Sustainable Buildings for the High North. Energy performance of current building stock in Scandinavia and Russia

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11.6.2015 ::

Metatiedot

Nimeke: Sustainable Buildings for the High North. Energy performance of current building stock in Scandinavia and Russia

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Aihe, asiasanat: asuinrakennukset, ekologinen rakentaminen, energiankulutus energiantuotanto, energiatehokkuus, kestävä kehitys, korjausrakentaminen, kunnostus, Norja, Pohjoismaat, päästöt rakennuskanta, rakennustekniikka, rakentaminen, Ruotsi, Suomi, uusiutuvat energialähteet, Venäjä Building technology, Buildings, Energy, Energy consumption, Finland, Norway, Renewable energy sources, Russia, Scandinavia, Sustainable buildings, Sustainable construction, Sweden

Aihe, luokitus:

Tiivistelmä: Worldwide, buildings are responsible for one-third of the total final energy consumption, and are among most significant creators of carbon dioxide emissions. Due to constantly increasing prices of energy and changing environmental circumstances, more emphasis is given on the discovery of energy efficient solutions. Exploitation of energy efficient technological solutions and renewable energy sources provide environmental friendly and cost-effective alternatives also for renovation of buildings and living.

Local infrastructure as well as directives, laws and standards set by the European Union and governments guide energy performance of buildings and implementation of renovations. By adjusting and unifying regulations, the challenges of cold climate could be encountered in sustainable manner and cross-border trade accelerated in the high north, where vast resources are available.

In this report, building stock, renovation status, energy production and usage are discussed in Finland, Sweden, Norway and Russia. The work is mainly done for the purposes of the SBHN-project. The goals of the Sustainable Buildings for the High North (SBHN) -project are to discover arctic climate- adjusted methods to improve energy efficiency of residential apartment buildings and to enhance cross-border trade between Scandinavian countries and Russia.

The results of the project are expected to promote various business opportunities and the development of close co-operation between the northern countries in the fields of building technology industry, innovative research and education among companies, universities, colleges and the authorities.

Julkaisija: Oulun ammattikorkeakoulu, Oamk

Aikamääre: Julkaistu 2015-06-11

Pysyvä osoite: http://urn.fi/urn:isbn:978-951-597-128-9

Kieli: englanti

ISBN: 978-951-597-128-9 (HTML)

Suhde: http://urn.fi/URN:ISSN:1798-2022, ePooki - Oulun ammattikorkeakoulun tutkimus- ja kehitystyön julkaisut

Näin viittaat tähän julkaisuun

Sirviö, A. & Illikainen, K. 2015. Sustainable Buildings for the High North. Energy performance of current building stock in Scandinavia and Russia. ePooki. Oulun ammattikorkeakoulun tutkimus- ja kehitystyön julkaisut 17. Hakupäivä 12.6.2015. http://urn.fi/urn:isbn:978-951-597-128-9 (http://urn.fi/urn:isbn:978-951-597-128-9).

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Summary

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Preface

The global rate of energy consumption is constantly growing along the energy prices. The progress of climate change forces the implementation of international and national level legislation, and standards are set to restrain the energy consumption and carbon dioxide emission levels (e.g. [1] (#cite-text-0-0)).

Globally, buildings comprise the largest energy consuming and carbon dioxide emission producing sector. On average 40 % of the primary energy is consumed in buildings, in comparison to the proportions of traffic 32 %, industry 24 % and agriculture 2 % (in EU 2010). Depending on the source and the processing method, considerable amount of carbon dioxide emissions are released in the stages of energy production.

The goals of the Sustainable Buildings for the High North (SBHN) -project are to discover arctic climate- adjusted methods to improve energy efficiency of residential apartment buildings and to enhance cross-border trade.

Finland and Sweden as member states are obligated to follow the set energy directives by EU. Norway and Russia have more national legislation-based decrees although both states have agreed to comply parts of the most important energy efficiency directive, EPBD. National level energy regulations and building codes guide the methods to calculate the energy consumption in the building stock. These issues are discussed in more detail in reports produced by other Work Packages of the project (e.g. Work Package 2, Umeå University).

In this report the energy performance of residential apartment buildings are discussed along the national level energy production and consumption in Norway, Sweden, Finland and

Russia. The report gives rather general level overview of the energy balances and energy usage in buildings. The data is gathered from various sources across the years and is mainly based on the published estimations. Not all the information of building energy use were available for the studied countries. In general level, versatile definitions of floor areas (external and internal gross, heated, net and treated parts of building) and lack of common building categories induce challenges in performing between-country comparisons [1] (#cite-text-0-0). Direct cross-border comparisons are done with caution as some uncertainties exist regarding the definitions.

1 Introduction

The concentrated gross floor space of European buildings equals roughly the area of Belgium which is 30,528 km^2 [1] (#cite-text-0-0). The growing population sizes and preference to inhabit larger floor spaces per capita emphasizes the need to improve energy performance of new and existing building stocks to respond to constantly increasing demand of energy. Especially old buildings, characterized by low energy performance level, constitute the vast majority of the European building stock.

Non-residential buildings comprise 25 % of the building stock in Europe. The sector includes offices, educational, wholesale and retail real estates [1] (#cite-text-0-0). Majority of the buildings are residential (75 %), and consequently they form the biggest energy consuming segment in the building sector. Forty percent were constructed before 1960, at the time when regulations guiding energy use in buildings were rather scarce. In a year 2009, households consumed 68 % of the total final energy use in buildings [1] (#cite-text-0-0).

Two third of the residential buildings are single family houses and one third apartment blocks. One in six of all residences locate in high-rise buildings established mainly in the period 1960-1980. According to the estimations, energy- and cost effective refurbishment of the apartment buildings could result in 28 % energy saving potential. The most promising area is Eastern Europe where regionally up to 39 % energy saving potential is reachable [2] (#cite-text-0-5).

European Union has given new directives concerning energy production and performance. The general goal is to reduce energy consumption and CO2 emissions both by 20 % and with the same percentage increase the portion of renewable energy sources by the year 2012. New directives guide energy use in buildings, and the main policy driver is Energy Performance of Buildings Directive (EPBD 2002/91/EC, EPBD recast 2010/31/EU) that imposes requirements for energy certification, construction, training, renovation and inspections for the Member States.

By this report, we aim to survey the energy performance and consumption of building stock in countries of Northern latitudes. The basic knowledge is used in further analysis to discover optimal low cost and high impact methods to improve energy performance of buildings especially in North-Western part of Russia, and to enhance cross border business between neighboring countries.

2 Finland

Finland is inhabited by 5.4 million people. Average density is 18 persons per square kilometer. More than half of the population lives in the southern third of the country. The total area 338 000 km^2 comprises 78 % forest, 10 % water and 8 % cultivated land. One third of the area resides north of the Arctic Circle.

Gross Domestic Production (PPP) was 172.59 billion in 2011. In the following year the value was 194 billion which equals to 35.9 per capita GDP. In 2011, primary energy supply 34.8 mtoe consisted mainly of oil, biofuel and nuclear energy [3] (#cite-text-0-6).

Energy mix of the country is diverse and well balanced. Power plants can be optimized for several fuels. The most important indigenous natural energy resources are hydro power, wood and the wood-like products, peat and pulping liquors. Domestic fuels and hydropower formed about one-third of the primary energy demand in 2009 [3] (#cite-text-0-6). Finland is highly dependent on the supplies of other countries, and substantial share of the energy is imported and refined by private enterprises. Crude oil, oil products, coal and natural gas are the most procured sources. Net import of electricity comprised approximately one fifth of the total supply in 2012 ([4] (#cite-text-0-8), see Tables 6-1, 6-2).

The cornerstones of the energy policy are security of supply, effective energy markets and economy, environmental acceptability and safety [3] (#cite-text-0-6).

2.1 Building stock

In a year 2012 Finnish building stock comprised almost 1.5 million buildings with gross floor area of 449 million square meters, when free-time residences (500 000), agriculture- and economic-related houses were excluded. Buildings are mainly classified according to the intended use; the purpose for which the largest part of the gross floor area of the building is used (see Table 2-1).

TABLE 2-1. Intended use of buildings is grouped by quantity and gross floor area in Finland in 2012 [5] (#cite-text-0-10)

	Number of buildings	**%**	**Gross floor area (km^2)**	**%**
Buildings total	**1 474 653**	**100,0**	**449 518 942**	**100,0**
Detached houses	1 122 315	76,1	156 380 401	34,8
Attached houses	77 931	5,3	33 187 176	7,4
Blocks or flats	57 849	3,9	92 514 761	20,6
Commercial buildings	42 580	2,9	28 320 836	6,3
Office buildings	10 907	0,7	19 229 947	4,3
Traffic buildings	55 915	3,8	12 159 931	2,7
Institutional buildings	8 414	0,6	11 677 272	2,6
Buildings for assembly	13 826	0,9	9 140 984	2,0
Educational buildings	8 916	0,6	18 104 779	4,0
Industrial buildings	41 799	2,8	47 958 684	10,7
Warehouses	28 582	1,9	18 946 162	4,2
Other buildings	5 619	0,4	1 898 009	0,4

The number of buildings has increased by 27 % since year 1990. Generally, Finnish building stock is rather young; only 5 % of buildings are built before 1920 (Figures 2-1, 2-2, [1] (#cite-text-0-0)). The most often used construction materials are wood 81 % and stone 16 % [5] (#cite-text-0-10).

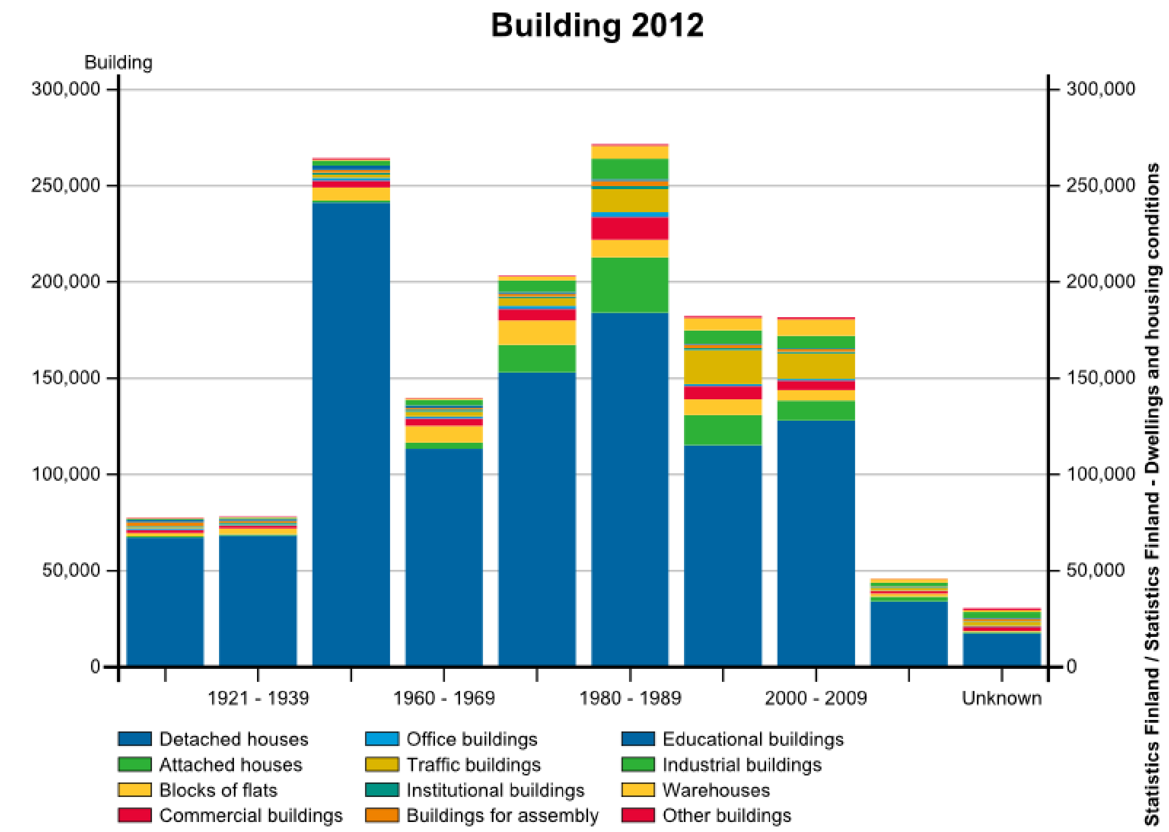


FIGURE 2-1. Finnish buildings classified according to unit number and type across the construction years [1] (#cite-text-0-0). Categories from the left: built before 1920, 1921-1939, 1940-1959, 1960-1969, 1970-1979, 1980-1989, 1990-1999, 2000-2009, 2010-2012, unknown.

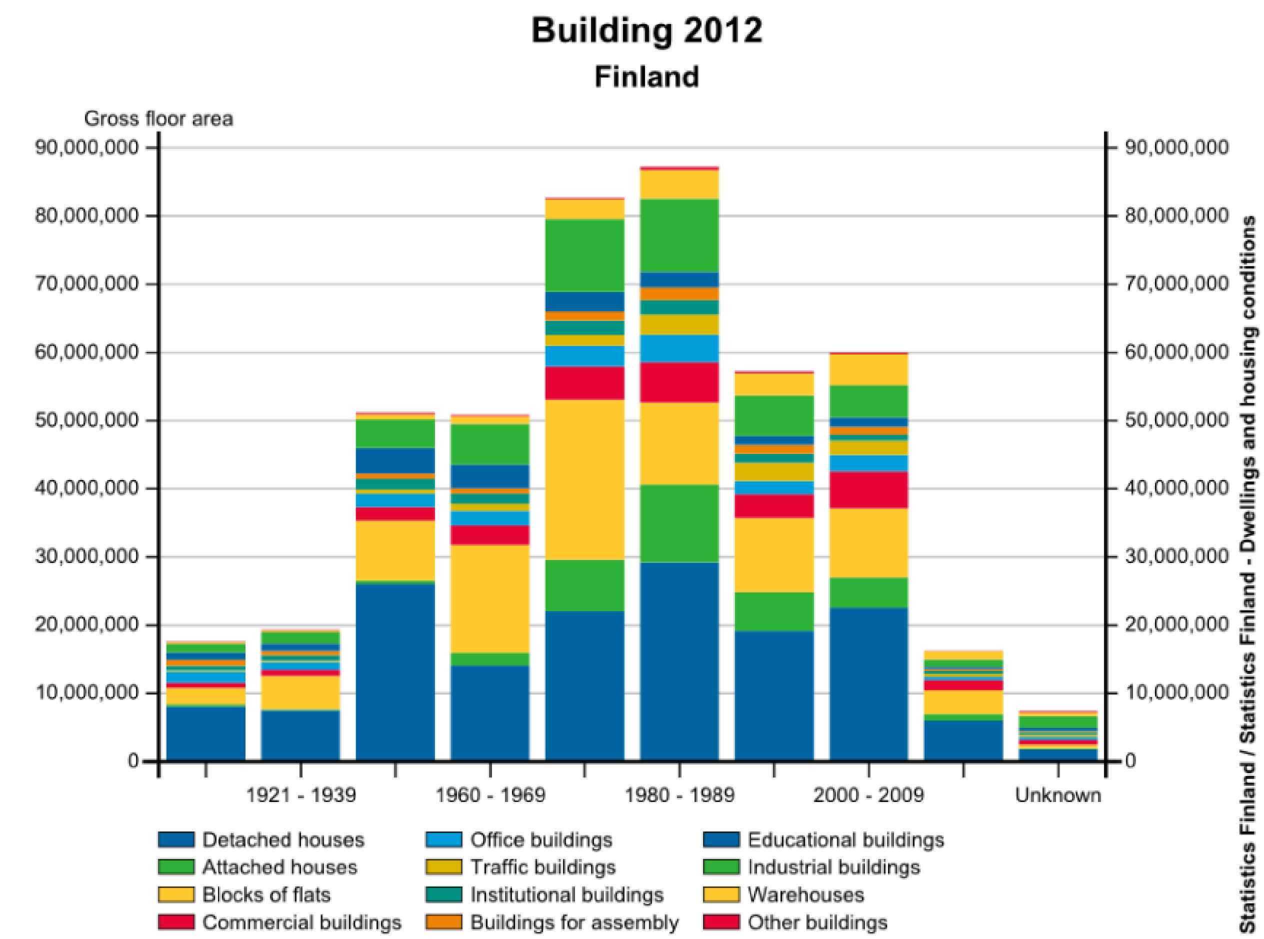


FIGURE 2-2. Buildings presented by gross floor areas and construction decades [2] (#cite-text-0-1). Categories from the left: built before 1920, 1921-1939, 1940-1959, 1960-1969, 1970-1979, 1980-1989, 1990-1999, 2000-2009, 2010-2012, unknown.

2.1.1 Residential buildings and dwellings

Residential buildings form majority of all the buildings with shares 85 % of building units and 63 % of gross floor area (Table 2-1, Figures 2-1 and 2-2). Detached houses compose seventy six percentage (1.1 million) of the total stock which in gross-floor area corresponds to one-third part (Table 2-1, Figure 2-2). The proportion of apartment and attached houses are four (0.58 million) and five percent (0.78 million) of the total stock (Table 2-1, Figure 2-1). In gross floor area the equivalent shares are 20 % and 7 % (Table 2-1, Figure 2-2).

Within residential sector, more than half of the gross floor area is formed by detached houses and one third by apartment buildings (see Table 2-1, Figure 2-2).

