^2)	0	0	0	0	0	1	0	2	0	2	0	2
El-equipment (2.0 W/m^2)	0	0	0	1	0	1	0	1	0	1	0	1
Heat recovery												
Ventilation exhaust air	4	26	4	26	3	20	3	18	2	14	3	19
Domestic hot water	2	14	2	14	2	14	2	14	2	14	2	14
Heat pump	14	95	11	77	10	66	7	50	6	44	6	42
Thermal insulation												
Windows - 1.6 W/m^{2}K	1	10	2	15	2	16	1	5	0	2	0	0
Windows - 1.2 W/m^{2}K	3	18	3	21	3	22	2	10	1	6	1	5
Windows - 1.0 W/m^{2}K	3	20	3	23	3	23	2	12	1	8	1	6
WFC – Scenario 2	8	51	3	23	2	12	1	6	0	0	1	6
WFC – Scenario 3	9	58	4	29	3	18	1	6	0	0	2	12
Large houses												
Internal heat load												
Lighting (1.0 W/m^2)	0	0	0	1	0	1	0	2	0	3	0	2
El-equipment (2.0 W/m^2)	0	0	0	1	0	1	0	1	0	1	0	1
Heat recovery												
Ventilation exhaust air	4	26	1	7	2	11	2	11	1	4	3	18
Domestic hot water	2	13	2	13	2	13	2	13	2	12	2	12
Heat pump	11	73	6	41	6	41	5	33	4	27	5	34
Thermal insulation												
Windows - 1.6 W/m^{2}K	2	14	1	8	2	11	1	4	0	1	0	0
Windows - 1.2 W/m^{2}K	3	21	2	12	2	15	1	8	1	5	1	4
Windows - 1.0 W/m^{2}K	3	23	2	13	2	17	1	9	1	6	1	5
WFC – Scenario 2	4	26	2	16	1	6	0	3	0	0	1	4
WFC – Scenario 3	4	29	3	21	1	10	1	4	0	0	1	7

5.2.3 Heat recovery of the wastewater

Heat recovery of the wastewater (grey water) is far from common in Norway. But the possibility of halving the energy use for domestic hot water production with low installation costs is very large. The energy use for domestic hot water is typically 4,000 kWh per household. Halving this would significantly contribute to reduce the total energy use. A simple heat recover with a heat recovery rate of 50 % is for instance available for about $ 250 on the US market (Vaughn, 1999), and a prototype heat recover for the grey water with 50 % heat recovery rate has been developed by NBI in Norway (Gundersen, 1999).

Since large energy savings can be obtained at a relatively low investment cost, the installation of wastewater heat recovery should be promoted when constructing new houses and renovating of existing houses.

5.2.4 Heat pumps

Heat pumps may give large energy savings. The estimated energy savings for heat pumps in detached houses constructed before 1956 are for instance assumed to cover an investment cost of close to NOK 140,000 per dwelling. But, the installation of heat pumps often involves very high investment costs. First of all, the house needs a hydronic heating system within the building to distribute the heat from the heat pump. The installation costs for hydronic heating in existing houses are rather high for the alternatives commercially available on the Norwegian market. Second, the heat pump has to utilise some sort of low-temperature energy source. The utilisation of ground heat for instance, requires the drilling of deep holes in the ground. Third, the costs of the heat pump itself and the service and maintenance of it has to be included in the economic account. Heat pumps have also shown to have shorter service life than 30 years. Even though new pumps may have a longer service life, the replacement costs for the pump should be included in the economic account.

The profitability of heat pumps normally increases the higher the energy demand of the buildings. It is therefore easier to obtain profitability for heat pumps in multi-family houses (blocks of flats, terraced houses etc.) where the investment costs can be distributed on several households, whereas it is more difficult to obtain profitability for heat pumps in well-insulated detached houses.

5.2.5 New windows

The energy savings obtained by replacing existing windows with new, energy efficient windows are normally not large enough to make the replacement profitable. New windows are therefore normally installed only when the existing windows need replacement.

Table 5.4 shows that the energy savings obtained by choosing windows with U-value 1.2 W/m^{2}K instead of 1.6 W/m^{2}K, cover an additional investment costs of NOK 8,000 to 10,000 per dwelling for detached houses, NOK 4,000 to 8,000 for divided small houses, and between NOK 4,000 and 7,000 for dwellings in large houses. Maximum additional investment costs are a little higher for windows with U-value 1.0 W/m^{2}K due to higher energy savings.

The price of windows with U-values 1.2 W/m^{2}K and 1.0 W/m^{2}K are typically 20 % and 35 % higher than the 1.6 W/m^{2}K alternative (NorDan, 1999). The price of a standard 1.2 m × 1.2 m window with U-value 1.6 W/m^{2}K is around NOK 3,150 included value-added tax, or NOK 2,200 per square metre. Assuming 20 m^2 of windows in a detached house, the total costs (excluding installation costs) for new windows will be around NOK 44,000 for windows with U-value 1.6 W/m^{2}K. The additional costs of installing windows with U-value 1.2 W/m^2 will be about NOK 8,800, which is covered by the energy savings as seen from Table 5.4. The window alternative with U-value 1.0 W/m^{2}K, in contrast, is not profitable compared to the 1.6 W/m^2 alternative since the additional costs will be NOK 15,400 and the energy savings only cover an additional investment of around NOK 10,000.

It should be noted that cold slide normally is not a problem for windows with U-value 1.2 W/m^{2}K or lower. This means that ovens and radiators do not have to be placed below the windows to prevent cold slide, but can be placed on interior walls instead. For radiators, this may reduce the installation costs significantly. If such savings are drawn into the economic assessment, improved U-value of windows may really pay off.

5.2.6 Additional thermal insulation

Additional thermal insulation of walls often involves high investment costs since the cladding has to be removed. Additional wall insulation should therefore be carried out in connection with ordinary refurbishment works when the old panel is removed anyway. It should be noted that a large share of the houses constructed during the 1960s and 1970s, with 4" timber frame and 100 mm thermal insulation, will need new cladding before 2030. The U-value of these walls could easily be improved in connection with the replacement of the cladding.

Many Norwegian houses have cold lofts. By adding thermal insulation on the loft floor, the U-value of the ceiling can be improved at a relatively low cost.

The best way to improve the U-value of floors is to fill the entire space between the beams with thermal insulation material. Additional thermal insulation is in practise not relevant for slab-on-grade constructions since this would elevate the floor, cause problems for doors and reduce the headroom.

5.2.7 Solutions for optimum energy use in the dwelling stock towards 2030

An optimum scenario is described in the following regarding the thermal performance of new houses and the energy efficiency measures that could be carried out in existing dwellings towards year 2030. In this scenario, all new dwellings constructed towards year 2030 are assumed thermally insulated according to Scenario 2 (see Table 4.6). These new dwellings are further assumed to have installed heat recovery of the ventilation exhaust air (60 % heat recovery rate) and the grey water (50 % heat recovery rate).

In dwellings constructed before 1999, a number of energy efficiency measures are assumed to be carried out towards year 2030 as seen from Table 5.5. These measures include additional thermal insulation of walls, floors and ceilings according to the medium standard shown in Table 4.7, new windows (U-value 1.2 W/m^{2}K) and doors (U-value 1.0 W/m^{2}K), and installation of heat recovers for ventilation exhaust air and grey wastewater.

Table 5.5 shows that 25 % of the dwellings constructed before 1991 are assumed to be unimproved throughout the period towards 2030, while a larger share of the dwellings are assumed to be unimproved for dwellings constructed between 1991 and 1998 (75 % for detached houses and 50 % for divided small houses and large houses).

The energy sources used for space heating and production of domestic hot water are assumed to be the same in the optimum scenario as in Scenario 1, 2 and 3 (see Table 4.8), with the exception for houses with heat pumps. By year 2030, heat pumps are assumed installed in 50 % of the dwellings in large houses and 25 % of the dwellings in divided small houses. For detached houses, heat pumps are only assumed installed in houses constructed before 1956. The heat pumps are further assumed to cover 80 % of the total energy demand for space heating and production of hot, domestic water, while electric power covers the remaining 20 %.

All dwellings are assumed to have energy efficient lighting (internal heat load 1.0 W/m^2) and energy efficient electric equipment and appliances (internal heat load 2.0 W/m^2). It could be argued that the effect of energy efficient installations currently is rather low in Norwegian houses due to the large share of electric heating. But the use of energy efficient installations should be encouraged. The indoor temperature is assumed to be 22 °C in all upgraded dwellings, whereas the lower "original" temperature is used for the unimproved dwellings (see Appendix 3).