More than half of the residential houses are constructed after the 1970s (Figure 2-1). Highest frequency for construction of block of flats was in 1970´s. Almost 13 000 residential buildings were established, which is double of the amount built in the 2000 decade (see Figure 2-3). For the detached houses, the single most construction intensive decade was 1980 (Figure 2-4). Currently, the construction of housing units is centralized in urban regions where 76 % of all the dwellings are built between 1995 and 2012 [5] (#cite-text-0-10). In 2013 major part (68 %) of Finnish people lived in buildings with one or two floors.

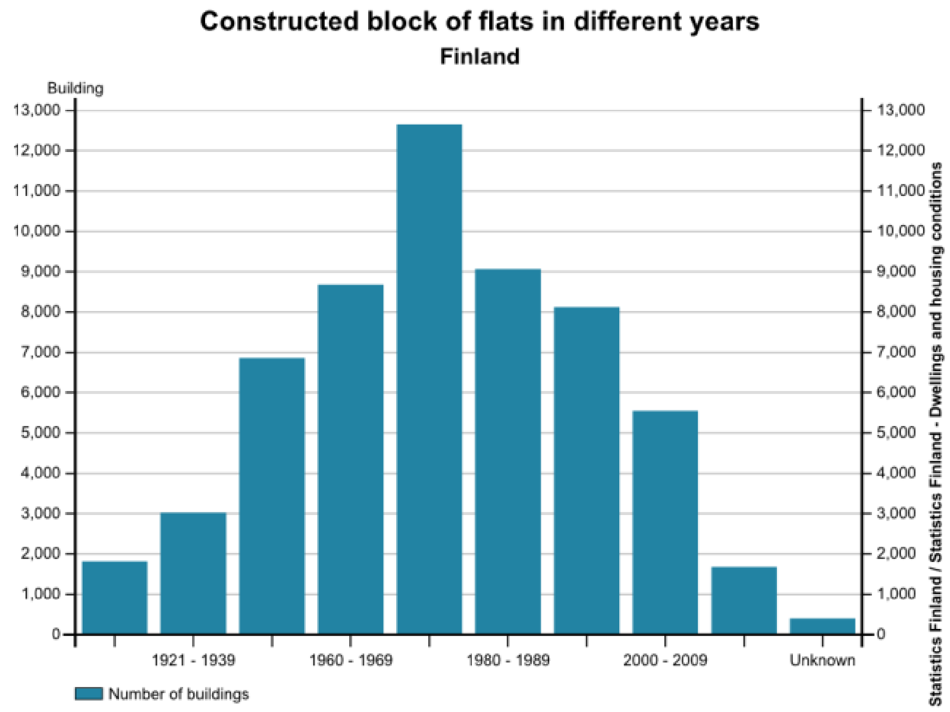


FIGURE 2-3. Number of constructed apartment buildings in Finland across the years, presented in columns as before 1920, 1921-1939, 1940-1959, 1960-1969, 1970-1979, 1980-1989, 2000-2009, 2010-2012, unknown [3] (#cite-text-0-2)

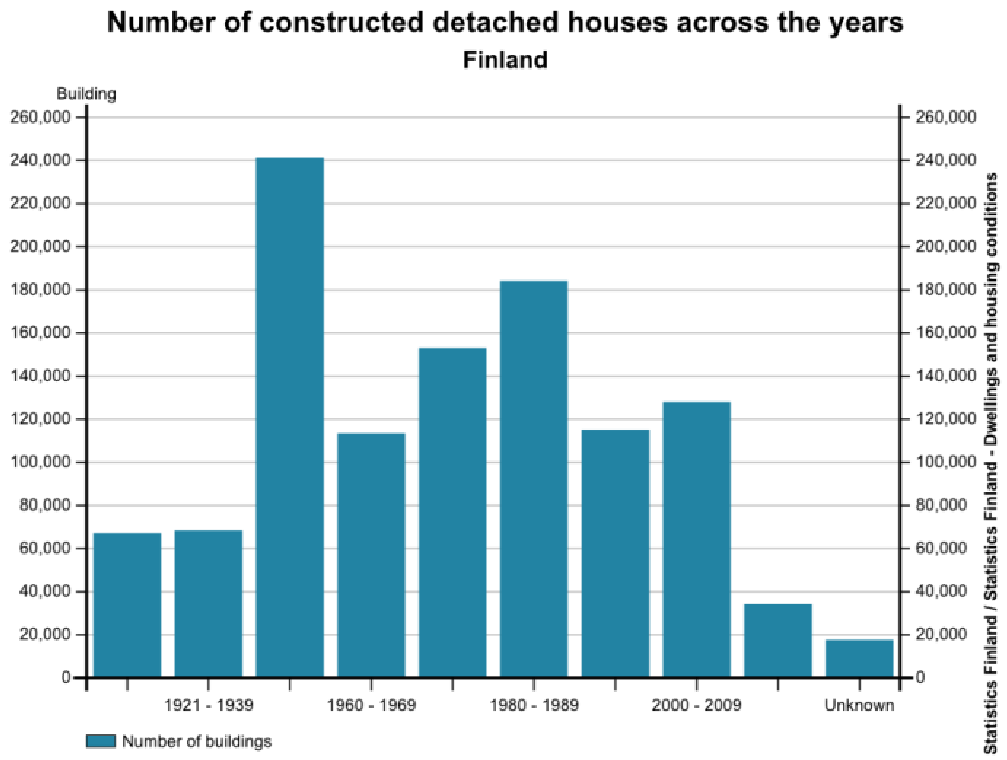


FIGURE 2-4. Construction frequencies are shown for detached houses in different decades in Finland [4] (#cite-text-0-3)

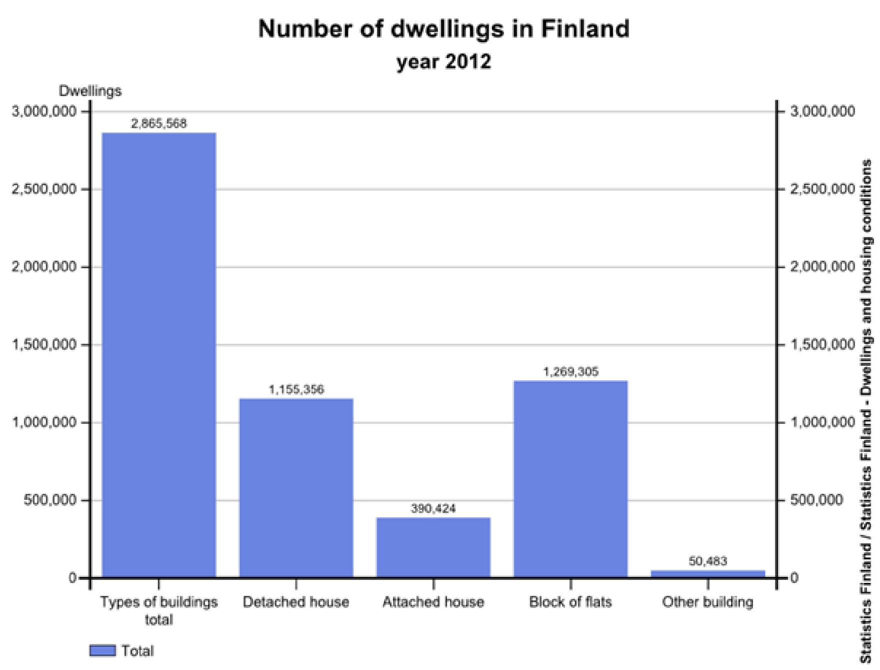


FIGURE 2-5. The total number of dwellings classified according to building types in 2012 [5] (#cite-text-0-4)

The total quantity of dwellings was 2.9 million in 2012 (see Figure 2-5). Since 1990, the number has increased by 656 000, or annually by 30 000. Largest proportion of dwelling units has been constructed in 1970-1980s. In comparison to preceding decade the growth of building stock was slowed in 2012.

In spite of the relatively high proportion of detached buildings, the share of dwelling units in block of flats with 44 % was a bit higher than in small houses 40 % (Figure 2-5). Until 2012, the quantity of attached houses has increased tenfold from the level of 1970, being 390 000 in 2012 [6] (#cite-text-0-14).

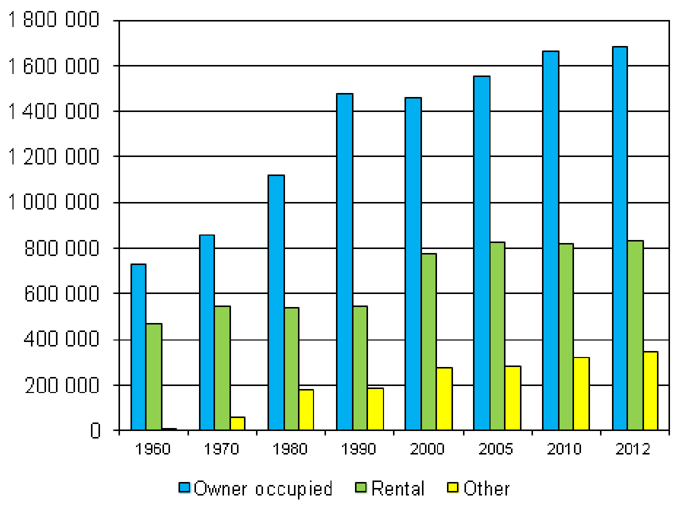


FIGURE 2-6. Tenure status of dwellings in Finland 1960-2012 [6] (#cite-text-0-5)

Since 1970, average floor area of the dwelling stock has increased by 20 m² and in 2012 it was 79.9 m² in 2012. At that year, two-room unit was the most common dwelling type.

More than half of the dwelling units are occupied by the owners. One third is tenured by tenants (see Figures 2-6, 2-7). In statistics tenure status is mainly determined for the regularly occupied dwellings in the statistics. Since 1990, the quantity of rented dwellings has increased by 287 000 and in the end of 2012, the amount was roughly 833 000. Of these 786 000 were permanently occupied [6] (#cite-text-0-14).

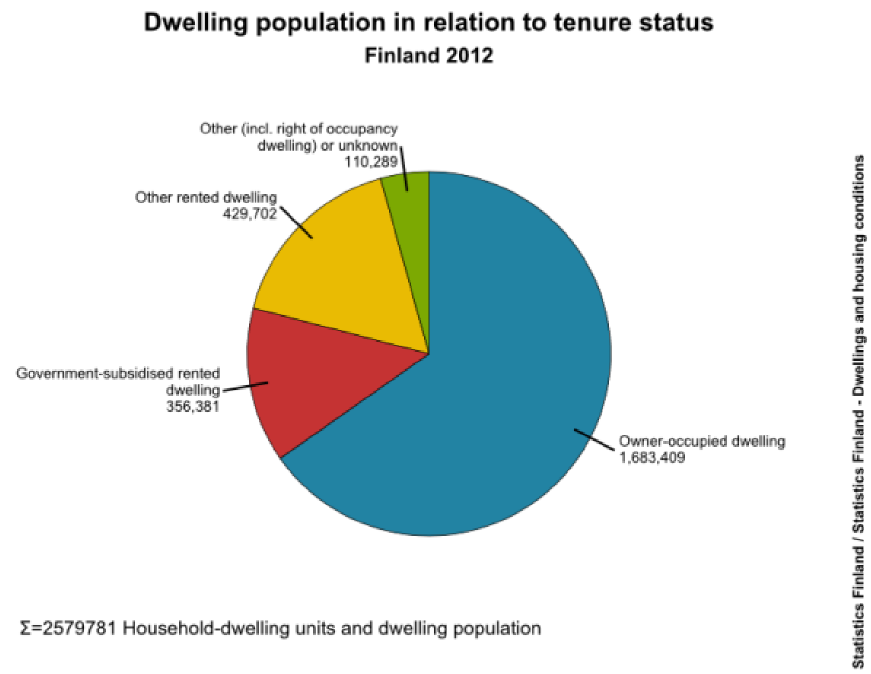


FIGURE 2-7. Most of the dwellings are occupied by owners. Household-dwelling units consist permanent occupants of dwellings [7] (#cite-text-0-6)

Most occupied dwellings were the ones constructed in 1970s, in the decade of intensive construction (Figure 2-8). Majority of the owner-occupied dwellings located in detached houses and the average floor area was 96 m². Correspondingly, majos part of the rental dwellings were in apartment buildings with the average floor area of 53 m². In 2012 size of household-dwelling units consisted mainly 1 person (41.5 %), 2 person (33.2 %) and 3 person (11.2 %).

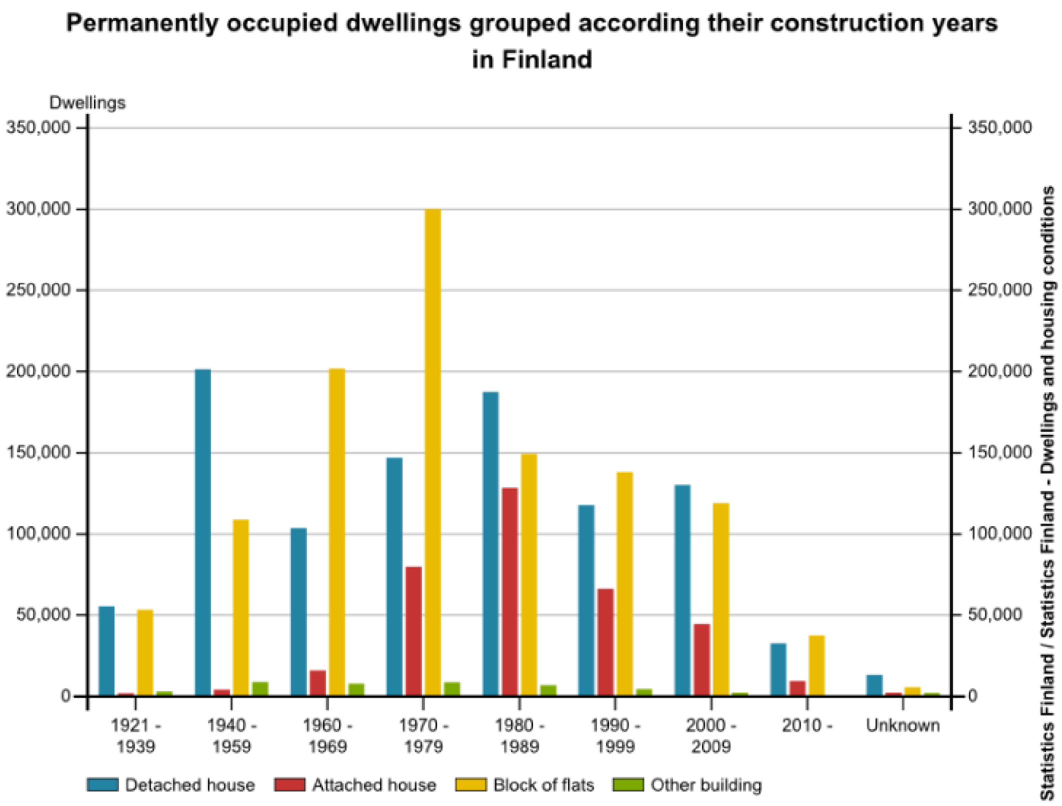


FIGURE 2-8. Currently occupied dwellings are shown according to building type and construction year [8] (#cite-text-0-7)

2.1.2 Renovation and investments

In 2012 construction enterprises renovated buildings to the value of 5.6 billion euro [7] (#cite-text-0-16). Half of the renovations were done for other than residential buildings, comprising 3 billion shares. The total value of renovations performed by housing companies was 1.2 billion euro in 2012 (Figure 2-9). The proportion grew by 5.1 % from the level in year 2011, and represented more than 75 % of all the performed renovations. Housing companies refurbished block of flats to the value 900.7 million, and especially the ones built in the 1970s and earlier decades were refurbished most. Renovation costs of this building type remained at the same level as ten years earlier. Attached buildings were renovated with 275.2 million euros by housing companies.

State-subsided housing corporations renovated with the total value of 343.4 million euros, which was 12 % less than the year before.

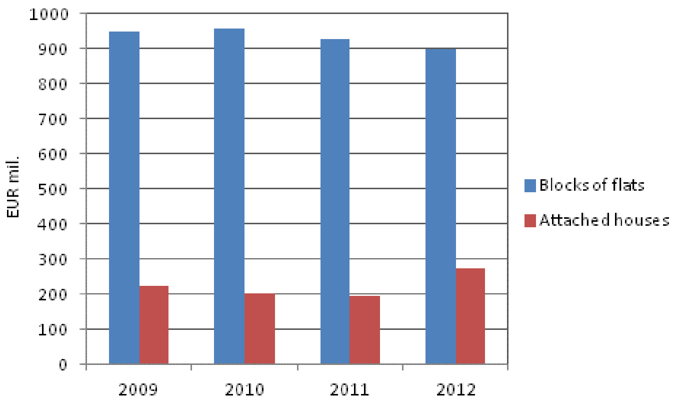


FIGURE 2-9. Refurbishment performed by housing companies [9] (#cite-text-0-8)

TABLE 2-2. Objects of renovations performed by housing companies are listed for the years 2009-2012 (EUR mil.) [7] (#cite-text-0-16)

Renovation costs by object of renovation	**2009**	**2010**	**2011**	**2012**
Outdoor areas	61	64	59	60
Foundation structures	10	42	42	60
External structures	438	326	337	408
Internal structures	129	103	91	75
Individual dwellings	78	73	92	74
Heating, plumbing and ventilations systems	332	442	365	332
Electrical systems	23	23	27	40
Other	100	88	107	127
Total	**1 171**	**1 160**	**1 119**	**1 176**

Among terraced houses the ones built in the 1970s and 1980s were renovated most, and their cost was one-fifth of all the renovations performed by all housing companies. The total value of these renovations was elevated by 42 % (Figure 2-9). External structures and heating-plumbing-ventilation were the major targets of the renovation in 2012 similarly as in preceding years (Table 2-2, [8] (#cite-text-0-18)). These formed more than 60 % share of the renovations costs.

2.2 Energy supply and consumption

Finland has diverse range of energy supply where no single fuel dominates the supply mix. In 2011, primary energy supply was 34.8 mtoe. Oil 27.3 %, biofuels and waste 24.1 % and nuclear energy 18 % were most used sources (see Figures 2-10, 2-11).

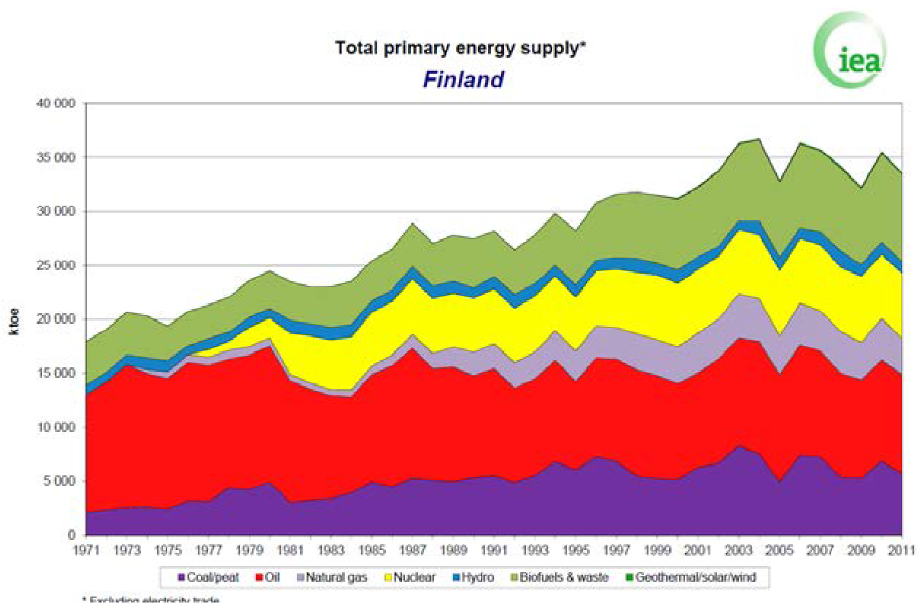


FIGURE 2-10. Total primary energy supply for Finland in 2011 [10] (#cite-text-0-9)

Overall energy consumption in Finland is high. The geographical location in northern hemisphere accompanied with cold climate and significant heavy industry sector are the primary causes for the enhanced energy use. In 2012, total consumption was almost double the EU average and equaled 381 TWh or 6.0 toe/cap. In the same year, the end-use was 307.6 TWh or 26.4 mtoe (Figures 2-12, 2-13).

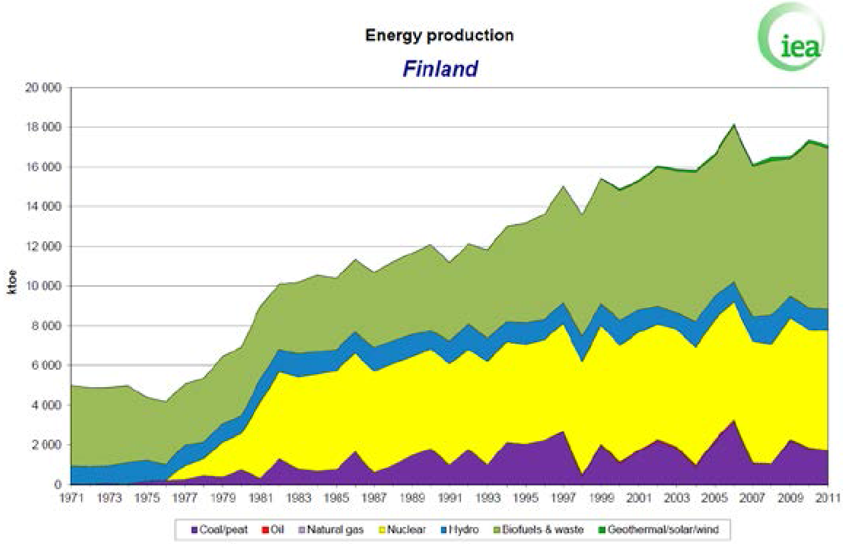


FIGURE 2-11. Energy production by fuels in Finland for years 1971-2011 [11] (#cite-text-0-10)

The overall use of renewable energy sources increased ten percent from the level in 2011. For the first time wood fuels were the most used sources (Figures 2-12, 2-13). The shares of fossil fuels and peat decreased, similarly as in preceding years.

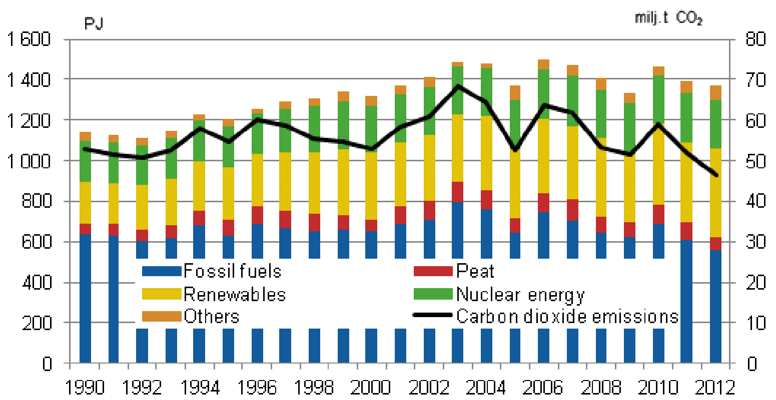


FIGURE 2-12. Between years variation in energy consumption is presented along the produced emission across the years [12] (#cite-text-0-11)

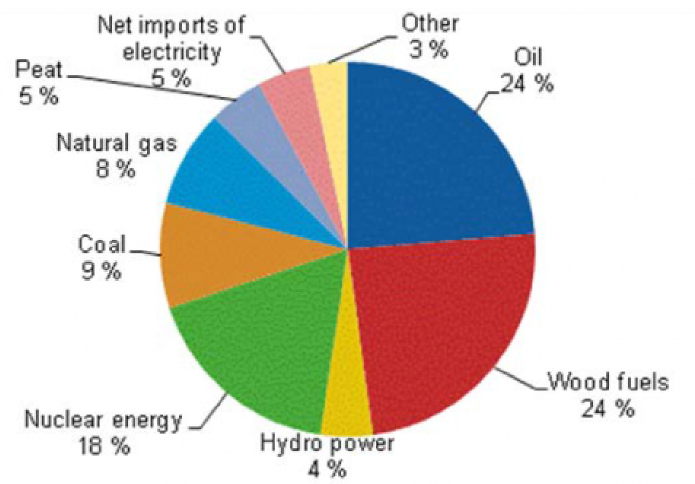


FIGURE 2-13. In 2012, the total energy consumption was 1.4 million TJ (381 TWh, 32.8 mtoe) [13] (#cite-text-0-12)

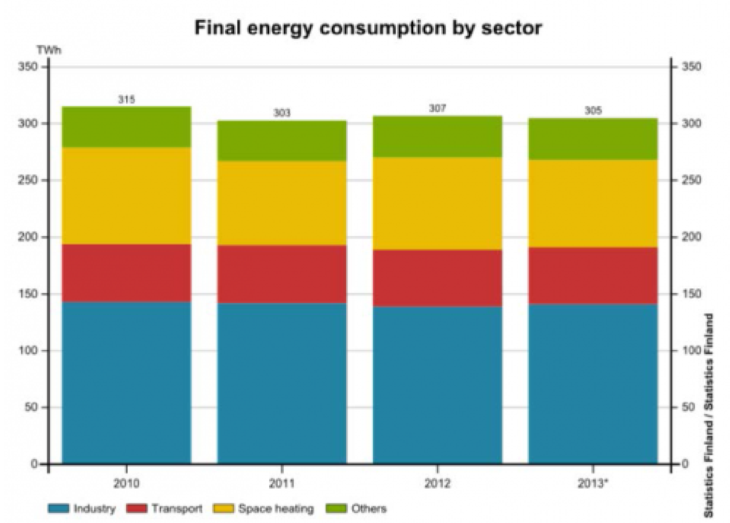


FIGURE 2-14. Final energy consumption by sectors in 2010-2013 [14] (#cite-text-0-13)

The energy end-use has been on the annual level 300-310 TWh, largely depending on the outdoor temperature changes on heating requirement. Industry, transport and heating were the major energy users (Figure 2-14). The proportion of space heating has been around 26 % of the end-use for several years (Figures 2-14, 2-15).

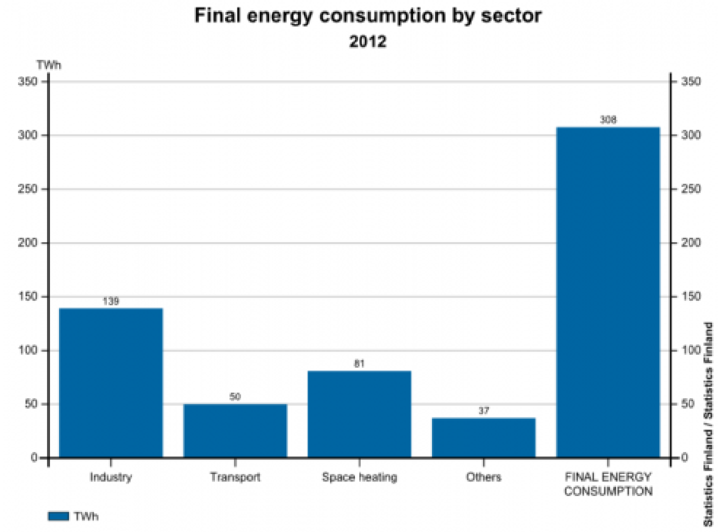


FIGURE 2-15. Final energy consumption by sectors [15] (#cite-text-0-14)

Electricity is produced from various sources with different proportions through the years (Figure 2-16). In 2012, approximately 67.7 terawatt hours (TWh) of electricity and heat were generated [4] (#cite-text-0-8). The trend of increasing use of renewable energy has continued, and the share was higher than a year before. Totally 46 % of the heat-electricity production was covered by renewable energy, including hydro-, wind-, geothermal power and wood-based material (Figures 2-17, 2-18).

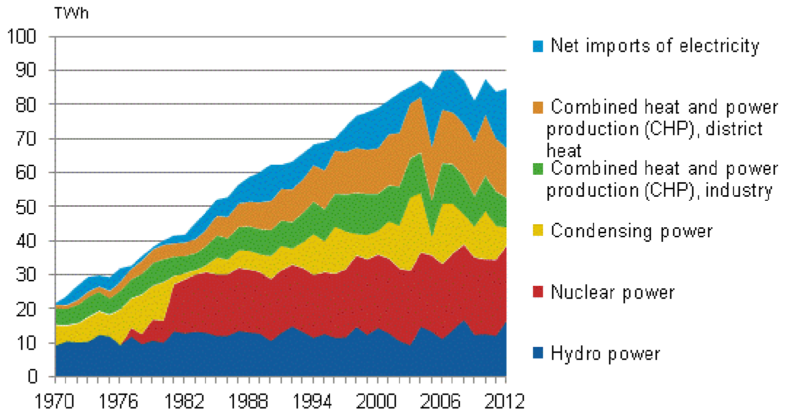


FIGURE 2-16. Electricity has traditionally been generated from various sources in different years [16] (#cite-text-0-15)

Proportions of fossil fuels and peat continued to decrease and were lower than in the preceding year. Fossil fuels and nuclear power covered 28 % and 14 % of the energy sources for electricity and heat productions (see Figures 2-17, 2-18).

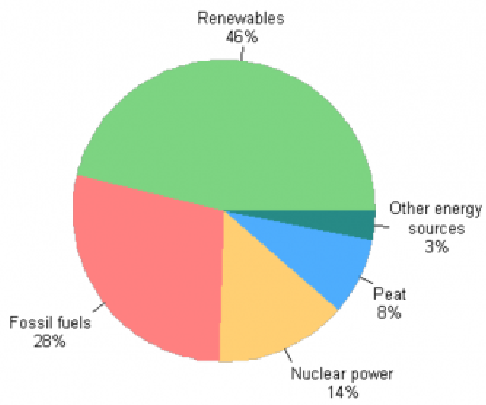


FIGURE 2-17. The usage of primary energy sources for the production of electricity and heat in Finland in 2012 [17] (#cite-text-0-16)

The total consumption of electricity was 85.1 TWh which was one percentage higher than in 2011 (see Table 6-1 (http://www.oamk.fi/epooki/files/9914/2986/7659/Table_6-1.PNG)). Domestic production covered 80 % of the need. Remaining demand was fulfilled by the net import (imports-exports) from Nordic countries, Russia and Estonia, which was 26 % higher than in preceding year [4] (#cite-text-0-8). Large share of the electricity was imported from Sweden. This was due to rather good water situation in Nordic Pool which decreased the price of produced hydroelectricity. Consequently the import from Russia decreased by 59 %, also partly because of growth in prices of Russian electricity. Greater share of electricity was exported to Estonia than was imported from there to Finland.

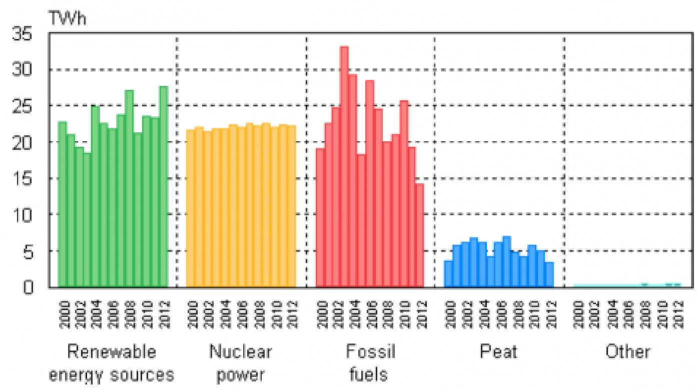


FIGURE 2-18. Electricity generation by energy sources in the period 2010-2012 [18] (#cite-text-0-17)

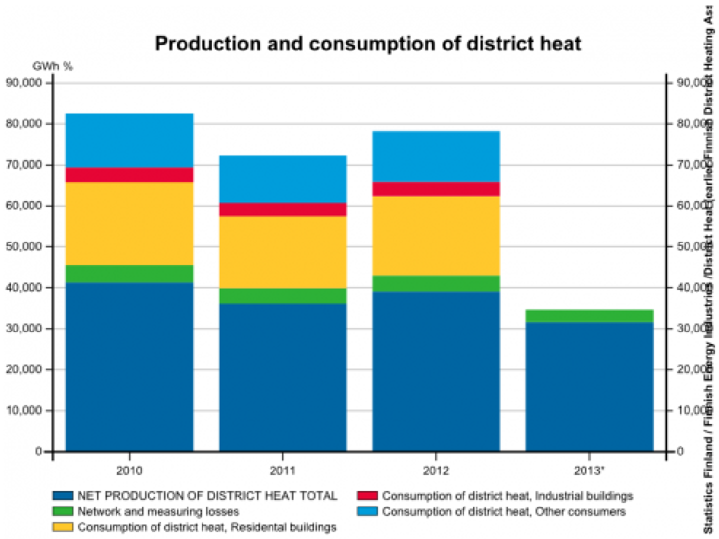


FIGURE 2-19. Production and consumption of district heat since 2010 in Finland [19] (#cite-text-0-18)

Net production of district heating has been on the level of 30-40 GWh in recent years (Figures 2-19, 2-20). In 2011 it was 36.1 GWh. Combined heat and power plants produce two third of the district heat. One third becomes from heat only plants. [9] (#cite-text-0-21)

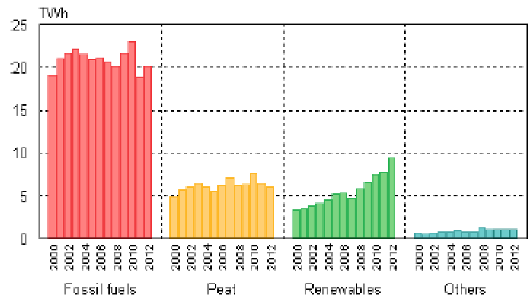


FIGURE 2-20. District heat production by fuels 200-2012 [20] (#cite-text-0-19)

Figure 2-20 shows the trend and fuel sources for district heat production since 2000. Fossil fuels, coal and natural gas, are still mostly used energy supplies. The renewables have steadily increased their proportion and in 2012, the exploitation increased by 22 % from the level of previous year. Largest proportion, with 55 % or 20 GWh, of the produced heat is consumed by residential apartment houses (see Figure 2-19).