Table 5.5 Optimum scenario. Percentage of the existing dwellings (constructed before 1999) where energy efficiency measures have been carried out by year 2030.

Energy efficiency measure	Year of construction				
	Bef 56	56-70	71-80	81-90	91-98
	%	%	%	%	%
Detached houses	**100**	**100**	**100**	**100**	**100**
AddInsul, WD, Vent-rec, WW-rec	25	25	25	25	-
AddInsul, WD	25	25	25	25	-
WD, HeatPump	25	-	-	-	-
WD	-	25	25	25	-
Vent-rec, WW-rec	-	-	-	-	25
Unimproved	25	25	25	25	75
Divided small houses	**100**	**100**	**100**	**100**	**100**
AddInsul, WD, Vent-rec, WW-rec	25	25	25	25	-
AddInsul, WD	25	25	25	25	-
WD, HeatPump	25	25	25	25	-
HeatPump	-	-	-	-	25
Vent-rec, WW-rec	-	-	-	-	25
Unimproved	25	25	25	25	50
Large houses	**100**	**100**	**100**	**100**	**100**
AddInsul, WD, Vent-rec, WW-rec	25	25	25	25	-
AddInsul, WD, HeatPump	25	25	25	25	-
WD, HeatPump	25	25	25	25	-
HeatPump	-	-	-	-	50
Unimproved	25	25	25	25	50

AddInsul: Additional insulation of walls, floors and ceiling according to the medium standard (see Table 4.7).
WD: New windows (1.2 W/m^{2}K) and doors (1.0 W/m^{2}K).
Vent-rec: 60 % heat recovery of ventilation exhaust air.
WW-rec: 50 % heat recovery of grey wastewater.
Heat Pump: Heat pumps cover 80 % of energy demand for space heating and production of domestic hot water.

Table 5.6 shows the total energy use in year 2030 according to the optimum scenario and the reference scenario (Scenario 1). The total energy use in the stock in 2030 is estimated to be 43.5 TWh for the optimum scenario. This is 16.3 TWh lower than in the reference scenario and 5 TWh lower than today's energy use in the stock. The total electricity use is similarly estimated to be 33.4 TWh in 2030, which is 13.5 TWh lower than in the reference scenario, and slightly lower than today.

Table 5.6 Optimum scenario. Total energy and electricity use in the dwelling stock in year 2030 by type of house for the optimum scenario and the reference scenario, and energy savings obtained for the optimum scenario. DH = detached houses, DSH = divided small houses, and LH = large houses.

Type of house	Energy			Electricity		
	Total use		Saving	Total use		Saving
	Optimum scenario	Reference scenario		Optimum scenario	Reference scenario	
	TWh	TWh	TWh	TWh	TWh	TWh
DH	**31.5**	**41.1**	**-9.6**	**23.3**	**31.3**	**-8.0**
Bef 56	9.1	13.1	-4.0	6.3	8.5	-2.2
56-70	5.8	6.6	-0.8	3.6	4.4	-0.8
71-80	5.7	6.4	-0.7	3.6	4.3	-0.7
81-90	4.1	4.4	-0.3	3.1	3.6	-0.5
91-98	1.7	1.8	-0.1	1.6	1.8	-0.2
99-30	5.0	8.8	-3.8	5.0	8.8	-3.8
DSH	**8.3**	**12.1**	**-3.8**	**7.1**	**10.3**	**-3.2**
Bef 56	2.0	2.9	-0.9	1.6	2.2	-0.6
56-70	1.4	2	-0.6	1.1	1.5	-0.4
71-80	1.3	1.7	-0.4	1.0	1.4	-0.4
81-90	1.1	1.4	-0.3	0.9	1.2	-0.3
91-98	0.8	0.9	-0.1	0.7	0.9	-0.2
99-30	1.7	3.1	-1.4	1.7	3.1	-1.4
LH	**3.7**	**6.6**	**-2.9**	**3.1**	**5.2**	**-2.1**
Bef 56	1.4	2.5	-1.1	1.1	1.6	-0.5
56-70	0.8	1.3	-0.5	0.7	1	-0.3
71-80	0.6	0.9	-0.3	0.5	0.7	-0.2
81-90	0.2	0.4	-0.2	0.2	0.3	-0.1
91-98	0.2	0.3	-0.1	0.2	0.2	0.0
99-30	0.4	1.3	-0.9	0.4	1.3	-0.9
Total	**43.5**	**59.8**	**-16.3**	**33.4**	**46.9**	**-13.5**
Before 1999	36.2	46.6	-10.4	26.2	33.7	-7.5
1999-2030	7.2	13.2	-6.0	7.2	13.2	-6.0

Of the 16 TWh saved in year 2030 in the optimum scenario, 10 TWh will be saved in houses constructed before 1999 and 6 TWh in the new houses constructed. It is therefore very important to improve the energy efficiency of the existing dwellings to influence the total energy use in the dwelling stock, even though large savings also may be obtained by designing and constructing more energy efficient new dwellings than standard today.

5.3 How to implement the optimum scenario?

The optimum scenario shows that the total use of energy and electricity in the dwelling stock in year 2030 can be lower than today. But, the dwelling stock consists of close to two million dwelling units, most of them privately owned. A huge number of house owners therefore have to be persuaded to carry out energy efficiency measures if the optimum scenario is to be accomplished. Many of the measures involve large investment costs, and relatively low profitability for the house owner. House owners are also often not aware about the profitable energy efficiency measures that can be carried out, and many of them are for various reasons reluctant to carry out the measures even if they are profitable.

In the following, it is discussed how the authorities can influence the energy use in the dwelling stock. In principle, three main types of instruments are available to improve the overall energy efficiency in new and existing dwellings:

- regulatory instruments,
- economic instruments,
- information campaigns to increase the energy awareness of the public, and education programmes to increase the competence of the professionals.

The Building Regulations is a powerful regulatory instrument. The construction of more energy efficient new houses can be ensured by stricter requirements in the Building Regulations. The Building Regulations, however, is not in force for existing houses. To improve the energy efficiency in existing houses, other instruments should be used.

5.3.1 Stricter energy requirements in the Building Regulations

The construction of new houses is today regulated through the requirements in the Building Regulations. Also extensions of existing houses have to comply with these requirements.

New Building Regulations were introduced 1 July 1997, enforced from 1 July 1998. The requirements for energy use are said to be 25 % stricter in these regulations as compared to the requirements in the previous regulations (Building Regulations 1987).

In a recent report to the Norwegian Parliament, it is stated that the potential for further reductions of the heating demand in buildings seems to be limited (St meld 29, 1999). For several reasons, this is not quite true. First of all, the Building Regulations do not require heat recovery of the ventilation exhaust air. Large energy reductions can be obtained at a relatively low cost by recovering this heat, and the installation of heat recovery of ventilation exhaust air should therefore be required in the regulations. Large energy reductions can similarly be obtained if the Building Regulations required heat recovery of the wastewater.

The Building Regulations include three main methods to satisfy the energy requirements for new buildings[13]. The first method is to satisfy the U-value requirements for all external constructions.

[13] There is actually also a fourth method described in the regulations, based on a life cycle assessment of the total energy demand and environmental load during the life cycle of the building. But it is not clear how this assessment is to be done, and the method is not used in practise.

The second method is to show that the heat loss of the real building is equal to or lower than the heat loss of a reference building with thermal insulation according to the U-value requirements. The third method is to show that the energy demand for space heating and ventilation of the real building is equal to or lower than the energy demand of a reference building with thermal insulation according to the U-value requirements. The reference building has the same size, shape, location etc. as the real building. But for some strange reason, a window area equal to 20 % of the floor space should be used when calculating the heat loss and energy demand of the reference building, while the real window area should be used for the real building. The window area in new houses is normally smaller than 20 % of the floor space. In new, detached houses, as an example, the window area is typically 15 % (Pettersen, 1998). Since the U-value of the windows is significantly poorer than the U-value of the walls, it is possible to satisfy the requirements according to method 2 and 3 for standard houses with a thermal insulation level actually worse than indicated by the U-value requirements (method 1).