When energy and electricity intensities (primary energy consumption per unit of GDP) are inspected, the declining trend of energy intensity has continued since 1970 (Figure 2-21). Between 1990-2009 intensity reduced by 1.4 % which is a bit lower than IEA average 1.6 % for the same period [10] (#cite-text-0-22). In 2012 it was less than 500 kwh/1000€ which is approximately 35 % less than in 1970. This is largely due to fall in the energy intensity of industrial sector. Instead, electricity intensity was raised strongly in the period 1970-1994, reaching the maximum value 680 kWh/1000€ in 1993. Since then is has been declining steadily and currently is a little bit more than energy intensity, about 540 kWh/1000€ (Figure 2-21).

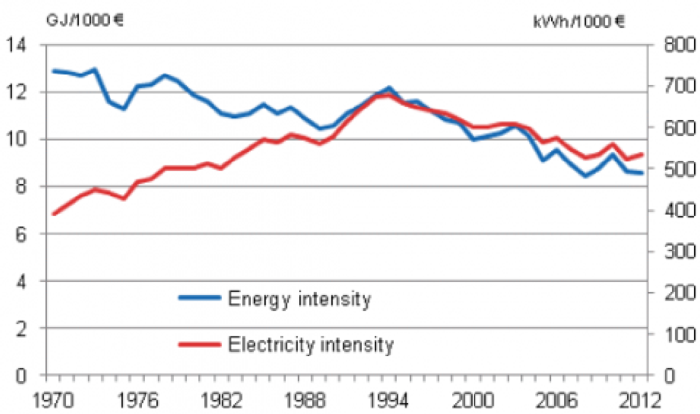


FIGURE 2-21. Development of energy and electricity intensities as proportion of used energy of GDP in euros [21] (#cite-text-0-20)

2.2.1 Energy use by residential sector

In 2012, the proportion of overall heating was 81 TWh which formed 26 % of the energy end-use. This includes heating residential, non-residential premises and industrial needs (Figures 2-14, 2-15).

When inspected in units, electricity, wood and oil-gas cover more than 80 % of the heating need. This is mainly due to relatively high number of detached houses that are mostly heated with electricity (see Figure 2-22).

In gross floor area, the most used heating systems were district heating, wood fuels and electricity, which are due to relatively high share of apartment buildings floor area (Figure 2-23).

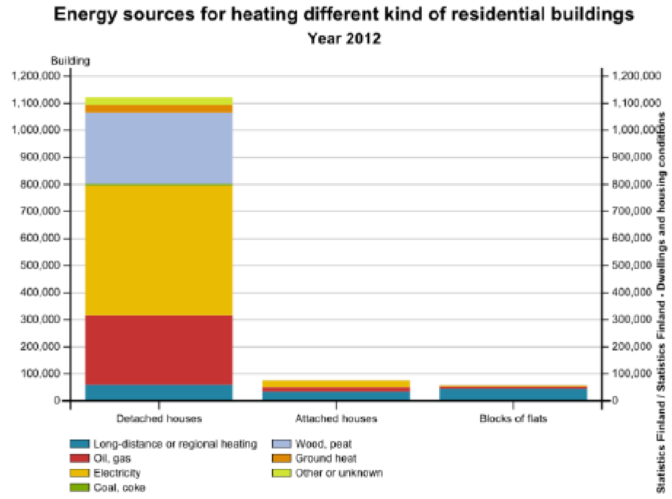


FIGURE 2-22. Residential buildings are heated with various energy sources [22] (#cite-text-0-21)

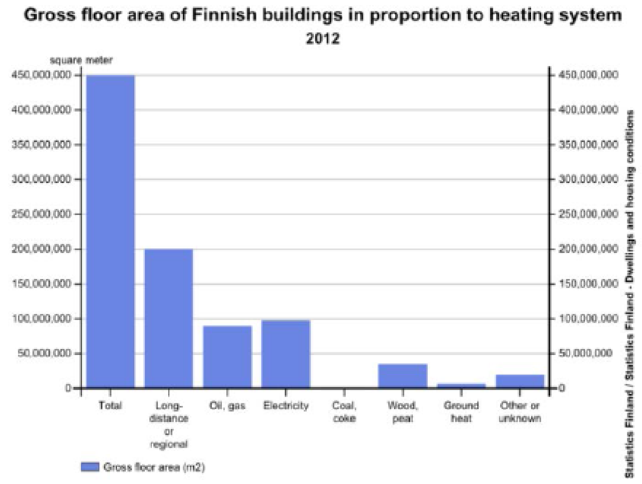


FIGURE 2-23. Gross floor area of Finnish buildings in relation to heating systems [23] (#cite-text-0-22)

Housing accounted roughly 20 percent (66 682 GWh) of the final energy end-use in country in 2012 (Figure 2-24, Table 2-23). Heating of residential buildings consumed 58 600 GWh which is more than 80 % of the energy use by buildings (Figures 2-24, 2-25).

Often main and supplementary heating systems are used concurrently. The share of energy extracted from the environment with the heat pumps, ambient energy, has been increasing and form currently seven percent (the cooling energy of the heat pumps is not included). Annual and monthly requirements for heating energy need of buildings are affected by outdoor temperature which can differ largely between countries and municipalities.

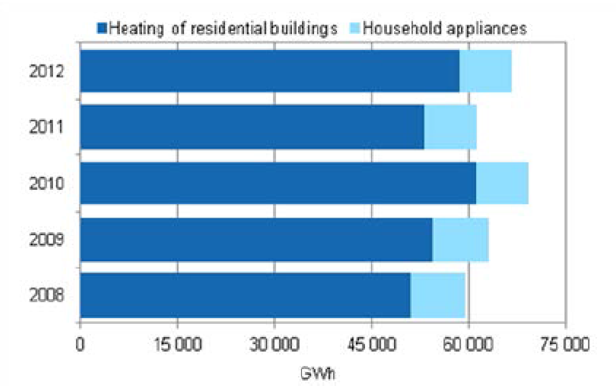


FIGURE 2-24. The energy consumption of residential buildings 2008-2012 [24] (#cite-text-0-23)

In order to compare standardized heating energy consumption of buildings, measure Heating Degree Days (HDD) is used. Fluctuations between months or years are followed on country or municipal level. The period between late spring and autumn is not taken into account in the measure; or when outdoor temperature rises above 10 degrees in spring time and remains above 12 degrees in autumn. This is based on the lack of heating need in warmer period. In calculations, differences between daily indoor and outside temperatures are added for a month or a year. Seventeen degrees is commonly used as a standard indoor temperature. Period 1981-2010 is regarded as a reference period that gives comparative value for average heating degree day [11] (#cite-text-0-23).

In 2012, heating degree day values varied between 3797-6186 in the geographic area between southern-northern parts of Finland. Year 2012 was not exceptional in comparison to other years (temperature was 0.4 higher than average) although individual months caused some energy peaks for the consumption.

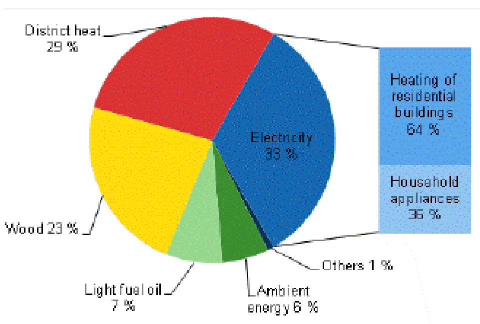


FIGURE 2-25. Overall energy consumption by households is shown according to energy sources. Used energy totaled 66 682 GWh in 2012 [25] (#cite-text-0-24)

In 2012, housing consumed 22 240 GWh of electricity which is five percent more than in previous year. This corresponds to 33 % of the energy consumption by housing (Figure 2-25). Household appliances used 20 % of the household energy which equals to 8 082 GWh of 36 % of the electricity use in homes (Figures 2-24, 2-25). The share of lighting was 2

538 GWh [12] (#cite-text-0-24).

Household appliances use 12 % of the energy, or 36 % of the electricity consumed by households. The share is expected to increase due to changes in consumer behavior and growing markets of electrical devices. In order to enable information sharing about the energy efficiency of devices, energy labelling and eco-design methods, directives obligate the manufacturer of a product to inform customer of the energy use of appliances.

2.3 Emissions

Carbon dioxide emission is the most important agent for climate change. Since 2002 emission level have been declining along the trend of reduced use of fossil fuels in the production of heat and electricity. In 2011 the amount of emission was 56 tons [13] (#cite-text-0-25) and in the following year 46.4 Mt (see Figure 2-16, [4] (#cite-text-0-8)). As overall, energy sector is responsible of 76 % of all the greenhouse gas emissions generated in Finland.

TABLE 2-3. Building stock, energy supply and -consumption in Finland in 2012

	Quantity/ gross floor area m² (5)	**Occupants per dwelling (7)/ total floor area per dwelling (5)**	**Owner-ship/ Renova-tion rate**	**Construction intensive decade of most occupied dwelling/ Main construction material**	**Average energy consumption for individual building (kWh)/ Dwellings (kWh/m²)**	**Final energy consump-tion GWh**	**Space heating energy consump/ GWh/ year (sum for all)**	**Electricity consump GWh (sum for all)**
Finland						307 591 (5) 205 153 (8)		85 131 (5) 80 200 (8)
Building stock	1 474 653 / 449 518 942		/ 2 % 1 - 1.5 % (11)	1980s / wood 81 % stone 16 %	310 (10)		93 607 (5) 47 481 (8)	125 kWh / m² (10)
Residencial buildings	1 258 095 / 282 082 338	4.2 / 81.5		1970s / wood 84 % stone 13 %		66 682 (5) 40 705 (8)	55 804 (5) 17 313 (8)	22 240 (5) 21 800 (8)
Detached houses (6)	1 122 315 / 156 380 401	2.4 / 109.5		1908s /	/ 130 - 229 (12)		33 723 (5) 20 - 25 MWh average / single house (9)	
Attached houses (6)	77 931 / 33 187 176	9 /		1990s	/ 150 (12)		5 773 (5)	
Block of flats (6)	57 849 / 92 514 761	31.6 /		1970s	/ 130 (12)		16 308 (5)	
Dwellings (6)	2 865 568 /	2.09 / 79.9	priv 60 %	1970s (1)				10 000 (13)
Detached houses	1 155 356 /	2.33 / 109.5		1980s (1)				
Attached houses	390 424 /	1.8 / 71.3		1980s (1)				
Block of flats	1 269 305 /	1.44 / 56.5		1970s (1)				

(1) permanently most occupied dwellings according to construction year of the building type. [6] (#cite-text-0-14)

(2) Primary energy sources

(3) measured as in building quantity. Abbreviations: e=electricity, o-g=oil-gas, w-p=wood-peat, d.h=district heating. Statistics Finland

(4) [14] (#cite-text-0-28)

(5) [4] (#cite-text-0-8)

(6) Detached house: include 1 to 2 dwellings in building, Attached house: include at least three adjoining dwellings, Block of flats: residential buildings of at least three dwellings in which at least two dwellings are located on top of each other and which do not belong to the previous categories, Dwellings: a room or a suite of rooms which is intended for year-round habitation, has a floor area of at least 7 square meters. Value for number of Dwellings includes also other than residential buildings dwellings

(7) Values are calculated so that persons per dwelling type are divided by number of the dwellings [5] (#cite-text-0-10)

(8) year 2011 [1] (#cite-text-0-0)

(9) [15] (#cite-text-0-32)

(10) Energy efficiency trend in buildings in EU [16] (#cite-text-0-33), specific energy consumption, electricity consumption per m²

(11) Ecorys The energy efficiency investment potentialfor the building environment

(12) EcoFys 2013, requirement values for new buildings given in the Building Code 2012. Detached house- value depends on the heated net area.

(13) [17] (#cite-text-0-34)

3 Norway

Norway is a country of 4.9 million inhabitants that has Gross Domestic Production GDP (PPP) of 231.47 billion (2005) USD [18] (#cite-text-0-35). Total primary energy supply (TPES) is 28.14 Mtoe (Table 6-1).

Substantial indigenous energy resources such as wind, water, oil and gas are located in the country. Electricity is mainly produced from water and hydroelectricity covers large proportion of domestic final energy consumption in the other than transportation sector. The largest shares of oil and gas resources are exported to the EU which is most important trading partner. As economic growth is related to increased energy consumption, it is expected that the share of energy export will even be larger in the future [18] (#cite-text-0-35).

3.1 Building stock

Building stock consists of 3.9 million units. Non-residential sector comprises totally 2.4 million buildings (Table 3-1). Residential buildings form biggest building category with 1.48 million units (Table 3-2).

TABLE 3-1. Non-residential building stock in Norway in 2012 [19] (#cite-text-0-37)

	Existing buildings
Holiday house, garage linked to dwelling etc	1 753 751
Industrial building	102 690
Agricultural and fishery building	509 071
Office and business building	38 671
Transport and communications building	10 447
Hotel and restaurant building	31 327
Building used for education, research, public entertainment and religious activities	46 648
Hospital and institutional care building	5 600
Prison, building for emergency preparedness etc.	4 782

TABLE 3-2. Residential buildings by type and amounts in 2012 [20] (#cite-text-0-38)

	Existing buildings
Detached house	1 137 938
House with 2 dwellings	152 084
Row house, linked house and house with 3 dwellings or more	148 175
Multi-dwelling building	34 726
Residence for communities	4 551

3.1.1 Residential buildings and dwellings

Majority (90 %) of the dwelling stock has been constructed after 1945 (Figure 3-1). Six major building groups can be separated according to construction decades. These have thermal insulation levels characteristic for the building periods [21] (#cite-text-0-39).

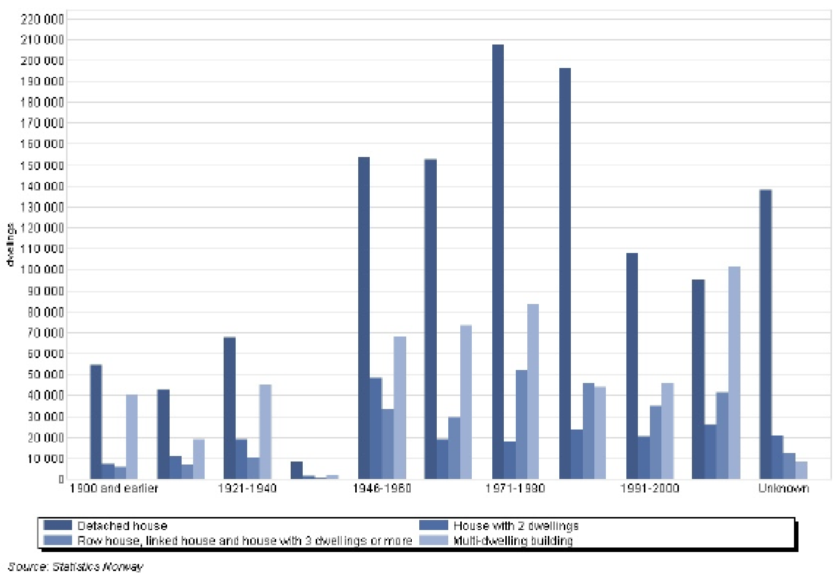


FIGURE 3-1. Dwellings by building type and construction year in the period of 1900-2011 [26] (#cite-text-0-25)

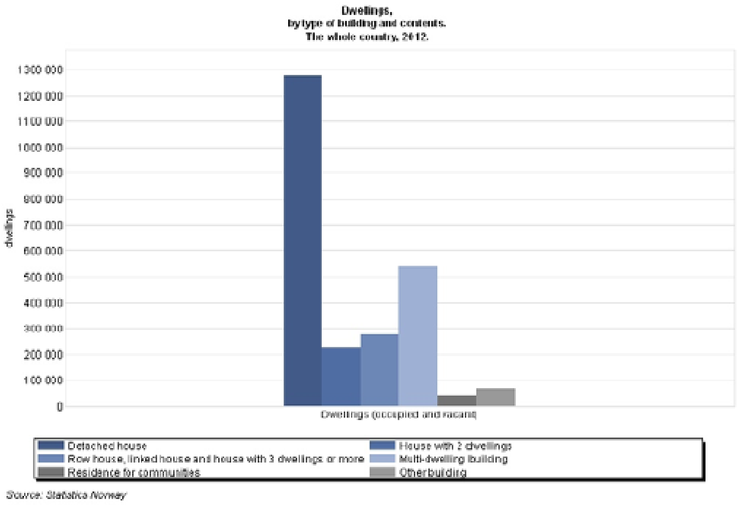


FIGURE 3-2. The sum of dwellings by type of building in Norway in 2012 [27] (#cite-text-0-26)

In 2012, majority of people live in dwellings located in detached and semi-detached houses. Around 53 % of the dwellings are in detached houses, 21 % in attached and 22 % in apartment houses (see Figure 3-2, Table 3-3). The number of apartment blocks has increased in recent years, and in 2001-2011 the construction exceeded the rate of detached houses (see Figure 3-1)). When inspected as number of residential buildings, the share of detached houses is 77 %, attached 20 % and apartment houses 2.4 % (Table 3-3).

More than 90 % of dwellings are privately owned when also private companies and housing cooperatives are included (Table 3-3). However, regional variations appear especially among smallest municipalities [19] (#cite-text-0-37).