The Building Regulations indicate a minimum standard with regard to energy use for space heating and ventilation. It is of course allowed for the builders to improve the standard by for instance insulating more or installing heat recovers. But this is seldom done, even though it may be profitable when considering future energy savings. A main reason is that many houses are constructed by developers for sale. The developers often choose the cheapest solutions to increase the profit of the sale, without considering the total life cycle costs. The requirements in the Building Regulations should therefore be made stricter to ensure a better energy standard of new houses.

The Building Regulations only consider the energy demand for space heating and ventilation, not the energy demand for lighting, electric equipment and production of domestic hot water. For modern, well-insulated buildings, lighting, electric equipment and production of domestic hot water represent more than 50 % of the total energy demand. The Building Regulations therefore only cover a minor share of the total energy use in houses. By including requirements on heat recovery of grey wastewater in the regulations, a larger share of the total energy use would be regulated by the regulations.

It is difficult to regulate the lighting systems and electric equipment actually used in houses. The best way to influence the consumers to choose the most energy efficient products is probably by increasing their awareness about energy related issues. This could be done by increasing the price of electricity and through information campaigns.

5.3.2 Economic instruments

Three types of economic instruments should be used to improve the energy efficiency in the dwelling stock. These types are charges, soft loans and tax allowances.

The price of energy is very important for the energy-related awareness in the population and the profitability of energy efficiency measures. It is a fact that the price of electric power has been very low in Norway, and that the price is lower than in our neighbour countries. The low price of electric power in Norway can be justified by the good supply of clean and cheap hydroelectric power. But, Norway is now facing a situation where the demand for electric power exceeds the production capacity of hydropower and where the country has become a net importer of power. This power is predominantly produced in coal fired power plants. According to the "Polluter-

Pays-Principle", which has been adopted as the central principle of the environmental policy in Norway, the polluter should pay the full costs of any damage caused by his operation. The tax on electric power should therefore be strongly increased to reflect the CO_2 emissions from the production of it. The tax on heating oil and other fossil fuels should simultaneously be increased to avoid a substitution from electric heating to the use of these energy sources.

The Government has recently decided to increase the tax on electric power from NOK 0.0594 per kWh to NOK 0.0844 per kWh. This increase of NOK 0.025 per kWh is far from enough to have any significant influence on the profitability of energy efficiency measures and conversions from electric heating to other types of heating. Significantly increased taxes on electric power would however represent a problem for many households. Examples are older people living on a minimum retirement income, and low income families with small children. It has therefore been suggested to introduce a step-wise tax on electric power, where there is a rather low tax on a basic use, and a higher, luxury tax above this level.

Charges could also be used to promote energy efficient products, such as electric appliances. Within EU, there is a system for energy labelling of white goods (washing machines, refrigerators, freezers etc.). The products are classified into different energy classes according to their efficiency. Levying a surcharge on the least energy efficient products would promote the most energy efficient products. The bureaucracy and administrative costs of such a system could however be a problem, but it should be noted that a deposit-refund system for electric appliances has recently been established in Norway, and that an energy efficiency tax could be linked to this system. An alternative to taxation of the least energy efficient products could be to ban them.

Subsidies could be used to promote important energy efficiency measures that involve large investment costs. Examples are additional thermal insulation, installation of heat recovery of the ventilation exhaust air, installation of heat pumps and replacement of windows. Several types of subsidies are available. The value-added tax of 23 % all private households must pay for renovation works could for instance be lowered. Private companies, as an example, only pay an investment tax of 7 % for similar works. Tax-free allowance for energy efficient renovation would also contribute to improve the energy efficiency in the existing stock.

Soft-loans could also be offered for energy efficient renovation works. Soft-loans are loans offered at lower rates to promote certain investments. The Norwegian State Housing Bank currently has a system for offering loans for energy efficient renovation of houses. The problem is that the rate they offer is not subsidised, but comparable to the rate offered in ordinary private banks. It would be positive if the Norwegian authorities, through the State Housing Bank, could offer lower rates for energy efficient renovation.

Increasing energy taxes will increase the energy costs of most households and contribute to increase the revenues of the state. The increased revenues should in turn be used to support and subsidise energy efficiency measures in houses. As an example: If the tax on electric power for households was increased by NOK 0.1 per kWh, this would represent an increase of about NOK 3.3 billion per year for all households. According to the optimum scenario (see Table 5.5), about 75 % of the existing dwellings should be upgraded in one way or another by year 2030. For simplicity, it assumed that the stock consists of 2.0 million dwellings. If 75 % are to be upgraded, this represents 1.5 million dwellings. Spread over 30 years, this makes 50,000 dwelling units per year. If the increased revenues of the government (approx. NOK 3.0 billion) were to used to subsidise energy efficiency measures in the dwelling stock, this would be as much as NOK 60,000 per dwelling. Such a large support would encourage the houseowners to carry out energy efficiency measures. And it should be noted that an increase of NOK 0.1 per kWh would represent a moderate increase the price of electricity, and still keep the price below the cost in most other countries.

5.3.3 Information campaigns and education programmes

Today, the energy related awareness must be said to be rather low in the population. Information campaigns to increase the energy awareness is therefore needed to improve the energy efficiency in the dwelling stock. These campaigns can both be general campaigns and more targeted campaigns directed towards a specific group of house types.

It is often hard to get energy related information about buildings and electric equipment. A typical example is the fact that the information about properties for sale seldom contain energy related information. More available energy related information would contribute to increase the energy related awareness in the population.

The EU-scheme for energy labelling of white goods (washing machines, refrigerators, freezers etc.) is one type of information scheme that is needed. This scheme will hopefully be expanded to include more product groups in the future, such as personal computers and television sets. Another type of information scheme is the Nordic Environmental Labelling (the Swan). The Swan-label says that the product complies with strict requirements regarding energy use and environmental load during the product's life cycle. The Swan-label does not inform directly about the energy use, but since energy use is a paramount factor in the overall environmental assessment, it can be assumed that the energy use related to the product is relatively good. The Swan-scheme currently includes several building related products.

The Eco-Profile method is a Norwegian scheme for environmental classification of buildings. The method was originally developed for commercial buildings (offices), but is now also available for residential houses. The environmental performance of the building is classified by classifying a number of environmental parameters within three different areas: Outdoor Environment, Resources and Indoor Environment. Very many of the parameters in the Eco-Profile method are energy related.

In Denmark, a system for energy certification of buildings has been established to be used in conjunction with sale of property. The requirement of such a scheme contributes to increase the energy related awareness and to increase the market value of the most energy efficient properties.

The economic costs associated with the energy classification or certification of buildings is a barrier for the introduction of such schemes. Today, the market does not ask for such information, and the costs of a detailed energy evaluation of a house will probably not pay off in conjunction with sale. Eco-Profile and schemes similar to the Danish Energy Certificate Scheme should therefore be subsidised by the authorities until the market asks and pays for such schemes.

Besides information campaigns aiming at the population, there is a need to increase the knowledge and competence about energy use in buildings amongst the professionals in the construction sector (architects, engineers, contractors etc.). Due to rather low awareness about energy related issues the last decades, many of the professionals are not aware of the energy saving potential in ordinary houses. The new, highly insulating constructions also increase the importance of thermal bridges and air-leaks (infiltration) for the overall energy use. Moreover, from a period of time where direct electric heating has been dominating in houses, the importance of hydronic heating and the use of alternative energy sources is increasing. Many of professionals are not ready for this transition, and lack knowledge and experience on the new solutions.

There is further a large need for more research and development of cost-effective solutions for energy efficiency in houses. This is especially important with regard to the existing housing stock, since very many of the energy efficiency measures that can be carried out in existing dwellings today are too expensive. Examples are additional thermal insulation measures and conversions from direct electric heating to other types of heating. The potential for developing more cost-effective solutions should be large, particularly if the solutions could be standardised and prefabricated. Demonstration projects should be actively used to test out and present the new solutions.

6 CONCLUSIONS

The scope of the work presented in this report has been to analyse the energy use in the Norwegian dwelling stock towards year 2030, and to study how the total energy and electricity use will be affected by alternative energy efficiency measures. The background for the work is the steadily growing energy use in Norwegian households. The annual growth was about 1.8 % per year as an average from 1976 to 1996, and the growth in the use of electricity was even higher due to more electric heating. Today, Norway has the highest use of electricity per capita in the world, and the total energy use per capita is the third highest.