3.1.2 Renovation and investments

No exact statistics exist on the rate of renovation rate in Norwegian building stock (e.g. [22] (#cite-text-0-41)). Estimates are done and some are presented here. Risholt et al [22] (#cite-text-0-41) studied the technical condition and up-grade status of detached houses built in 1980s. They form 10 % of the Norwegian dwelling stock and are dispersed all over the country. The houses are bigger and generally various architectural solutions are used. These dwelling have the highest annual energy needs in comparison to dwellings of other decades, and are under the national focus for energy efficiency. Norwegians are enthusiastic to upgrade their homes, and usually bathrooms and kitchens are the primary targets. According to study no correlation could be found between the upgrade status and the technical condition of the house. Redecoration and renovation of the houses may have used significant resources of the property owners but often they do not meet the actual need for maintenance and repair. Knowledge, priorities and resources of the homeowners should be directed toward the real major defects in envelope and technology.

In another study [21] (#cite-text-0-39) model was created to study energy consumption and energy saving potential in residential building stock. Single-family houses, divided small houses and apartment houses were classified according to five main construction decades; before 1945, 1946-1970, 1971-1980, 1981-1990, 1991-2005. Largest energy saving potential was discovered to be in single-family houses built before 1945 when number of dwellings and specific energy saving potential were taken into account. Here two renovation packages, moderate and ambitious produced almost 2.9 TWh (25 %) and 4.5 TWh (40 %) energy saving potential. As overall, it has been estimated in the theoretical model for the year 2005 that totally 12-17 TWh of energy reduction potential exist for the building sector, depending on the usage of moderate or ambitious renovation package.

3.2 Energy supply and consumption

In 2011, total primary energy sources accounted 28.1 mtoe, and constituted mainly of oil, water, gas and wind [18] (#cite-text-0-35). Energy was produced 195.4 mtoe. Domestic final energy consumption was 20.3 mtoe. Largest share 173 mtoe of the produced energy was exported to other countries (Table 6-1).

In 2011, the production of hydroelectricity resulted in 128 TWh and it covered the total domestic consumption of 114 TWh (final electricity consumption 105 TWh). The rest 14 TWh was sold to international grids. Electricity is regarded in Norway as the main energy source. In overall, totally 38 million tons of carbon dioxide emissions were produced during the year (Table 6-1). In 2012, high water reservoir level was attributed to high electricity production and decrease in electricity prices. Electricity was produced 148 TWh and the share of hydropower was 97 %. Wind and thermal (gas power) energy were produced 1.6 TWh and 3.4 TWh. Natural gas was produced 12 % more than the year before and it exceeded the production level of crude oil. The trend of increasing natural gas production has continued since 2004, although Norway has traditionally been regarded as crude oil producer [19] (#cite-text-0-37).

Share of renewable energy sources is high due to usage of water- and wind-based electricity production. In 2011 renewable energy proportion was 65 % that is two percentages less from than the target set by 2020. The share has increased 3.6 % from the 2010 level. Year 2011 was mild which decreased the overall energy consumption, thus giving lower relative proportion of used energy in denominator while renewable energy quantity as numerator stayed on the same level. In 2012, the country level usage of bioenergy (wood, pellets, bark, wood chips and -waste, black liquor) was 8 % less than in the previous year. This is due to changes in industrial sector that faced many closures and production shutdowns of especially pulp and paper industry that are major consumers of the bioenergy [23] (#cite-text-0-46).

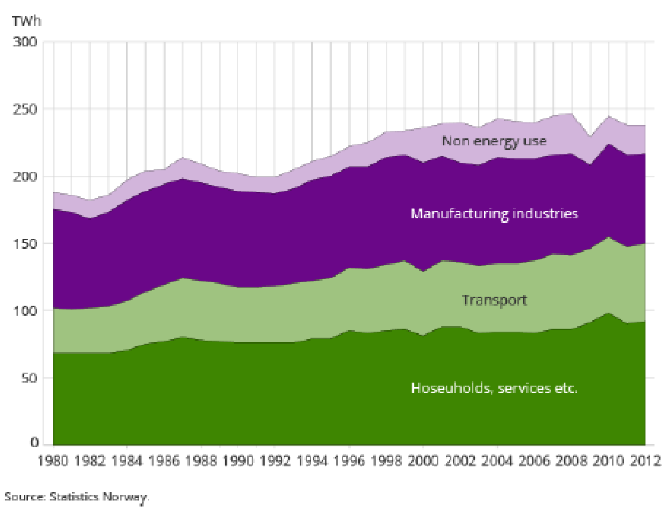


FIGURE 3-3. Total energy consumption by consumer group between years 1980-2012 [28] (#cite-text-0-27)

The main energy consuming sectors are households-services, manufacturing and transportation (Figure 3-3). Apart from transportation sector, electricity is regarded as the main energy source. Stationary energy consumption (final energy consumption- export) has increased 19 % from 1982 to 2005 [21] (#cite-text-0-39) and was 160 TWh in 2011 (see Figure 3-3). Electricity covers more than 70 % of the stationary energy consumption [24] (#cite-text-0-48). Both energy and electricity consumptions have been flattening since 1990s due to energy-efficiency measures, better-designed buildings, better heating systems and milder climate since 1980. Also closures of energy intensive industrial businesses have had a role in the trend development.

In 2012, transportation sector consumed also 2 % more energy than in previous year. The most essential energy products are diesel, gasoline, marine gas oil, but large increase was in the use of natural gas and biofuels. Biodiesel and bioethanol were sold 15 % more than a year before, resulting in 180 million liters which corresponds to 2.5 % of total energy use in transportation sector [25] (#cite-text-0-49).

3.2.1 Residential buildings

A share of households of total stationary energy consumption in mainland Norway is about 30 %. Although building mass has increased constantly, energy consumption in households has increased at lower rate during the last 20 years than in the preceding period (see Figure 3-3). In 2009 household energy consumption was 3 % and 10 % less than in years 2004 and 1993. Since 1995 the consumption has been on the level of 44-50 TWh [24] (#cite-text-0-48).

Electricity formed 78 % of the energy use in dwelling stock in 2009 (Figure 3-4). In residential premises, the space heating consumes the largest share of the energy. Approximately 70 % of the dwellings are heated solely by electricity heating system or in combination with other systems [21] (#cite-text-0-39).

Although the general trend of flattening electricity and energy use mentioned in previous chapter, yearly variations in outdoor temperature can cause up to 9 TWh difference in the energy use of building stock [24] (#cite-text-0-48).

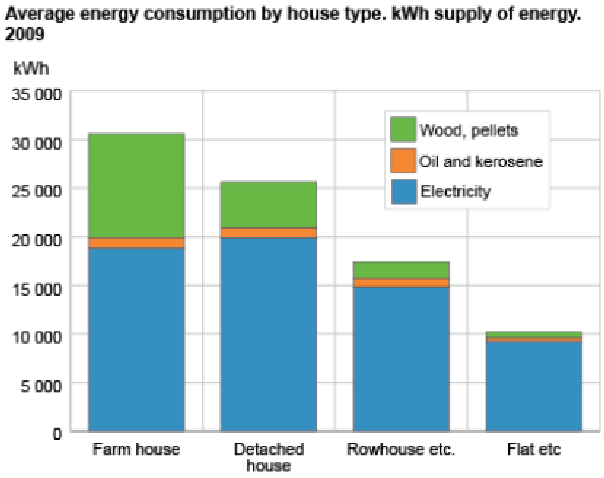


FIGURE 3-4. Average energy consumption by house type in 2009 [29] (#cite-text-0-28)

According to estimates the share of heating has been 58 %, but newer calculations indicate the higher average proportion of heating approximately 66 % (13 900 kWh) of total household energy consumption. The share of water heating is 12 % (2 600 kWh) and electricity-specific energy (appliances) consumption 22 % (4 500 kWh) of which one fifth part (1000 kWh) is used for lighting [24] (#cite-text-0-48). Average household use about 21 000 kWh of energy per year, and of this 16 000 kWh is attributed to the electricity [24] (#cite-text-0-48). Total net consumption of electricity in households per capita was 7 282 kWh.

Values represent consumption for an average dwelling, and many factors such as dwelling size and type, choice of heating system, geographical location, household size and occupant behavior influence on the consumption of individual dwelling. Electricity-specific consumption (usage of electricity devices) is mostly influenced by the number of people in the premise (see [24] (#cite-text-0-48)).

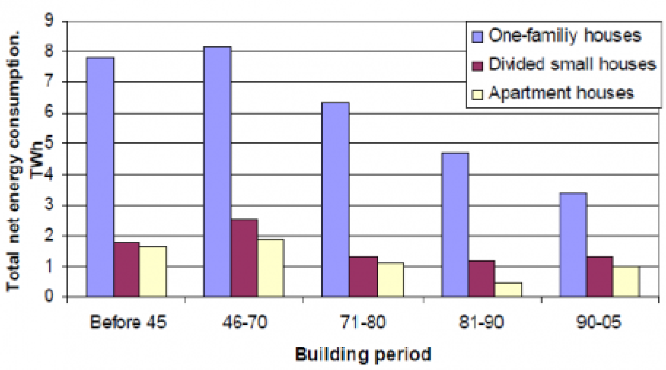


FIGURE 3-5. Estimated total useful energy consumption per year for the housing sector split into building types and building period [30] (#cite-text-0-29)

Detached and attached houses (semi-detached, vertically divided, terraced) consumed approximately 85 % of the energy used by dwelling stock in 2005 (Figure 3-5 [21] (#cite-text-0-39)). Of the buildings constructed in the period 1990-2005 the majority of total net energy was used by one-family houses, approximately 3.4 TWh per year.

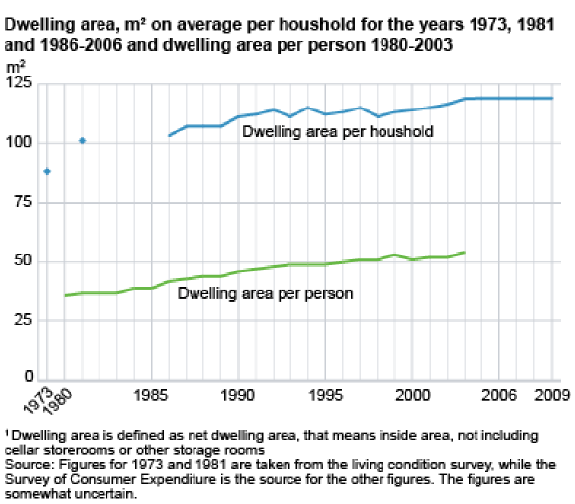


FIGURE 3-6. Dwelling area presented as average quantity of square meters per household and person until 2009 [31] (#cite-text-0-30)

Divided small houses including row-houses and semi-detached houses consumed roughly 1.2 TWh, whereas block of flats 1 TWh (Figure 3-5). Average energy use by dwelling unit has decreased in recent years.

The rise of floor area per person has been reducing and flattening due to urbanization and higher housing prices which also have lowered per area consumption (see Figures 3-6, 3-8). Additionally, dwelling standards and energy requirements have promoted energy improvement to existing houses and better quality in newer dwellings (built in 1990s and forward) which have co-decreased the consumption. Also the climate has been milder since 1980s which has lowered the heating requirement for houses. According to estimations, the total annual reduction of 2-3 TWh of energy in Norwegian households has resulted from the climate change [24] (#cite-text-0-48). In recent years, average dwelling energy use per square meter has been approximately 180 kWh [24] (#cite-text-0-48) and 170 KWh/m² if average is calculated across the years (Figure 3-7, Table 6-2 [19] (#cite-text-0-37)).

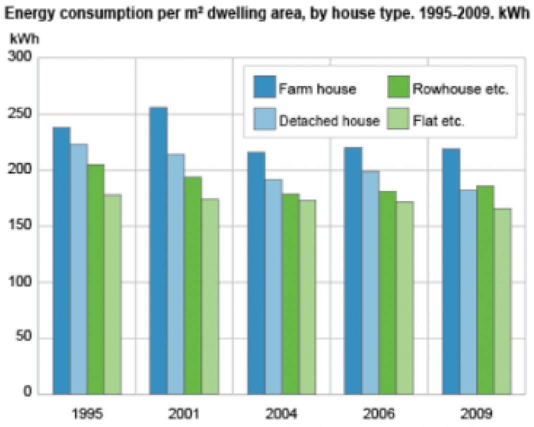


FIGURE 3-7. Energy consumption per square meter of dwelling area by house type [32] (#cite-text-0-31)

In 2012, energy prices decreased due to high electricity production. Average outdoor temperature was 1.4 degrees lower than in 2011. Concurrently, the price of heating oil increased which made electricity even more beneficial energy form. The cold weather and relatively low electricity prices induced 3 % increase in household consumption in comparison to the preceding year. Also district heating was used 20 % more, although the overall share of district heating is only 2 % of the total household energy consumption. The heating oil, district heating and wood-originated fuels form important addition to heating energy reservoir and their usage is highly dependent on the pricing of electricity and variations in climate temperature. In 2012, households consumed 10 % more wood fuels than the year before, resulting to 1.5 million tons. Other energy products than electricity, e.g. heating oil, firewood, pellets, district heating are mainly used for heating, thus variations in outdoor temperature induce also more variations in their consumption [24] (#cite-text-0-48). In 2009, heating oil comprised 4 % of the total energy consumption and was used 845 kWh which was 46 % less than in 2004 [19] (#cite-text-0-37). Large proportions of oil and gas-fired boilers have been replaced to boilers utilizing bioenergy. The shares of fuelwood and district heating have constantly been growing [24] (#cite-text-0-48).

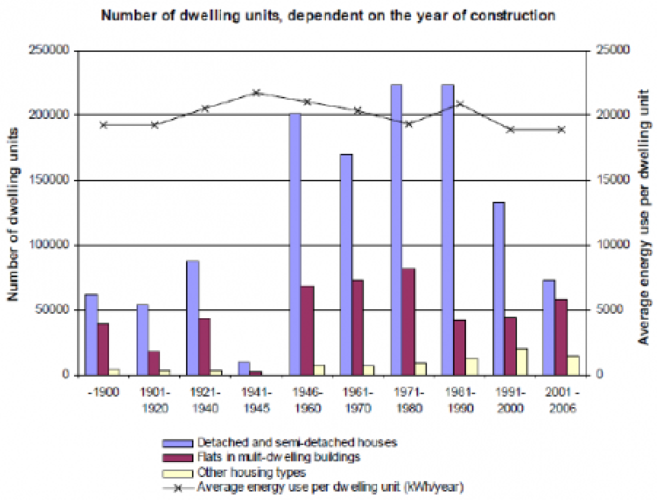


FIGURE 3-8. The number of dwelling units in different building types according to the construction year [33] (#cite-text-0-32) [19] (#cite-text-0-37)

Electricity as the main heating energy product poses challenges to a grid during cold winters. Power grid has not been the target of the high investments during the last 20 years. Along the energy efficiency plans high transmission capacity is required to secure electricity for consumers, as well as equilibrium between the production and demand (see [24] (#cite-text-0-48)).

Carbon dioxide emissions generated by households are mainly due to the consumption of heating oil which formed 1.5 % of the total emissions (see Tables 6-1, 6-2).

	Quantity / gross floor area m²	Average energy consump-tion for individual buildings kWh / dwellings kWh / m²	Occupants per dwelling / utility floor area m² per inhabitant	Ownership / annual need for renovation rate	Construction intensive decades/ Main construction material	Final energy consump-tion	Heating energy consump-tion	Final Electricity consump-tion
Norway						850 PJ (5) 238 TWh	14 PJ (5) 3.9 TWh	378 PJ (5) 116 TWh
Building stock	3 980 461 (1)/							
Residential buildings	1 477 474 (1) 230 000 000 (12)	52 600 (14)		priv 76 % (13) /1.5 % (18)		163.3 PJ (5) 45.4 TWh	2.8 PJ (5) 0.78 TWh	127 PJ (5) 35.4 TWh
Detached houses	1 137 938 (1)	25 100 (14) / 229 kWh/m² (17)		priv 96 % (2)	1970 / concrete / masonry / timber (15)	3.2 TWh (13)	45 kWh / m²	
Attached houses	300 259 (1)	17 500 (14)		priv 91 % (2)	1980	1.2 TWh (13) 8.8 TWh (14)		

Block of flats	34 726 (1)	10 000 (14) /218 kWh/m² (17)			2000	1 TWh (13) 5.7 TWh (14)	31 kWh/m²	
Dwellings	2 422 048 (2)	/170 (10) 185 (20)	2.2 9)/70 (13) 119 (9)	priv 90 % (2)/		21 000 kWh (11) 20 415 (19)		16 000 kWh (average) (11)
Detached houses	1 275 190 (2)	/168 (10) 198 (20)	2.5	priv 96 % (2)	1970	25 705 kWh (6)		19 919 kWh (6)
Attached houses	497 694 (2)	/178 (10) 180 (20)	2.2 (3)	priv 91 % (2)	1980	17 726 kWh (6)		14 764 kWh (6)
Block of flats	536 995 (2)	/162 (10) 156 (20)	1.6	priv 83 % (2)	2000	10 541 kWh (6)		9 191 kWh (6)
Residences for communities	44 480 (2)			priv 61 % (2)				
Other	67 419 (2)		1.4 (3)	priv 74 % (2)				

(1) [19] (#cite-text-0-37) Building stock for the year 2012, residences for communities (4551) are not included

(2) Occupied and vacant for the year 2012 [19] (#cite-text-0-37)

(3) Statistics for the year 2011. Average is calculated for the semi-attached, row houses, linked houses and houses with 3 dwellings or more [19] (#cite-text-0-37). "Other" value include residences for communities and other

(4) year 2011, value for private household. 28 Use of energy products inside and outside energy sectors. [19] (#cite-text-0-37)

(5) [26] (#cite-text-0-69) Rounding is done.

(6) [19] (#cite-text-0-37) 4 Consumption of different energy commodities by house type and household size. Supply of energy per household on average. 2009

(7) average consumption in kWh/m². [19] (#cite-text-0-37)

(8) [19] (#cite-text-0-37) 2 Average specific energy consumption, total and by energy commodity. 1993-1995, 2001, 2004, 2006 og 2009. kWh supply of energy per m² dwelling area per household

(9) [19] (#cite-text-0-37) 5 Average energy consumption, by year of construction, region and dwelling area. kWh supply of energy per household. 2009.

(10) [19] (#cite-text-0-37) 6 Average energy consumption by house type, year of construction and region. kWh utilized energy per household1.1995, 2001, 2004, 2006 og 2009. Average over the years.

(11) [24] (#cite-text-0-48) value per unit of dwelling per year

(12) [21] (#cite-text-0-39) Estimate for the total heated area.

(13) [21] (#cite-text-0-39) Final net energy consumption for all the detached/attached /block of flats constructed 1990-2005.

(14) [19] (#cite-text-0-37)

(15) [22] (#cite-text-0-41)

(16) Calculated according to number of each dwelling type and per dwelling yearly final energy consumption.

(17) [27] (#cite-text-0-80) net energy

(18) Ecorys 2012 The energy efficiency investment potential for the building environment 28

(19) [19] (#cite-text-0-37) year 2012 Specific Energy consumption in households kWh per square meter

(20) [19] (#cite-text-0-37) year 2009, 3 Average energy consumption by housetype, household size and net income, total and per m2 dwelling area. kWh supply of energy per household. 1995, 2001, 2004, 2006 og 2009

4 Sweden

There are 9.45 million occupants in Sweden. Gross domestic production (PPP) is 331.89. The primary energy sources are oil, nuclear energy and biofuels. Electricity is produced mainly from hydropower and nuclear energy. [28] (#cite-text-0-83)

4.1 Building stock

4.1.1 Residential buildings and dwellings

In 2012, the total amount of dwelling stock was 4.5 million units. The share of apartment buildings, 2.5 million, was 25 % more than proportion of detached and semi-detached buildings (Tables 4-1, 4-2). The amount of one- and two dwelling houses increased by 11 000 from the level of year 2011 and with 2 million units, comprised 44 % of the dwelling stock.

Proportions of dwelling in detached or apartment houses vary depending on the urbanization level of the region. For example the highest share, 73 % of apartment dwellings, is in Stockholm County.

TABLE 4-1. One or two-dwelling buildings by the quantities and construction year [29] (#cite-text-0-84)

Year	**One or two dwelling buildings**										
	-1930	**1931-40**	**1941-50**	**1951-60**	**1961-70**	**1971-80**	**1981-90**	**1991-2000**	**2001-**	**Missing**	**Total**
2010	415 599	141 268	137 319	164 182	287 760	426 404	210 979	97 725	105 257	10 751	1 997 244
2011	414 513	140 737	136 976	163 839	287 413	426 201	211 113	97 831	113 939	10 574	2 003 135
2012	413 947	140 479	136 676	163 372	287 597	425 893	211 400	97 920	127 681	9 429	2 014 397

TABLE 4-2. Apartment buildings by the quantities and construction years [29] (#cite-text-0-84)

Year Multi dwelling buildings

	-1930	1931-40	1941-50	1951-60	1961-70	1971-80	1981-90	1991-2000	2001-	Total
2010	226 378	160 343	247 739	415 675	624 898	323 266	220 025	155 068	137 737	2 511 129
2011	226 268	160 164	247 644	415 471	624 392	323 581	219 368	154 317	149 952	2 521 157
2012	227 178	160 172	247 632	415 920	623 589	322 700	218 942	153 433	167 819	2 536 385

The dwellings in houses constructed before 1930 and in 1971-1980 form the largest proportions with more than 400 000 dwellings (Figure 4-1, Table 4-1). In percentages, these constitute 42 % of the dwelling stock among one and two dwelling houses. About 35 % of the dwellings were built in the period 1961-1980.

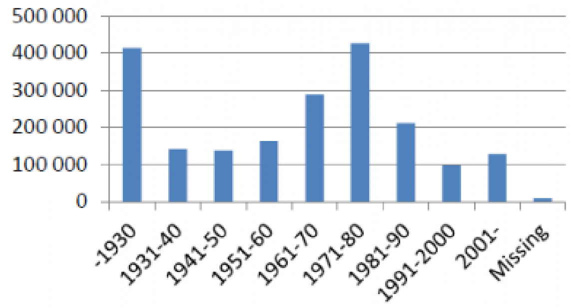


FIGURE 4-1. The quantities of one- and two-dwellings in Sweden classified according to the construction years of buildings [34] (#cite-text-0-33)

The quantity of multi-dwellings has been increasing in recent years, for example in 2012 it was 15 000 higher than in preceding year. More than 0.6 million or 25 % of the currently standing multi-dwelling buildings were constructed in 1961-1970. The second most common type are the ones erected in 1951-1960, comprising 16 % (Table 4-2, Figure 4-2).

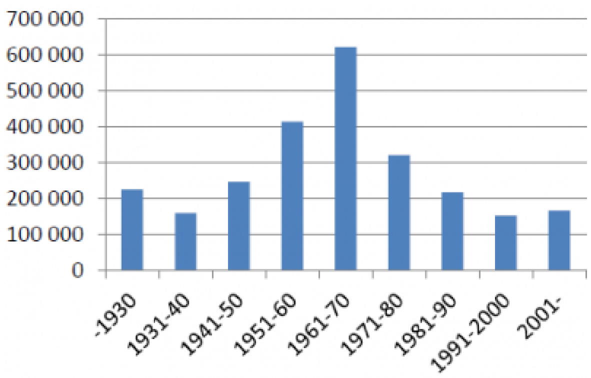


FIGURE 4-2. The number of apartments grouped by the construction years of apartment houses [35] (#cite-text-0-34)

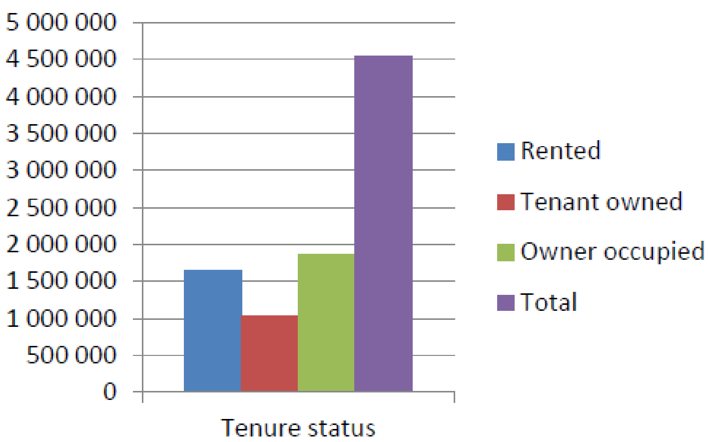


FIGURE 4-3. Dwelling stock by type of building and tenure in 2012

When inspecting the tenure status of the whole dwelling stock, 1.8 million are owner-occupied and 1.6 million units are rented (Figure 4-3). When dwellings are divided into the detached and semidetached houses and apartment houses, the formers are more owner-occupied (Figure 4-5) and latter more rental-based (Figure 4-4).

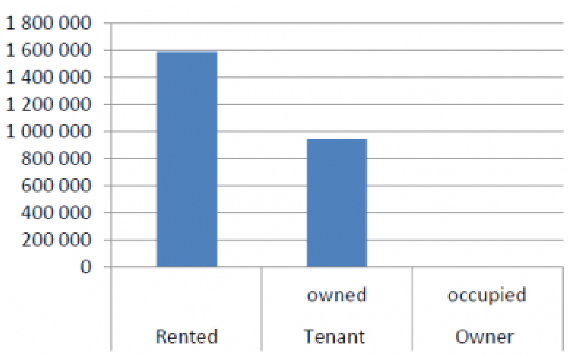


FIGURE 4-4. Tenure status of multi-dwelling buildings, year 2012 [36] (#cite-text-0-35)

Of the apartment dwellings the proportion of rented is 63 %. Here, regional variations occur, and lowest rental and highest tenant-owned percentages are in the areas of big cities such as Stockholm and Uppsala where 52 % and 48 % are tenant-owned. In the period 1990-2012, the number of rental dwellings has grown by 34 300. Simultaneously, the quantities of tenant-owned dwellings have increased ten-fold, and reached the value of 331 000 in 2012.

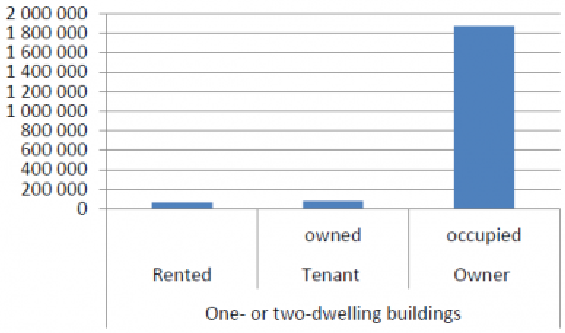


FIGURE 4-5. Tenure status of one- or two-dwelling buildings, year 2012 [37] (#cite-text-0-36)

4.1.2 Renovation and investments

Tax reliefs for repair, maintenance, conversion and extension building work have been adopted in Sweden since December 2008. In addition to creation of jobs in the building industry, reduction of energy consumption is aimed by the tax deductible measures. These include replacement of windows, drilling for ground-source heat pumps etc (e.g. [30] (#cite-text-0-86)).

4.2 Energy supply and consumption

Since 1970, the quantity of total energy supply has grown approximately by 26 % until 2013. In the same period, the content of the supply has changed remarkably. The proportion of crude oil and oil products has decreased from 77 % to 38 %, and the oil supply has been replaced by biofuels, nuclear power, peat and waste.

In 2011 total amount of supplied energy (TPES) was 571 TWh (49.1 mtoe). The share of used energy accounted 380.3 TWh (32.7 mtoe). Two years later, the TPES and used energy were almost on the same levels 577 TWh (49.6 mtoe) and 379 TWh (32.6 mtoe). The major energy carriers were oil 38 %, nuclear 32 % and biofuels 20 % (Table 6-3, [28] (#cite-text-0-83)).

In the period 1990-2010 the proportion of renewable energy sources in energy production has increased from 33 % to 48 % (Figure 4-7). Higher share of biofuels especially in the production of electricity and heat is one of the main causes for the trend. Also the use of heat pumps has grown during the recent years [30] (#cite-text-0-86).

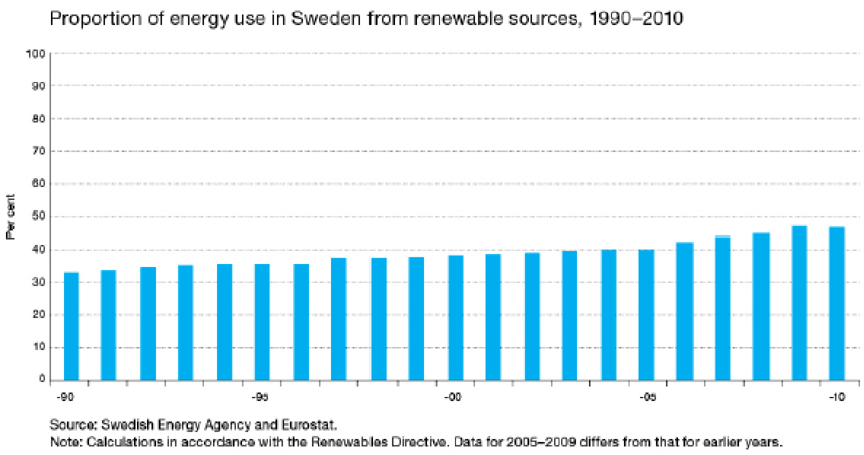


FIGURE 4-6. Proportion of energy use in Sweden from renewable sources 1990-2010 [38] (#cite-text-0-37)

Major sources for electricity production were hydro and nuclear power (Figure 4-7). The share of hydroelectricity has constantly increased in the period 1970-1985, and after 1985 has been on the level 60-80 TWh. In years of low water reservoir levels the production capacity has been reduced (e.g. year 1996, Figure 4-1). In 2012 roughly 160 TWh of electricity was produced and the share of domestic consumption was around 140 TWh.

Electricity system is connected to neighboring countries and during the year electricity is either imported or exported (see Table 6-3). Whether Sweden is net importer or -exporter depends greatly on the weather conditions. Dry or/and cold years reduce the production whereas warm years with high precipitation elevate the proportion of hydroelectricity [30] (#cite-text-0-86).

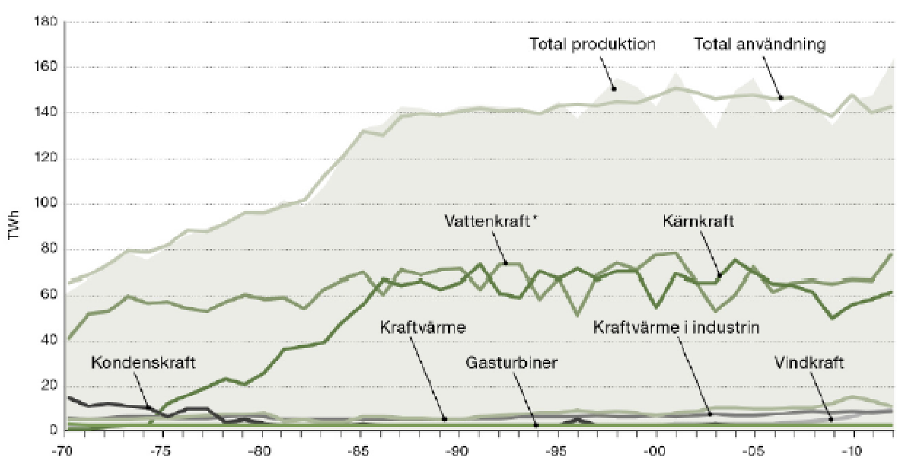


FIGURE 4-7. Electricity production by production modes and total electricity consumption 1970-2012 [39] (#cite-text-0-38) *I posten Vattenkraft ingår vindkraft till och med 1996.

Since 2000, the installed production capacities for wind power stations has steadily risen and in 2011 formed roughly 2000-3000 MW share (see Figures 4-7, 4-8). In the end of 2013 the wind production capacity had reached 4 470 MW [31] (#cite-text-0-90).

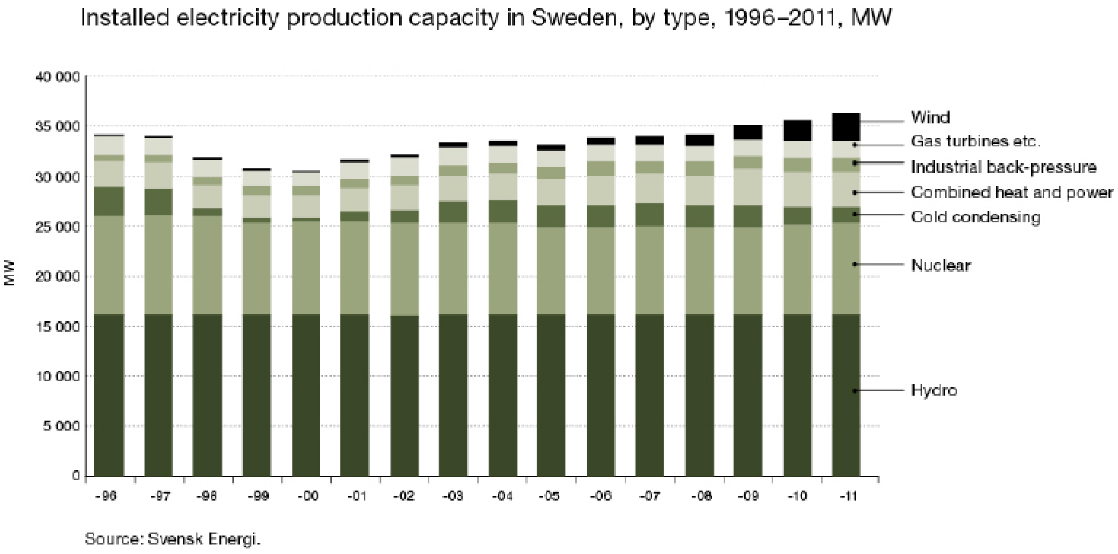


FIGURE 4-8. Installed electricity production capacity in Sweden, by type, 1996-2011, MW [40] (#cite-text-0-39)

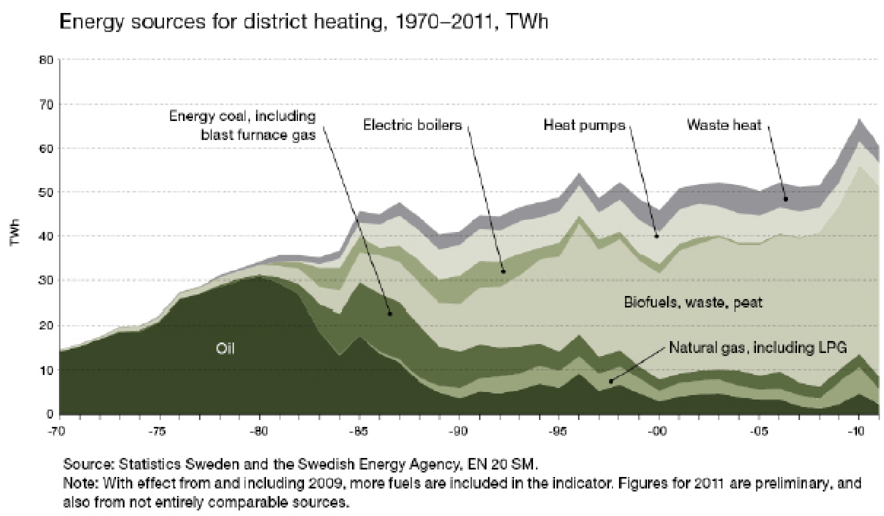


FIGURE 4-9. Energy sources for district heating 1970-2011 in TWh [41] (#cite-text-0-40)

Major energy sources for district heating generation have been renewables (biofuels, waste, peat, waste heat, heat pumps) since 1990. Currently the share of oil and coal are clearly marginal (Figure 4-9).