The environmental burden connected to the production, transportation and use of energy use is one of the most important environmental problems. The power production in Norway has traditionally been based on hydropower, but the country is now facing a situation where hydropower can not cover the increasing power demand. Instead, electric power produced from fossil fuels must be used to cover the demand, involving large emissions of CO_2. In a sustainable context, the growing energy use in Norwegian households conflicts with the need to reduce overall resource consumption and environmental load.

A calculation model is used to estimate the total energy and electricity use in the dwelling stock towards year 2030 for four different scenarios; a reference scenario based on today's requirements in the Building Regulations for new houses and limited improvement of the thermal performance of existing houses (Scenario 1), an improved energy efficiency scenario (Scenario 2), a high energy efficiency scenario (Scenario 3), and a heat pump scenario (Scenario 4). In all these scenarios, the total floor space in the stock is assumed to increase from 211 million m^2 in 1998, to 291 million m^2 in 2030. The total number of dwelling units is correspondingly estimated to increase from 1.88 million units to 2.36 million units, and the average dwelling size from 112 m^2 to 123 m^2.

The total energy use in the dwelling stock in 1998 is estimated to be 49 TWh and the total electricity use 35 TWh. The reference scenario shows that the total energy use in the stock will grow strongly to 60 TWh in 2030, and the electricity use to 47 TWh. According to Scenario 2, the total energy use will be 52 TWh in year 2030, and the total electricity use 40 TWh. Scenario 3 shows a significant decrease in total energy and electricity use. The total energy use is estimated to be 36 TWh in 2030, and the total use of electricity 29 TWh. To obtain these reductions while the total floor space simultaneously increases as much as it does, average specific energy and electricity use has to be almost halved in Scenario 3. It should be noted that no conversion from direct electric heating to other types of heating is assumed in these three scenarios, and all new houses constructed towards year 2030 are assumed to have electric heating. For Scenario 4, the heat pump scenario, the total energy use is estimated to be 46 TWh in 2030 and the corresponding electricity use 39 TWh.

Based on the results from the four scenarios and a judgement of the profitability of alternative energy efficiency measures, a fifth optimum scenario is defined. This scenario is in many ways similar to Scenario 2, but with a large share of heat pumps, especially in large houses. According to the optimum scenario, the total energy use in the stock will reduce from today's 49 TWh to 44 TWh in year 2030, and the total electricity use from 35 TWh to 33 TWh.

The optimum scenario shows that the total energy and electricity in the dwelling stock can be lower in year 2030 than today if the right energy efficiency measures are being carried out. The calculations show that new houses constructed towards year 2030 will represent a significant share of the total energy use in year 2030. The total energy use in year 2030 can be several TWh lower if the new houses are constructed more energy efficient than common today. It is therefore recommended to tighten the energy related requirements in the Building Regulations to ensure the construction of energy efficient new houses. The Building Regulations can not be used the same way to regulate the thermal performance of existing houses. Instead, a combination of economic instruments, information campaigns and education programmes should be used to influence the existing housing stock. It is shown that by increasing the price of electricity by NOK 0.10 per kWh for all households, and earmark these money for energy efficiency measures, annually more than 50,000 dwelling units could be subsidised NOK 60,000 for investments in energy efficiency measures.

The calculations shows that the energy and electricity use in the dwelling stock will increase significantly towards year 2030 if the appropriate measures are not carried out. The optimum scenario shows that it is possible to stabilise and even lower the total energy and electricity use in year 2030 as compared to today's situation.

The growing energy and electricity use in Norwegian households conflicts with the need to reduce overall resource consumption and environmental load. A key task on the way towards sustainable development should therefore be to improve the energy efficiency in the dwelling stock.

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APPENDIX 1 - EVOLUTION OF THE DWELLING STOCK

Figure A1.1 shows the development of the total number of dwellings in Norway from 1960 to 1990, based on information from the population and housing censuses of 1960, 1970, 1980 and 1990. The figure shows the number of dwellings constructed before 1961 (A) still existing in 1970, 1980 and 1990, respectively. The new dwellings constructed during the period are quantified by three factors; replacement of departing dwellings (B), decreasing household size (C) and population growth (D). Decreasing average household size quantifies as much as 45 % of the dwellings constructed from 1960 to 1990, while replacement of existing dwellings only quantifies 31 % and population growth 25 % of the dwellings constructed during this period. This indicates that decreasing household size has been a more important factor for the increasing number of dwellings than population growth.

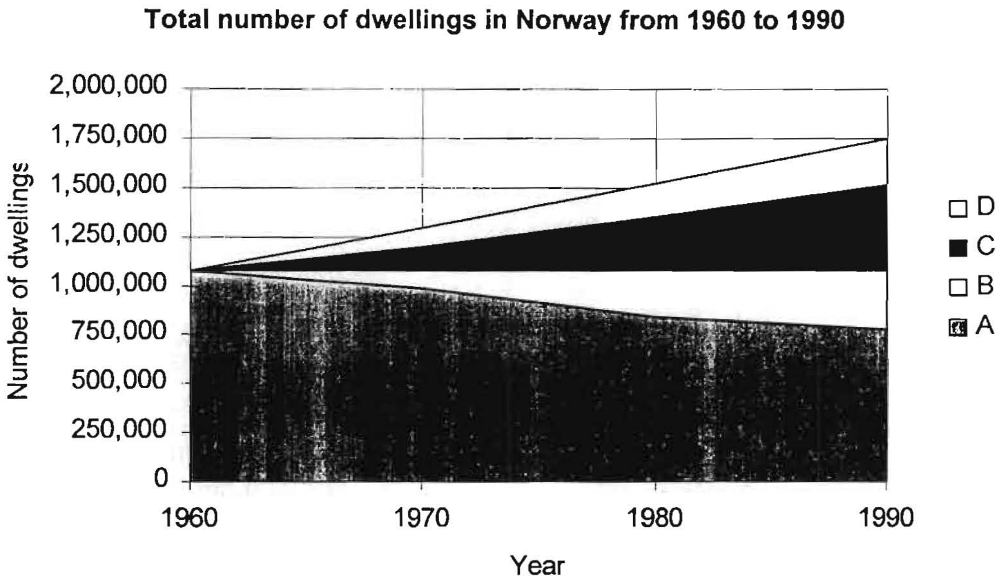

Figure A1.1 Total number of dwellings from 1960 to 1990. The increased number of dwellings is shown explained by population growth, decreasing size of households and replacement of departing dwellings. A = constructed before 1961, B = replacement of departing dwellings, C = decreasing household size, and D = population growth. (Myhre, 1995).

The average size of the dwellings has been steadily increasing during the last decades. This increase has both been driven by the construction of new, large dwellings, by the extension of many existing dwellings, and by the departure of smaller dwellings.

Below, the total floor space in the dwelling stock one year is quantified as the total floor space the previous year, added the floor space of the new dwellings constructed and the total floor space of extensions during the year, subtracted the total floor space of the dwellings being demolished or left empty during the year.

$$A_{tot\ i} = a_{avg\ i} \cdot n_{tot\ i} = a_{avg\ i-1} \cdot n_{tot\ i-1} + a_{new\ i} \cdot n_{new\ i} + a_{ext\ i} \cdot n_{ext\ i} - a_{dem\ i} \cdot n_{dem\ i} \quad \textit{(Equation A.1)}$$

where

$A_{tot\ i}$	= total floor space in the dwelling stock in year i,
$a_{avg\ i}$	= average size of dwellings in year i,
$n_{tot\ i}$	= total number of dwellings in year i,
$a_{avg\ i-1}$	= average size of dwellings in year i-1,
$n_{tot\ i-1}$	= total number of dwellings in year i-1,
$a_{new\ i}$	= average size of new dwellings completed in year i,
$n_{new\ i}$	= number of new dwellings completed in year i,
$a_{ext\ i}$	= average extension of dwellings extended in year i,
$n_{ext\ i}$	= number of dwellings extended year i,
$a_{dem\ i}$	= average size of the dwellings demolished or left empty in year i,
$n_{dem\ i}$	= number of dwellings demolished or left empty in year i.

The total number of dwellings ($n_{tot\ i}$) can be expressed as:

$$n_{tot\ i} = n_{tot\ i-1} + n_{new\ i} - n_{dem\ i} - n_{merged\ i} \quad \textit{(Equation A.2)}$$

where $n_{merged\ i}$ is the number of dwellings merged with another dwelling into one larger unit.

The average size of the dwellings can thus be calculated as:

$$a_{avg\ i} = \frac{a_{avg\ i-1} \cdot n_{tot\ i-1} + a_{new\ i} \cdot n_{new\ i} + a_{ext\ i} \cdot n_{ext\ i} - a_{dem\ i} \cdot n_{dem\ i}}{n_{tot\ i-1} + n_{new\ i} - n_{dem\ i} - n_{merged\ i}} \quad \textit{(Equation A.3)}$$

Equation A.2 and A.3 are used in Table A1.1 to extrapolate the total number and average size of dwellings from 1984 to 1995, using information about the total number and average size of dwellings in 1981, the number and average size of dwellings completed, and the estimated extent of extensions, demolishing and merging of dwellings during the period. The estimates correspond well with the total number and average size of dwellings observed in connection with the surveys of housing conditions in 1988 and 1995.

In principle, the annual building statistics should contain information about extensions. Local authorities should, according to the regulations, send all relevant information about extensions exceeding 30 m^2 to the central building register (GAB). But, this information has shown to be faulty. In practise, a number of extensions are not reported, and many wrongly classified. The local authorities are furthermore not required to send information about smaller extensions to the GAB-register. Consequently, this register does not contain reliable information about the annual extensions in existing dwellings. Therefore, in Table A1.1, the total floor space of extensions is based on information about the annual costs of renovations work in dwellings, estimated share of these investments used for extensions, and corresponding investment costs per square metre for extensions.

Table A1.1 Total number and average size of dwellings in 1981, 1988 and 1995. Total number and average size of dwellings completed each year from 1983 to 1995. Estimated total floor space of extensions in existing dwellings. Estimated number and average size of dwellings demolished or left empty each year. Estimated total number of dwellings merged with another dwelling into a larger unit. Total number and average size of dwellings prognosticated from 1983 to 1995.

Year	Survey of Housing Condition 1)		Completed dwellings 2)		Extensions 3)		Demolished or left empty		Merged with another unit 4)	Total stock Estimated numbers	
	Number of units	Avg. size	Number of units	Avg. size	Invest-ments	Estimated floor space	Number of units	Avg. size	Number of units	Number of units	Avg. size
	(n_{tot})	(a_{avg})	(n_{new})	(a_{new})		(A_{ext})	(n_{dem})	(a_{dem})	(n_{merg})	(n_{tot})	(a_{avg})
	Mill. units	m^2		m^2	Bill. NOK	Mill m^2		m^2		Mill. units	m^2
1981	**1.52**	**98**	34,700				-5,000	100	-2,000	1.55	
1982	1.54	99	38,500				-5,000	100	-2,000	1.58	
1983	1.56	101	32,164	156			-5,000	100	-2,000	1.60	101
1984	1.58	102	30,505	156	26.7	0.8	-5,000	100	-2,000	1.63	102
1985	1.59	104	26,014	166	27.8	0.8	-4,000	100	-2,000	1.65	104
1986	1.61	105	27,391	*164*	23.5	0.7	-4,000	100	-2,000	1.67	105
1987	1.63	107	28,767	*161*	30.5	0.9	-4,000	100	-2,000	1.69	107
1988	**1.65**	**108**	30,144	159	23.8	0.7	-4,000	100	-1,850	1.72	109
1989	1.68	109	26,515	*142*	24.4	0.7	-4,000	100	-1,350	1.74	110
1990	1.71	109	22,886	125	21.2	0.6	-4,000	100	-1,100	1.76	110
1991	1.74	110	21,689	116	18.9	0.5	-3,000	100	-525	1.77	111
1992	1.76	110	17,789	117	16.0	0.5	-3,000	100	-250	1.79	111
1993	1.79	111	15,897	120	19.5	0.6	-3,000	100	-375	1.80	111
1994	1.82	111	17,836	123	22.3	0.6	-3,000	100	-250	1.82	112
1995	**1.85**	**112**	19,214	128	20.9	0.6	-3,000	100	-50	1.83	112

1) Based on information from the surveys of housing condition 1981, 1988 and 1995 conducted by Statistics Norway. Interpolated number of dwellings and average floor space for the intermediate years.
2) Based on information about the total number and average size of dwellings completed each year from the annual building statistics from Statistics Norway.
3) Based on information from Raadhuus (1997) about the annual investment costs in dwellings for renovation, rebuilding and extensions. It is assumed that 20 % of these investments are related to extensions, and a corresponding investment cost of the extensions of NOK (1996) 7,000 per m^2.
4) Based on estimates from BUMOD about the number of dwellings annually merged with another unit (Barlindhaug, 1996).

The number of dwellings annually demolished or left empty each year in Table A1.1 is estimated to have been 5,000 units until 1983, 4,000 units between 1984 and 1990, and 3,000 units from 1991 onwards. The reason for the lower number is reduced construction activity during the

1990s, a growing attitude amongst people against demolishing houses, and few dwellings destroyed by fire[14].

The number of dwellings departing the stock because they are integrated (merged) with another unit is based on estimates from BUMOD (Barlindhaug, 1996). Three activities have been especially important the last decades: the merging of two smaller apartments in blocks of flats into a larger unit, the integration of a smaller apartment with the main apartment in small houses, and the conversion of a horizontally divided two-family house into a single-family house. Most of the old blocks of flats typically containing small apartments have already been retrofitted. Many of the smaller apartments in small houses have also been integrated with the larger unit, as well as a large number of the horizontally divided two-family houses has been converted to single-family houses. Based on this, the number of dwellings being merged may be assumed to have declined from about 2,000 in the beginning of the 1980s, to almost zero in 1995.

It should be noted that the surveys of housing conditions refer to dwelling floor space (boligareal), while utility floor space (bruksareal) is used for completed dwellings in the annual building statistics. Utility floor space includes storage rooms and closets, and is therefore a little larger than dwelling floor space that does not.

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[14] In 1993, there were 450 to 500 fires in residential buildings in Norway which involved damages above 500,000 NOK (DBE, 1995). A fire causing damages of 500,000 NOK, however, does not necessarily imply that the dwelling is destroyed. Thus, the yearly number of dwellings destroyed in fire each year can be estimated to be a couple of hundreds at most.

APPENDIX 2 – DESCRIPTION OF STEREOTYPES OF HOUSES 1991 - 1998

Close to 150,000 dwellings were completed between 1991 and 1998 according to Statistics Norway. As a part of the local treatment of building projects, new buildings are classified into one of 21 detailed groups according to type of building. This information is thereafter reported to the GAB register by the building inspectors. Table A2.1 shows the 21 building types and the corresponding number of dwellings and average utility floor space of the dwellings constructed between 1991 and 1998. The average size of the dwellings constructed was 122 m^2, ranging from 204 m^2 in detached dwelling houses on farm, to 70 m^2 in dwellings in multi-dwelling houses with more than four storeys. In the table, the detailed groups are merged into three main groups to correspond with the main division used in the dwelling stock model.

Table A2.1 Number of dwellings completed between 1991 and 1998 by type of building. Average size of dwellings (utility floor space per dwelling unit), and total utility floor space. Based on information from the Building Statistics (Statistics Norway, 1999).

Type of building	Data from SSB				Estimated numbers for the dwelling stock model		
	No. of dwellings	Avg. size	Total utility floor space		Dwelling units per building	No. of buildings	Avg. size of building
		m^2	1,000 m^2				m^2
Detached houses	**71,779**	**161**	**11,548**	**100%**	**1.1**	**63,040**	**183**
1 Detached house	51,585	174	8,955	78%	1	51,585	174
2 Detached house with 2 dwelling units	17,479	117	2,039	18%	2	8,740	233
11 Dwelling house on farm, detached	2,715	204	553	5%	1	2,715	204
Divided small houses	**55,500**	**91**	**5,029**	**100%**	**2.7**	**20,220**	**249**
3 Semi-detached house	10,865	112	1,219	24%	2	5,433	224
4 House with 2 dwelling units	2,613	99	259	5%	2	1,307	198
5 Row house (20-21 from 1993)	11,252	87	974	19%	4	2,813	346
6 Linked house, atrium (22-23 from 1993)	1,717	100	171	3%	2	859	200
7 House with 3 or 4 dwellings	10,135	79	804	16%	4	2,534	317
12 Dwell. house on farm, semi-detached	131	153	20	0%	2	66	306
13 Dwell. house on farm, with 2 dwell. units	218	133	29	1%	2	109	267
18 Other type of dwellings	8,214	72	593	12%	4	2,054	289
19 Extensions	3,704	91	338	7%	1	3,704	91
20 Row houses with 3 or 4 dwelling units	2,039	107	219	4%	4	510	429
21 Row houses with 5 or more dwell. units	1,802	96	173	3%	6	300	576
22 Linked detached houses, 2-4 dwell. units	392	133	52	1%	3	131	400
23 Linked detached houses, > 4 dwell. units	245	92	23	0%	6	41	553
24 Two-storey building, > 4 dwell. units	2,173	72	156	3%	6	362	431
Large houses	**22,369**	**76**	**1,744**	**100%**	**19.4**	**1,155**	**1,510**
8 Multi-dwelling house, 3 or 4 storeys	10,685	81	861	49%	16	668	1,289
9 Multi-dwelling house, 5 storeys and over	7,206	70	504	29%	24	300	1,677
10 Terraced house	2,187	101	220	13%	24	91	2,415
31-99 Other buildings than dwellings	2,291	70	159	9%	24	95	1,668
Total dwelling stock	**149,648**	**122**	**18,320**			**84,414**	