Total final energy consumption in Sweden has increased from 31.2 mtoe to 33.4 mtoe in the period 1990-2009. Final energy consumption is divided into three main sectors. The shares of residential and industry sectors have slightly decreased or remained on the same level, whereas the proportion of transport has increased in 20 years Energy efficiency policies and measures in Sweden. [32] (#cite-text-0-91) Yearly, residential and service sector uses around 40 % of the supplied energy.

The dwellings and service-sector used largest share of the electricity, approximately 73 TWh in 2012. The second largest consumer was industry with 53 TWh. Following a period of strong growth in electricity use, the consumption has flattened since 1987 (see Figure 4-10).

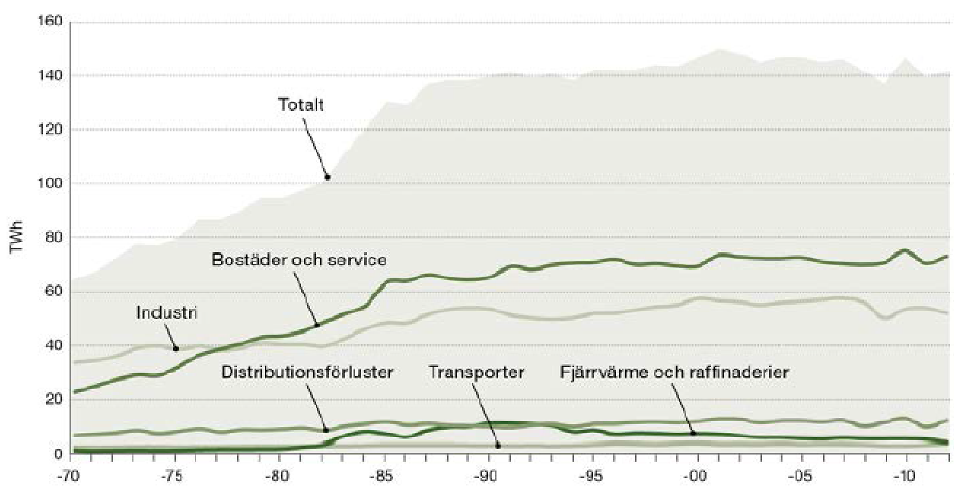


FIGURE 4-10. Electricity use by sector in Sweden in the period 1970-2012. “Industri”=industry, “Bostäder och service”=dwelling and service, “Totalt” =total, “Distributionsförluster”= distribution lost, “Transporter”=transportation, “Fjärrvärme och raffinaderier”= districh heat and refinery [42] (#cite-text-0-41)

4.2.1 Energy use in residential sector

Total final energy use for the residential and service sector has decreased since 1990. During the last decade the actual- and temperature corrected use of heating energy decreased with 27 % and 22 % when compared to 1985 [33] (#cite-text-0-92).

As outdoor temperature conditions affect indoor heating need, yearly variations in temperature have significant influence on the energy consumption. Countries with various temperature zones have rather large range in energy consumption by buildings measured as per house and square meter (see Figure 4-11). Temperature conditions are corrected statistically to enable reliable comparison between years.

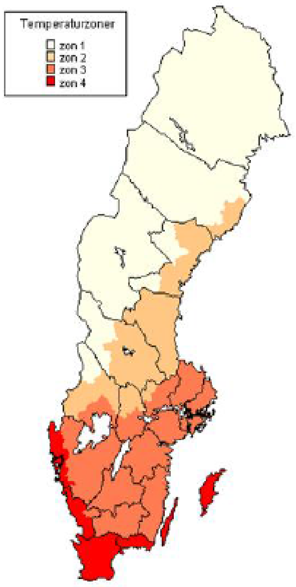


FIGURE 4-11. The four temperature zones are classified in Sweden [43] (#cite-text-0-42)

Climate corrected energy use for the residential and service sector was 157 TWh, and actual use 147 TWh (Figure 4-12). This corresponds to 40 % of the final energy use in Sweden in 2011. Year 2010 was exceptionally cold which can be seen in the increased actual energy consumption of 156 TWh.

Of the energy use in residential and service sector 60 % was directed for space heating and hot water production in 2011. In the following year, overall 79.5 TWh of energy was used for heating the dwellings and non-residential premises. Approximately 32 % was consumed by multi-dwelling buildings, 41 % detached and semi-attached buildings and 27 % non-residential premises [34] (#cite-text-0-93).

The most used heating energies were electricity, district heating and biofuels (logs, wood chips, sawdust, pellets). From year 1970 to 1990, the electricity use for heating increased from 5 TWh to 29 TWh in residential and service sector. Since 1990 the use has been falling and in 2010, 20 TWh of electricity was used for heating [30] (#cite-text-0-86).

Detached houses were mainly heated with electricity and biofuels, although the district heating has become more popular (Figure 4-12). In 2010, total of 16 TWh of electricity was used in detached houses. The use of biofuels has increased most of the forms of energy sources and totally 12 TWh was consumed. In the same year, the supply of district heating accounted for 6 TWh in detached houses [30] (#cite-text-0-86).

Eighty-five percentage of the apartment area in multi-dwelling apartments were district-heated in 2010 Energy efficiency policies and measures in Sweden [32] (#cite-text-0-91). Totally, 25 TWh of district heating, 1 TWh of electricity and 0.4 TWh of oil heating were used.

Different combinations of heating systems are commonly used in the buildings, for example by having electricity-heat pump or oil-air source heat pump systems. More than one million heating pumps reside in dwellings and majority is in attached and semi-attached houses [34] (#cite-text-0-93). Constantly increasing quantities have resulted to 46 % share of some form of heat pump in detached houses [30] (#cite-text-0-86). The most common types of pumps are geothermal-, lake water- and air source heat pumps.

The oil-based heating systems are not common and the proportion has continued to decline in 2012 (see Figures 4-9, 4-12). This is partly due to the rise of oil prices, changes in energy taxation and investment policies [32] (#cite-text-0-91). In one and two-dwelling buildings, 2.7 % of the heating energy was oil-originated. The values for multi-dwelling houses and premises were one and three percentage [35] (#cite-text-0-100).

The average use of heating and hot water energy were 121 kWh and 140 kWh per square meter for dwellings in detached and apartment houses (see Table 4.4). In comparison to preceding year, energy use was reduced by 18 kWh in multi-dwelling buildings. Annually, approximately 23 200 and 10 200 kWh of heating energy were used in single- and multi-dwelling buildings, although regional temperature zone -dependent variation exists [35] (#cite-text-0-100). Highest energy consumption were for single-dwelling houses in northern counties with 26 700 kWh of consumption and lowest in the ones located in southern part with 21 000 kWh.

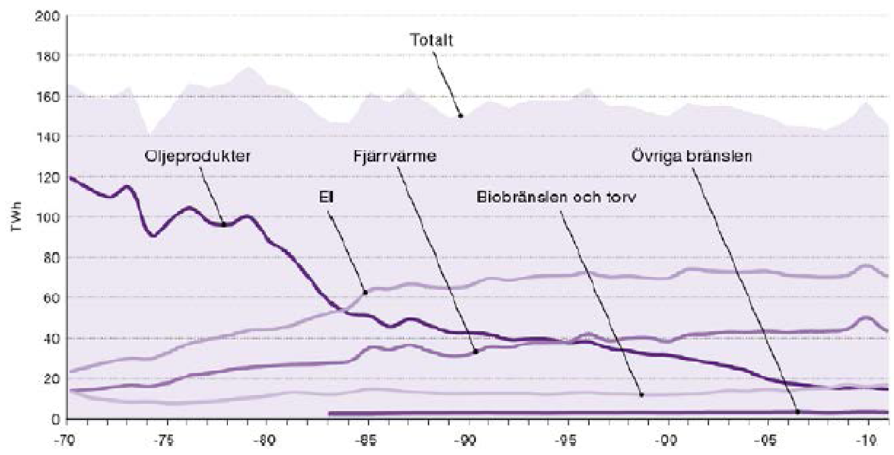


FIGURE 4-12. Energy use in building and service sector 1970-2011. “Oljeprodukter”=oil products, “El”=electricity, “Fjärrvärme”= district heat, “Totalt”=total, “Biobränslen och torv”= biofuels and peat, “Övriga bränslen”= residual fuels. [44] (#cite-text-0-43)

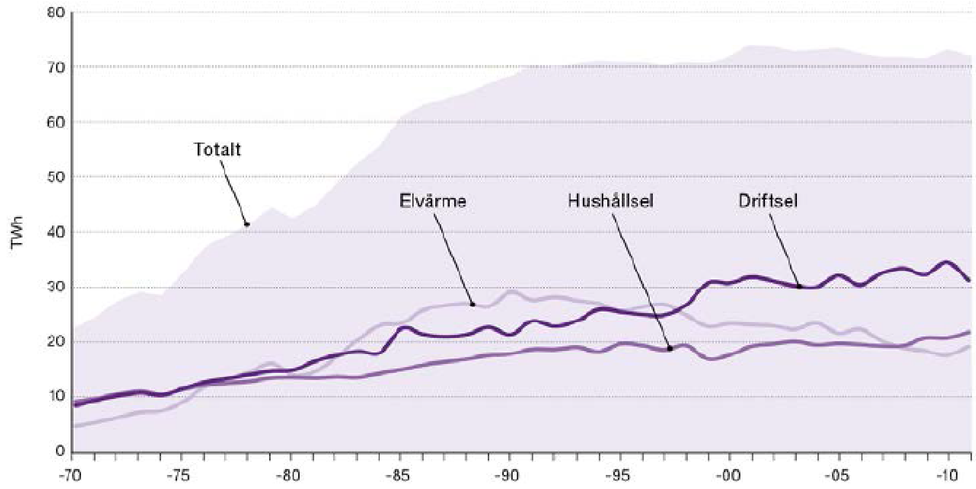


FIGURE 4-13. Temperature corrected electricity use in building and service sectors 1970-2011. Totalt=total, “Elvärme”=electricy produced heat, “Hushållsel”= household electricity, “Driftsel”= electricity use. [45] (#cite-text-0-44)

4.2.2 Emissions

Total average yearly reduction in carbon dioxide emissions has been 0.8 % in the period 1990-2010. Large variations appear between the sectors. Residential and tertiary sector have managed to reduce annual emission production by 3.3 % and industry share the similar trend with 0.8 % annual decrease. Contrarily emission production from transportation has increased by 0.4 % during the recent years. The most probable reasons for emission reduction in residential and tertiary sector are the conversion of oil based heating systems to biofuel based district heating, biomass-fuelled boilers and heat pumps [32] (#cite-text-0-91).

Carbon dioxide taxation has been used in Sweden since 1991 as one of the policy measures to include additional costs related to energy production and distribution. Correctly priced energy is prerequisite for supporting investments in production facilities with lowest possible level of environmental impact. Exclusion of the most polluting forms of production enables sustainable generation of energy [30] (#cite-text-0-86).

TABLE 4-4. Energy use in Swedish buildings

	Quantity gross floor area (million m²)	**Average energy consumption for ndividual building (kWh), dwellings (kWh/m²)**	**Occupants per dwelling / utility floor area m² per inhabitant**	**Ownership / annual need for renovation rate**	**Construction intensive years / Main construction material**	**Final energy consumption**	**Heating energy consumption**	**Final Electricity consumption**
Sweden						380.3 TWh (14)		125 TWh (14)
Building stock	686 mln (20)					143 TWh (15) 147 TWh (13)	80 TWh (19)	
Residential buildings						57 TWh (14)	29.1 TWh (14)	36.4 TWh (14) 70.9 TWh (16)
One and two dwelling houses	1 985 000 (20) / 301 (6)	23 200 kWh 7)			1970s wood mansory (1)	21.4 MWh/house (19)	35.8 TWh (9) 33 TWh (19) 18.8 MWh/building (19)	heat. 16 TWh (13) 17.2 MWh/house (19)
Block of flats	/ 238 (5) 186 (21)				1960s masonry-concrete (1)	37 TWh (5)	29 TWh (5) 24 TWh 27.2 TWh (13)	8 TWh (5) (incl 6 TWh household energy)
Dwellings	4 550 779		/44.4 (4)				183 kWh/m² (18)	
In one or two dwelling houses	2 014 394			97 %/		158 kWh/m² (8)?	23.2 MWh/dwell (8) 121 kWh/m² (10) 113 kWh/m² (19)	6 000 kWh/house (12) 142 kWh/m² (11) 125 kWh/m² (19)
In block of flats	2 536 385			37 % (2)/		155 kWh/m² (17)	10.2 MWh/dwell (8) 140 kWh/m² (8) 144 kWh/m² (19)	1 000 - 5 000 kWh/apart 40 kWh/m² (12)

(1) [14] (#cite-text-0-28) material in the facades 38

(2) [35] (#cite-text-0-100)

(3) [35] (#cite-text-0-100), oil use 115 000m³ is not added. Energy statistics for multi-dwelling buildings

(4) year 2003, calculated from occupied dwelling stock

(5) total area in m² Atemp3, “15 proposals to accelerate energy efficiency in current apartment buildings

(6) [36] (#cite-text-0-107) Costs for reducing the energy demand in the Swedish building stock according to national energy targets

(7) average, Swedish energy agency 2010

(8) [37] (#cite-text-0-108)

(9) [32] (#cite-text-0-91)

(10) [35] (#cite-text-0-100) electricity for household purposes excluded

(11) [35] (#cite-text-0-100), buildings 2008 that are heated solely with electricity, with breakdown by heated living area. Include electricity for other household purposes.

(12) [32] (#cite-text-0-91), average domestic electricity (used for lighting, white goods, domestic appliances, other electrical equipment) per year.

(13) [30] (#cite-text-0-86), values are for the year 2010, electricity, heating energy use are for detached houses

(14) IEA Report for countries 2011

(15) Statistics Sweden 2013

(16) year 2011, Final energy use in residential and service sector, [30] (#cite-text-0-86) [35] (#cite-text-0-100), temperature corrected energy 157.1 TWh, electricity 70 TWh

(17) total floor area in m² Atemp3, "15 proposals to accelerate energy efficiency in current apartment buildings"

(18) Sbsa 2007, values are calculated for heating space and water for benchmark dwelling according to calculation procedure of each country. Degree days are not taken into account.

(19) Include space heating and warming the water in a year 2012 for the units (?) Rounding is made for the values that are presented for unit of buildings. Detached house values include also semi-detached houses, multi-dwelling apartment values consist block of flats and attached houses [34] (#cite-text-0-93)

(20) heated area in 2003 [38] (#cite-text-0-117)

(21) [33] (#cite-text-0-92) Heated area

5 Russia

Russia is a country of 142 million inhabitants. Gross Domestic Production (PPP) is 2103.54 [39] (#cite-text-0-119). Country has several natural energy resources such as oil, gas and coal. It is among the world´s biggest energy producer when inspected as in the export of oil, gas, electricity and coal. At the same time Russia is third most energy consuming country in the world [40] (#cite-text-0-120). It is estimated that the state has vast potential to enhance the economy by improving domestic energy efficiency. Of primary energy consumption 45 % or 340 billion kWh of electricity could be saved if energy efficiency was enhanced. Or in other terms, equivalent to approximately 300 mtoe per year or 2.1 toe per habitant saving could be achieved. This level of savings corresponds to all the produced and imported energy (net of exports) by France or United Kingdom, or to 2 % of the energy produced by the world in 2005. In addition to benefit of saved energy to the economy, additional earnings can be derived from increased energy selling abroad [40] (#cite-text-0-120).

The largest energy saving potential in end-use energy consumption resides in residential sector, electricity production, manufacturing, transportation and heat supply [40] (#cite-text-0-120). The reduction of end-consumption has also indirect energy saving effects when energy required for transformation primary supply to energy end-use form and transportation of the energy products are decreased. Reduction in electricity consumption cause five-fold decrease in overall energy consumption. With energy efficiency measures the carbon dioxide emissions would be about 20 % lower by 2030 than in 1990.

5.1 Building stock

Approximately 19.65 million buildings accounted for total area of 177 million m² or in floor space 3.2 milliard m² [41] (#cite-text-0-123). Prevailing form of tenure is the private ownership (Figure 5-2). Residential buildings, the majority 70 % is multiapartment building and the rest individual buildings. Estimated average age of building is 42 years. In the period 1990-2005 growth rate of housing stock was significantly slower than in the following period that reached the average level of the 1980th in 2007. Housing stock increased by 14 % from 2000 to 2009. Annual increase is approximately 3 % [41] (#cite-text-0-123). Privatization of residential buildings begun in the beginning of 1990s´ and currently it is around 90 % (Figure 5-2).