For the purpose of the dwelling stock model, Table A2.1. also shows estimates on the number of dwelling units per building for each of the 21 detailed groups of building types. The total number of buildings is calculated by dividing the total number of dwelling units within each group, by the assumed number of dwelling units per building. Table A2.1 further shows that the average detached house constructed between 1991 and 1998 had 1.1 dwelling units and a total utility floor space of 183 m^2. The average divided small house had correspondingly 2.7 dwelling units and a floor space of 249 m^2, while the average large house had 19.4 dwelling units and a total floor space of 1,155 m^2.

Detached houses containing one dwelling unit represent as much as 83 % of the total utility floor space in the group of detached houses. The remaining share is found in detached houses having one supplementary dwelling. The supplementary dwelling is normally rather small, and even though main dwelling unit is relatively large, the average size of the to units (117 m^2) is significantly smaller than for detached houses with one dwelling unit only (174 m^2). A 1 ½ storey house with full basement and a utility floor space of 183 m^2 is defined as stereotype of house for detached houses constructed between 1991 and 1998. The stereotype is assumed to be representative for 63,040 detached houses, including a total of 71,779 dwelling units and a total utility floor space of 11.5 million m^2.

Vertically divided houses (semi-detached houses, row houses and linked houses) represent 57 % of the total utility floor space in divided small houses constructed between 1991 and 1998. The remaining share of the total utility floor space was evenly distributed between horizontally divided small houses (houses with two dwelling units, and houses with 3-4 dwelling units) and other types of divided small houses. A vertically divided house is defined as stereotype of house for divided small houses constructed between 1991 and 1998. The building is assumed be a two-storey house with a total utility floor space of 249 m^2. The building is taken to be representative for a total of 55,500 dwelling units having a total utility floor space of 5.0 million m^2.

Multi-dwelling houses with three or more storeys represent close to 80 % of the total utility floor area in the group of large houses constructed between 1991 and 1998, while 13 % is found in terraced houses and 9 % in other types of buildings (combined residential/commercial buildings). A four-storey block of flats is defined as stereotype of house for large houses constructed between 1991 and 1998. The building is assumed to have a total utility floor space of 1,510 m^2, and is taken to be representative for a total of 22,369 dwelling units having a total utility floor space of 1.7 million m^2.

Table A2.2 shows the fifteen sub-groups of dwellings of the dwelling stock model per December 1998 with the corresponding total number of dwelling units, average floor space per dwelling and total floor space for the sub-groups. The stereotypes of houses defined for the dwelling stock per 1990 are assumed representative for today's dwelling stock constructed before 1991 with regard to energy use per square metre. But the size and number of the dwellings constructed before 1991 have changed from 1990 to 1998 to departure and extensions of dwellings.

These changes are accounted in Table A2.2 by estimating the total floor space of departure and extensions of existing dwellings from 1991 to 1998. The percentages of departure correspond with a total number of about 3,000 dwellings units per year. The table further shows that the total number of dwellings in the stock is estimated to have increased from 1.75 million units in 1990, to 1.88 million units in 1998 and the total floor space from 191 to 211 million m^2. The average size of all the dwellings is calculated to have increased from 109 m^2 per dwelling in 1990, to 112 m^2 in 1998.

Table A2.2. Total number, average size and total floor space of the dwelling stock in December 1998 by type of house and year of construction. Based on the dwelling stock per 1990, added the number of dwellings completed between 1991 and 1998, added the total floor space of extensions of existing dwellings, subtracted the number of existing dwellings assumed departing the stock. DH = detached houses, DSH = divided small houses, LH = large houses.

	Stock per 1990			Departure		Extensions		Stock per December 1998		
	Number of units	Avg. size	Total floor space	annual %	Total fl. space 91-98	annual %	Total fl. space 91-98	Number of units	Avg. size	Total floor space
	1,000	m^2	Mill m^2		Mill m^2		Mill m^2	1,000	m^2	Mill. m^2
DH	**1,018**	**125**	**127**					**1,076**	**130**	**140**
-56	384	121	46	-0.30%	-1.1	0.30%	1.1	375	124	46
56-70	235	118	28	-0.25%	-0.6	0.30%	0.7	231	121	28
71-80	215	133	29			0.30%	0.7	215	137	29
81-90	184	133	24			0.30%	0.6	184	136	25
91-98								72	161	12
DSH	**380**	**98**	**37**					**431**	**99**	**43**
-56	121	92	11					118	94	11
56-70	94	101	10	-0.30%	-0.3	0.30%	0.3	92	103	10
71-80	87	101	9	-0.25%	-0.2	0.30%	0.2	87	103	9
81-90	78	101	8			0.30%	0.2	78	103	8
91-98	0					0.30%	0.2	56	91	5
LH	**353**	**74**	**26**					**370**	**74**	**28**
-56	142	75	11					138	75	10
56-70	107	68	7	-0.30%	-0.3			105	68	7
71-80	72	79	6	-0.25%	-0.1			72	79	6
81-90	32	78	2					32	78	2
91-98	0							22	81	2
Total stock	**1,751**	**109**	**191**		**-2.5**		**4.0**	**1,877**	**112**	**211**

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APPENDIX 3 - INPUT DATA FOR THE DWELLING STOCK MODEL

DETACHED HOUSES	Before 1956					1956-1970					1971-1980					1981-1990					1991-1898				1999-2030			
	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Medium	High	Heat pump	Low	Medium	High	Heat pump
Average dwelling size (m^2)	124					121					137					136									153			
Dwellings/house	1.00					1.00					1.00					1.00									1.33			
Indoor air temperature (°C)	19.4	19.4	22	22	22	19.9	19.9	22	22	22	19.9	19.9	22	22	22	19.9	19.9	22	22	22	20.2	22	22	22	22	22	22	22
Infiltration (1/h)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ventilation (1/h)	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.5
% with vent. heat rec.	0%	0%	0%	100%	0%	0%	0%		100%	0%	0%	0%		100%	0%	0%	0%		100%	0%	10%	10%	100%	10%	0%	100%	100%	0%
Efficiency of heat rec.	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
Domestic hot water (kWh)	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	2250	4500
Window area (% of floor)	0.2					0.15					0.15					0.15					0.15				0.15			
Solar factor	0.71	0.63	0.63	0.55	0.63	0.77	0.63	0.63	0.55	0.63	0.78	0.63	0.63	0.55	0.63	0.78	0.63	0.63	0.6	0.63	0.68	0.68	0.68	0.63	0.63	0.63	0.55	0.63
South	35%					35%					35%					35%					35%				38%			
East	20%					20%					20%					20%					20%				19%			
North	10%					10%					10%					10%					10%				24%			
West	35%					35%					35%					35%					35%				19%			
Walls (W/m^2K)	0.55	0.55	0.25	0.20	0.55	0.39	0.39	0.22	0.18	0.39	0.38	0.38	0.22	0.18	0.38	0.26	0.26	0.18	0.18	0.26	0.26	0.26	0.26	0.26	0.27	0.20	0.14	0.27
Ceiling (W/m^2K)	0.38	0.38	0.20	0.15	0.38	0.32	0.32	0.20	0.15	0.32	0.20	0.20	0.20	0.15	0.20	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.15	0.12	0.08	0.15
Floors (W/m^2K)	0.53	0.53	0.20	0.20	0.53	0.27	0.27	0.20	0.20	0.27	0.36	0.36	0.20	0.20	0.36	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.15	0.13	0.10	0.15
Doors (W/m^2K)	2.50	1.20	1.00	0.80	1.20	2.50	1.20	1.00	0.80	1.20	2.50	1.20	1.00	0.80	1.20	1.50	1.20	1.00	0.80	1.20	1.50	1.50	1.50	1.50	1.20	1.00	0.80	1.20
Windows (W/m^2K)	2.24	1.60	1.20	1.00	1.60	2.72	1.60	1.20	1.00	1.60	2.80	1.60	1.20	1.00	1.60	2.00	1.60	1.20	1.00	1.60	1.80	1.80	1.80	1.80	1.60	1.20	1.00	1.60
Lighting (W/m^2)	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	2.00	1.00	3.00	3.00	2.00	1.00	3.00
Persons (W/m^2)	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Electric equipment (W/m^2)	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.35	2.00	2.70	2.70	2.35	2.00	2.70
Supplied energy use for space heating and ventilation																												
El	50%	50%	50%	50%	20%	47%	47%	47%	47%	20%	47%	47%	47%	47%	20%	61%	61%	61%	61%	20%	90%	90%	90%	20%	100%	100%	100%	20%
Oil	17%	17%	17%	17%		18%	18%	18%	18%		18%	18%	18%	18%		13%	13%	13%	13%		0%				0%			
Bio	33%	33%	33%	33%		35%	35%	35%	35%		35%	35%	35%	35%		26%	26%	26%	26%		10%	10%	10%		0%			
Heat pump	0%				80%	0%				80%	0%				80%	0%				80%	0%			80%	0%			80%
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplied energy use for hot water production																												
El	100%	100%	100%	100%	20%	100%	100%	100%	100%	20%	100%	100%	100%	100%	20%	100%	100%	100%	100%	20%	100%	100%	100%	20%	100%	100%	100%	20%
Oil	0%					0%					0%					0%					0%				0%			
Bio	0%					0%					0%					0%					0%				0%			
Heat pump	0%				80%	0%				80%	0%				80%	0%				80%	0%			80%	0%			80%
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

DIVIDED SMALL HOUSES	Before 1956					1956-1970					1971-1980					1981-1990					1991-1898				1999-2030			
	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Medium	High	Heat pump	Low	Medium	High	Heat pump
Average dwelling size (m^2)	94					103					103					103					91				94			
Dwellings/house	2					4					4					4					2.74				4			
Indoor air temperature (°C)	20.5	20.5	22	22	22	20.7	20.7	22	22	22	20.7	20.7	22	22	22	20.7	20.7	22	22	22	20.7	22	22	22	22	22	22	22
Infiltration (1/h)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ventilation (1/h)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.5
% with vent. heat rec.	0%	0%		100%	0%	0%	0%		100%	0%	0%	0%		100%	0%	0%	0%		100%	0%	10%	10%	100%	10%	0%	100%	100%	
Efficiency of heat rec.	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
Domestic hot water (kWh)	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	2000	4000
Window area (% of floor)	0.2					0.15					0.15					0.15					0.15				0.15			
Solar factor	0.71	0.63	0.63	0.55	0.63	0.77	0.63	0.63	0.55	0.63	0.78	0.63	0.63	0.55	0.63	0.68	0.63	0.63	0.55	0.63	0.68	0.68	0.68	0.63	0.63	0.63	0.55	0.63
South	35%					60%					60%					35%					60%				55%			
East	20%					0%					0%					20%					0%				5%			
North	10%					40%					40%					10%					40%				35%			
West	35%					0%					0%					35%					0%				5%			
Walls (W/m^2K)	0.55	0.55	0.25	0.20	0.55	0.39	0.39	0.22	0.18	0.39	0.38	0.38	0.22	0.18	0.38	0.26	0.26	0.18	0.18	0.26	0.26	0.26	0.26	0.26	0.27	0.20	0.14	0.27
Ceiling (W/m^2K)	0.38	0.38	0.20	0.15	0.38	0.32	0.32	0.20	0.15	0.32	0.20	0.20	0.20	0.15	0.20	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.15	0.12	0.08	0.15
Floors (W/m^2K)	0.51	0.51	0.20	0.20	0.51	0.26	0.26	0.20	0.20	0.26	0.20	0.20	0.20	0.20	0.20	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.15	0.13	0.10	0.15
Doors (W/m^2K)	2.50	1.20	1.00	0.80	1.20	2.50	1.20	1.00	0.80	1.20	2.50	1.20	1.00	0.80	1.20	1.50	1.20	1.00	0.80	1.20	1.50	1.50	1.50	1.50	1.20	1.00	0.80	1.20
Windows (W/m^2K)	2.24	1.60	1.20	1.00	1.60	2.72	1.60	1.20	1.00	1.60	2.80	1.60	1.20	1.00	1.60	2.00	1.60	1.20	1.00	1.60	1.80	1.80	1.80	1.80	1.60	1.20	1.00	1.60
Lighting (W/m^2)	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	2.00	1.00	3.00	3.00	2.00	1.00	3.00
Persons (W/m^2)	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Electric equipment (W/m^2)	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.35	2.00	2.70	2.70	2.35	2.00	2.70
Supplied energy use for space heating and ventilation																												
El	64%	64%	64%	64%	20%	59%	59%	59%	59%	20%	59%	59%	59%	59%	20%	71%	71%	71%	71%	20%	90%	90%	90%	20%	100%	100%	100%	20%
Oil	16%	16%	16%	16%		18%	18%	18%	18%		18%	18%	18%	18%		13%	13%	13%	13%		0%				0%			
Bio	20%	20%	20%	20%		23%	23%	23%	23%		23%	23%	23%	23%		16%	16%	16%	16%		10%	10%	10%		0%			
Heat pump	0%				80%	0%				80%	0%				80%	0%				80%	0%			80%	0%			80%
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplied energy use for hot water production																												
El	100%	100%	100%	100%	20%	100%	100%	100%	100%	20%	100%	100%	100%	100%	20%	100%	100%	100%	100%	20%	100%	100%	100%	20%	100%	100%	100%	20%
Oil	0%					0%					0%					0%					0%				0%			
Bio	0%					0%					0%					0%					0%				0%			
Heat pump	0%				80%	0%				80%	0%				80%	0%				80%	0%			80%	0%			80%
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

LARGE HOUSES	Before 1956					1956-1970					1971-1980					1981-1990					1991-1898				1999-2030			
	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Low	Medium	High	Heat pump	Unimproved	Medium	High	Heat pump	Low	Medium	High	Heat pump
Average dwelling size (m^2)	75					68					79					78					81	81	81	81	79			
Dwellings/house	8					24					24					24					19.37	19	19	19	16			
Indoor air temperature (^oC)	21.5	21.5	22	22	22	21.1	21.1	22	22	22	21.2	21.2	22	22	22	21.4	21.4	22	22	22	21.4	22	22	22	22	22	22	22
Infiltration (1/h)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ventilation (1/h)	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.5	0.2	0.3	0.3	0.3	0.5	0.3	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
% with vent. heat rec.	0%	0%		100%	0%	0%	0%		100%	0%	0%	0%		100%	0%	25%	25%	25%	100%	25%	75%	75%	100%	75%	0%	100%	100%	0%
Efficiency of heat rec.	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
Domestic hot water (kWh)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	1750	3500
Window area (% of floor)	0.2					0.15					0.15					0.15					0.15				0.15			
Solar factor	0.75	0.63	0.63	0.55	0.63	0.75	0.63	0.63	0.55	0.63	0.78	0.63	0.63	0.55	0.63	0.68	0.63	0.63	0.55	0.63	0.68	0.68	0.68	0.63	0.63	0.63	0.55	0.63
South	60%					60%					60%					60%					60%				55%			
East	0%					0%					0%					0%					0%				5%			
North	40%					40%					40%					40%					40%				35%			
West	0%					0%					0%					0%					0%				5%			
Walls (W/m^2K)	0.82	0.82	0.30	0.25	0.82	0.67	0.67	0.30	0.20	0.67	0.49	0.49	0.30	0.20	0.49	0.35	0.35	0.25	0.20	0.35	0.27	0.27	0.27	0.27	0.27	0.20	0.14	0.27
Ceiling (W/m^2K)	0.36	0.36	0.20	0.15	0.36	0.28	0.28	0.20	0.15	0.28	0.20	0.20	0.20	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.15	0.12	0.08	0.15
Floors (W/m^2K)	0.39	0.39	0.20	0.20	0.39	0.34	0.34	0.20	0.20	0.34	0.24	0.24	0.24	0.24	0.24	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.15	0.13	0.10	0.15
Doors (W/m^2K)	2.50	1.20	1.00	0.80	1.20	2.50	1.20	1.00	0.80	1.20	2.50	1.20	1.00	0.80	1.20	1.50	1.20	1.00	0.80	1.20	1.50	1.50	1.50	1.50	1.20	1.00	0.80	1.20
Windows (W/m^2K)	2.56	1.60	1.20	1.00	1.60	2.56	1.60	1.20	1.00	1.60	2.80	1.60	1.20	1.00	1.60	2.00	1.60	1.20	1.00	1.60	1.80	1.80	1.80	1.80	1.60	1.20	1.00	1.60
Lighting (W/m^2)	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	2.00	1.00	3.00	3.00	2.00	1.00	3.00
Persons (W/m^2)	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Electric equipment (W/m^2)	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.70	2.35	2.00	2.70	2.70	2.35	2.00	2.70	2.70	2.35	2.00	2.70
Supplied energy use for space heating and ventilation																												
El	56%	56%	56%	56%	20%	69%	69%	69%	69%	20%	69%	69%	69%	69%	20%	78%	78%	78%	78%	20%	90%	90%	90%	20%	100%	100%	100%	20%
Oil	35%	35%	35%	35%		24%	24%	24%	24%		24%	24%	24%	24%		17%	17%	17%	17%		5%	5%	5%		0%			
Bio	9%	9%	9%	9%		7%	7%	7%	7%		7%	7%	7%	7%		5%	5%	5%	5%		5%	5%	5%		0%		0%	
Heat pump	0%				80%	0%				80%	0%				80%	0%				80%	0%			80%	0%			80%
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplied energy use for hot water production																												
El	56%	56%	56%	56%	20%	69%	69%	69%	69%	20%	69%	69%	69%	69%	20%	78%	78%	78%	78%	20%	90%	90%	90%	20%	100%	100%	100%	20%
Oil	35%	35%	35%	35%		24%	24%	24%	24%		24%	24%	24%	24%		17%	17%	17%	17%		5%	5%	5%		0%			
Bio	0%					0%					0%					0%					0%				0%			
Heat pump	0%				80%	0%				80%	0%				80%	0%				80%	0%			80%	0%			80%
Sum	91%	91%	91%	91%	100%	93%	93%	93%	93%	100%	93%	93%	93%	93%	100%	95%	95%	95%	95%	100%	95%	95%	95%	100%	100%	100%	100%	100%

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They are actively engaged in initiating projects for R&D and information exchange, organising workshops, symposia and congresses and producing publications of acknowledged global repute.

It is their ability to bring a multi-national and multi-disciplinary approach to bear on the subject matter delineated in their Terms of Reference that is their strength.

CIB Members come from institutes, companies, partnerships and other types of organisations as well as individual experts involved in research or in the transfer or application of research results. More than 130 Universities worldwide have joined.

CIB is an Association that utilises the collective expertise of its membership to foster innovations and to create workable solutions to technical, economic, social and organisational problems within its competence.

Details on Membership and Activities are obtainable from the General Secretariat at the address above.

CIB TASK GROUPS (TG) AND WORKING COMMISSIONS (W)

(as at 1st May 2000)

Task Groups

TG17 Protection Against Electromagnetic Radiation
TG19 Designing for the Ageing Society
TG20 Geographical Information Systems
TG21 Climatic Data for Building Services
TG22 Environmental Design Methods in Materials and Structural Engineering (also RILEM TC EDM)
TG23 Culture in Construction
TG25 Facade Systems and Technologies
TG27 Human-Machine Technologies for Construction Sites
TG28 Dissemination of Indoor Air Sciences (joint CIB-ISIAQ Task Group)
TG29 Construction in Developing Countries
TG31 Macro-Economic Data for the Construction Industry
TG32 Public Perception of Safety and Risks in Civil Engineering (joint CIB-IABSE Group)
TG33 Concurrent Engineering in Construction
TG34 Regeneration of the Built Environment
TG35 Innovation Systems in Construction
TG36 Quality Assurance
TG37 Performance Based Building Regulatory Systems
TG38 Urban Sustainability
TG39 Deconstruction
TG40 Informal Settlements
TG41 Benchmarking Construction Performance
TG42 Performance Criteria of Buildings for Health and Comfort (Joint CIB – ISIAQ Task Group)

Working Commissions

W014 Fire
W018 Timber Structures
W023 Wall Structures
W024 Open Industrialisation in Building
W040 Heat and Moisture Transfer in Buildings
W051 Acoustics
W055 Building Economics
W056 Sandwich Panels (joint CIB - ECCS Commission)
W060 Performance Concept in Building
W062 Water Supply and Drainage
W063 Affordable Housing
W065 Organisation and Management of Construction
W067 Energy Conservation in the Built Environment
W069 Housing Sociology
W070 Facilities Management and Maintenance
W077 Indoor Climate
W078 Information Technology for Construction

CIB TASK GROUPS (TG) AND WORKING COMMISSIONS (W)
(as at 1st May 2000)

W080 Prediction of Service Life of Building Materials and Components (also RILEM SLM)
W082 Future Studies in Construction
W083 Roofing Materials and Systems (also RILEM MRS)
W084 Building Non-Handicapping Environments
W085 Structural Serviceability
W086 Building Pathology
W087 Post-Construction Liability and Insurance
W089 Building Research and Education
W092 Procurement Systems
W094 Design for Durability
W096 Architectural Management
W098 Intelligent and Responsive Buildings
W099 Safety and Health on Construction Sites
W100 Environmental Assessment of Buildings
W101 Spatial Planning and Infrastructure Development
W102 Information and Knowledge Management in Building
W103 Construction Conflict: Avoidance and Resolution
W104 Open Building Implementation

CIB HOME PAGE

WWW.CIBWORLD.NL

The CIB home page contains the following main and publicly accessible sections:

1. General Information
2. Newsletter
3. Databases

General Information

Included is General Information about CIB in the following sub-sections:

- Introduction, including among others: CIB in the past and present
- Mission Statement
- Membership which includes information on the various types of CIB Membership and on developments in the composition of the CIB Membership
- Organisation, including the composition of the CIB Board and its Standing Committees and of the CIB General Secretariat and links with the CIB Partner Organisations
- Programme of Activities
- Services to Members, and in addition the possibilities for Members to participate in CIB's Programme of Activities
- Fee System and How To Join, including the description of the current Membership Fee Levels and the option to electronically request a Membership Application Form

Newsletters

In this section electronic copies are included of the various issues of INFORMATION, the CIB Bi-Monthly Newsletter, as published over the last couple of years. Also included is an Index to facilitate searching articles on certain topics published in all included issues of Information.

Databases

This is the largest section in the CIB home page. It includes fact sheets in separate on-line regularly updated databases, with detailed searchable information as concerns:

- ± 500 CIB Member Organisations, including among others: descriptions of their Fields of Activities, contact information and links with their Websites
- ± 5000 Individual Contacts, with an indication of their Fields of Expertise, photo and contact information

- ± 50 CIB Task Groups and Working Commissions, with a listing of their Coordinators and Members, Scope and Objectives, Work Programme and Planned Outputs, Publications produced so far, and Schedule of Meetings
- ± 100 Publications, originating to date from the CIB Task Groups and Working Commissions, with a listing of their contents, price and information on how to order
- ± 250 Meetings, including an indication of subjects, type of Meeting, dates and location, contact information and links with designated websites for all CIB Meetings (± 50 each year) and all other international workshops, symposia, conferences, etc. of potential relevance for people interested in research and innovation in the area of building and construction

Searchable Data: an Example

Searching for certain publications in the Databases in the CIB home page can be done in the following three ways:

1. In the home page itself a pre-selection is included of all recent CIB publications (published in the last 4 to 6 months). By clicking on "New Publications" the respective list will appear. By clicking on a title in this list the information fact sheet about this Publication will appear, including the option for an electronic order if it concerns a publication produced by the CIB Secretariat.
2. In the description of a Task Group or Working Commission in the database "Commissions" a pre-programmed selection is included of all publications produced under the responsibility of each Commission.
3. In the database "Publications" one can search, for example, for all publications on a certain topic, by simply typing the word that covers this topic in the box "Title" in the search page that appears when one asks for this database.

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