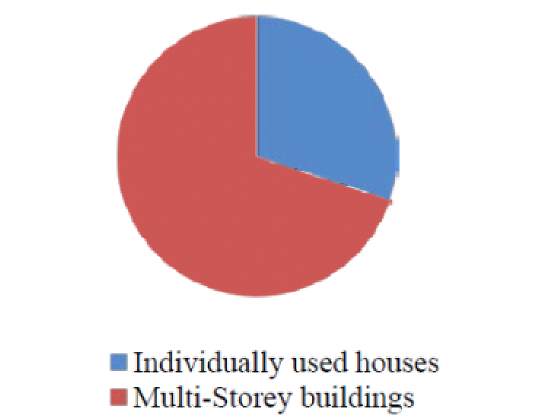


FIGURE 5-1. Building stock composition by total area in Russia. Information derived from Murmansk State Technical University

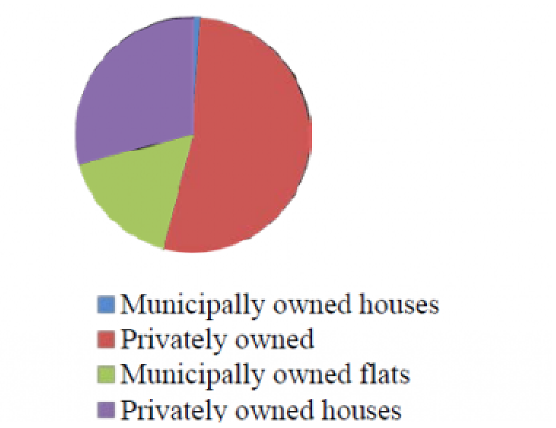


FIGURE 5-2. The ownership structure of Russian houses by total area (m²). Information derived from Murmansk State University.

5.1.1 Residential buildings and dwellings

In rural areas residential buildings are usually single-family houses and in urban regions multi-floor buildings. Approximately 73 % of the total housing stock located in urban area in 2002 (Chapter III). Number of block of flats is 3.2 million which consist of 2.2 milliard m² of floor space (see [42] (#cite-text-0-125)). Housing stock in Russia includes also buildings with special purposes such as hostels, shelter etc. but do not include summer cottages. This is major difference when compared to data collection system operated in Western countries (Chapter III).

Most intensive construction years for the apartment buildings were in the period 1960-1985 (see Table 5-1). Construction begun to industrialize in 1950s and since then rapid erection of multistory buildings with pre-casted concrete large-panel was established. Three basic categories can be discovered for residential panel buildings that are called First (built 1959-1969), Second (1961-1975) and Third (1976->) generation buildings. Currently, this can be seen us rather uniform appearance of urban housing stock (Chapter III). In 2009, on average 90% of buildings in 43 regions were constructed before 1995 [41] (#cite-text-0-123).

TABLE 5-1. Age of the housing stock is presented. The table is formatted from the source: Chapter III.

	Percentage of dwelling space			
Construction date	**Moscow**	**St. Petersburg**	**Russia (1)**	**EU**
Before 1917	2	19		32
1918 - 1945	3	3	34	
1946 - 1975	52	43	63	40
1976 and later	43	35		28

(1) [41] (#cite-text-0-123)

The percentage of unfinished construction is rather high and regional differences are observed. For example in regions of Murmansk, Tula, Kamchatka, Magadan and Jewish autonomous regions the ratio of uncompleted dwellings to completed new dwellings was 10:1 in 2001. In the same year, the number of unfinished residential houses were 38 700 which corresponds to 44 million m² of total floor area (Chapter III). The trend of unfinished construction has consistently decreased during the years, and in year 2010 the total floor area of uncompleted residential buildings was 29.7 million m² (Table 5-2, [42] (#cite-text-0-125)). Generally, the level of insufficient investments and the rise of construction costs have caused delays or total inability to complete the building (Chapter III). The growth of Russian construction sector is expected to occur due to high demand for residential properties and infrastructure development. In 2012 the sales and orders of construction companies have increased and the value of completed projects have risen by 5.2 % when compared to the value of preceding year [42] (#cite-text-0-125).

TABLE 5-2. Information on uncompleted construction of Russian residential buildings. The table is originally presented by [42] (#cite-text-0-125)

Year	1995	2000	2005	2006	2007	2008	2009	2010
Total area (million m²)	90.1	45.2	35.0	36.1	39.2	39.5	33.9	29.7

Basic amenities vary in apartments. In 2002 urban housing stock was lacking running water in 13 %, sewage in 15 %, central heating in 12 %, integrated baths/shower in 20 % and running hot water in 23 % of its buildings. These utilities were missing in 59-81 % of the rural building stock. Approximately half of the total population lives in houses equipped with all the utilities (Chapter III).

5.1.2 Renovation and investments

The survey done by Russian Federal State Statistics Service (1.1.2013) indicates that 30-65 % of the total quantity of multi-floor buildings have experienced depreciation. Major repair is required for 1.6 million units that are inhabited by 45 million people. Roughly 58-60 % of all the apartment houses need major complex-level repair (see Figure 5-3). Majority of these have at last 25 years of existence.

Among the multi-floor buildings, the total area of the dilapidated housing stock (38.4 mln m²) and the ones that have experienced depreciation more than 66 % (18.6 mln m²) result in 56.9 million m².

Large-scale modernizations of apartment houses are needed to improve energy efficiency and housing quality for inhabitants. According to estimations, approximately 187 billion RUR of utilities costs can be saved by enhanced energy efficiency and effective production of energy [40] (#cite-text-0-120).

In the evaluations, the costs of major repair and modernization of apartment houses vary between 220 billion-1 trillion in the period 2013-2035. The former cost accounts for repairing some technical defects and latter include complex repair with energy saving material and technologies.

FIGURE 5-3. Annual (average growth of the housing stock floor space and dynamics of the dilapidated and unsafe housing share [46] (#cite-text-0-45)

HURIF (Housing and Utilities Reform Initiative Fund) as a main financier together with regional governments and individual owners have funded the renovation of 135.36 multi-storey buildings of the total area 404.57 m² with the total sum of 295.97 billion RUR in the period 2008-2012.

In 2013 totally 98.6 billion RUR were spent on renovation on apartment houses. Necessarily not full scale repair has been performed for all the buildings, which may be shown as differences between qualitative evaluation and the figures/numbers. Renovations of selected constructive elements or facilities were supposed to remove the physical dilapidation.

Heat and hot water is provided by district heating systems to almost all urban populations and industry [43] (#cite-text-0-132). Inadequate maintenance and minor investments made in 1990´s are currently reflected as lower level reliability of supply. Reduction of losses by improved energy efficiency measures and enhanced efficiency of heating plants could aid in achieving significant energy savings. According to IEA data, or Russian energy experts, approximately 3 %, or 20-30 %, of the generated heat is lost in transmission and distribution processes. Major repair or replacement is needed for roughly 60 % of the district-heating network [43] (#cite-text-0-132).

Poor insulation around heat pipes causes large heat losses. Flow is not controlled or measured in transmission/distribution lines in most heating networks, and uneven distribution lead to situation of overheating buildings in upstream and under-heating others in downstream [43] (#cite-text-0-132). Heat limitations set to certain radiator restricts the stream to other radiators of the same building, caused by system design. Meters were not used for residential and commercial customers and the charging based on equation including floor space is paid as part of the rent. Industrial use is charged based on the heat consumed and higher tariff is set for the use exceeding amounts defined in the supply contract. Generally, tariffs do not cover the costs of supply; rather these are cross-subsidized with the funds from electricity sales [43] (#cite-text-0-132). Tariffing systems leads to inadequate maintenance, under investment and repair funds. Full costs should be covered by electricity and heat tariffs to confirm the long-term viability of the systems. Meters and heat-regulating devices should be installed to enable end-customers to regulate their consumption. Objection is presented by politicians that have point of view that heat is free form of subsidy to the population.

In residential sector, investments on existing buildings are hindered by various reasons. Major obstacles are; energy efficiency is not monitored, apartment owners have insufficient information on energy efficiency, energy efficiency investments require capital to which owners have limited access, lack of incentives to invest in energy efficiency, split incentives and underpriced energy in Russia [40] (#cite-text-0-120). Simultaneous or separate repair and renovation of apartment houses provide opportunities for energy efficiency projects also afterwards. Improvement of energy efficiency along with renovation is most costeffective and convenient manner for inhabitants to ensure improved air quality and the fulfillment of current and future energy and eco-efficiency requirements (e.g. [44] (#cite-text-0-137)).

5.2 Energy supply and consumption

The primary energy supply was 731 mtoe in 2011 and more than half of it was comprised of natural gas. Other important supplies were oil and coal/peat (Figure 5-4). [39] (#cite-text-0-119)

Energy production has increased from the level of 910 mtoe in 1997 to 1300 mtoe in 2011 (Figure 5-5). Year 2009 was exceptional and the drop to level of 1200 mtoe was experienced from the level of 1260 in preceding year. [39] (#cite-text-0-119)

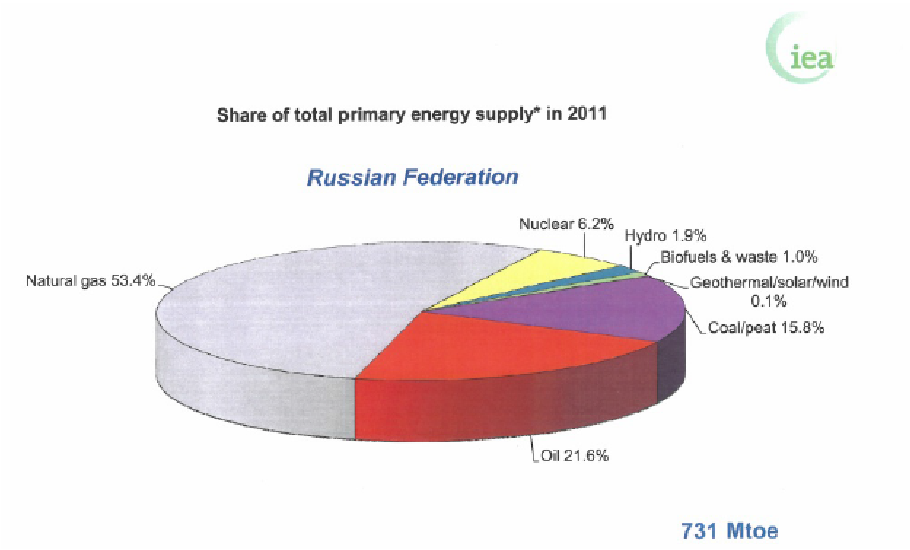


FIGURE 5-4. Share of total primary energy supply in 2011. Electricity trade is excluded. [47] (#cite-text-0-46)

The total production of electricity and heat were 1055 TWh and 6381 TWh in year 2011 [39] (#cite-text-0-119). Large share (30 %) of electricity is produced as a side-product of a heat, and often heat and electricity sectors are issued together.

The electricity is mainly produced from natural gas (49.2 %), nuclear (16.4 %), hydro (15.9 %) and peat-coil (15.6 %), oil (2.6 %), waste (0.26 %), geothermal (0.05 %) and biofuels (0.003%) (Figure 5-6). The main users are industry (46 %), commercial-public services (22 %) and residential (18 %) [39] (#cite-text-0-119).

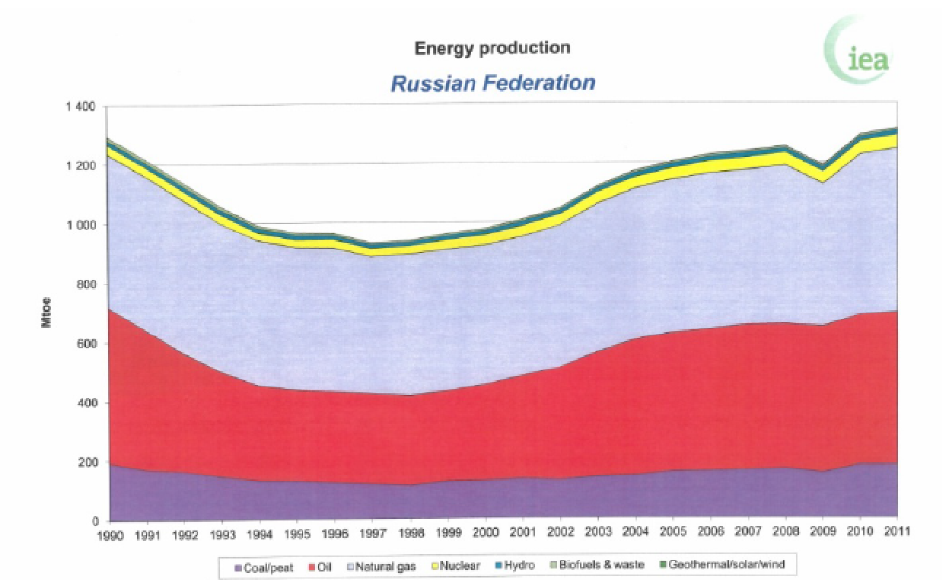


FIGURE 5-5. The energy production by energy sources in Russia through the years [48] (#cite-text-0-47)

The proportion of imported electricity was 1 558 GWh and exported 24 111 GWh (Appendix Table 6-3). Export is on the same level than in 1999. In 2002 Russia was regarded as fourth largest electricity providers in the world after United States, China and Japan. Two thirds of the electricity was commonly directed to CIS countries but this has reduced due to non-payment. Since then increasing quantities of electricity have been planned to export to Western European countries as representing major potential source of funds [43] (#cite-text-0-132).

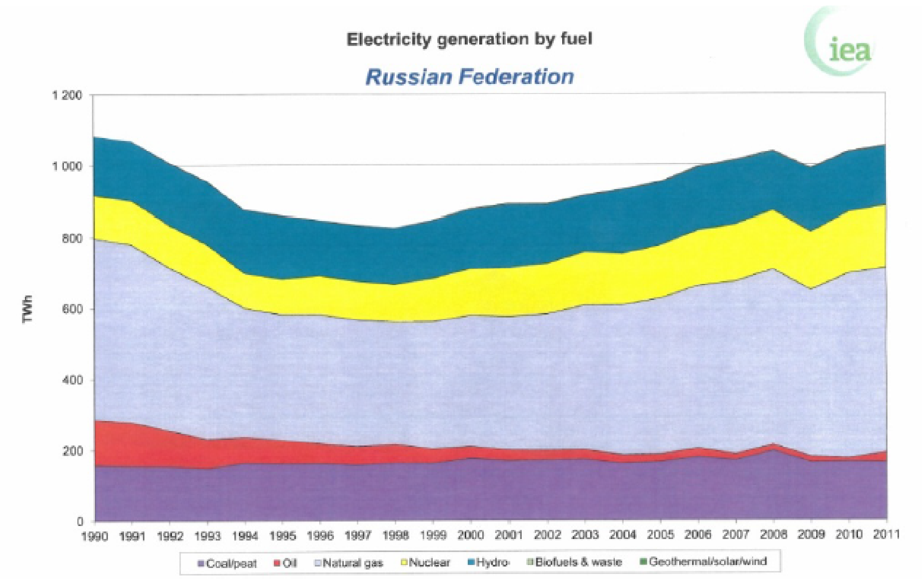


FIGURE 5-6. Electricity production by fuels in Russia between 1990-2011 [49] (#cite-text-0-48)

Russia is third largest energy consuming state in the world. Measured as energy use per unit of GDP, energy intensity, the state is ranked among the highest energy users. Russia has extensive domestic energy supply and inefficient technology that are used in cold climate which poses challenges in attempts to improve the level of energy efficiency. This influences all the sectors of economy [42] (#cite-text-0-125).

For long time heating has accounted major portion of energy consumption. For example in 1999 it consumed 5 706 PJ and formed 33.2 % of the final energy consumption [43] (#cite-text-0-132). In 2011 the consumption was 2439 PJ that accounted for 22.6 % of TFC [39] (#cite-text-0-119). The heating energy is produced from gas (67.3 %), coal-peat (19.9 %), oil (5.6 %), other sources (5.1 %), waste (1.3 %), biofuels (0.6 %) and nuclear (0.2 %). Largest shares are consumed by residential (47 %), industry (38 %) and commercial-public services (11 %).

In 2011 the total final energy consumption was 458.6 mtoe which was shared between industry 128.1 mtoe, transportation 98.4 mtoe and other 165.4 mtoe. The building and more specifically residential building sector is included within "other" where they formed a largest share with 144 mtoe and 117.5 mtoe [39] (#cite-text-0-119).

5.2.1 Energy use in building sector

Lack of official statistics on the structure of the energy end-use creates challenges on gaining good comprehension [40] (#cite-text-0-120).

After manufacturing, the building sector is the second largest energy end-consumer in Russia. Building sector has the largest potential for improving energy efficiency exists; investments could promote saving of 68.6 mtoe per year [40] (#cite-text-0-120). Three quarters of the energy is used by residential houses.

According to study done by World Bank in 2008 the share of space and water heating of the overall energy consumption by residential building is 58 % and 25 %. Share of cooking is 10 %, appliances 4 %, lighting 2 % and other 1 % (Figures 5-7, 5-8, see [40] (#cite-text-0-120) [42] (#cite-text-0-125). Long heating season and inefficient design of buildings results in two times higher energy use of heating a square meter of space in comparison to values of Canadian houses locating in corresponding climatic conditions and geography [45] (#cite-text-0-151).

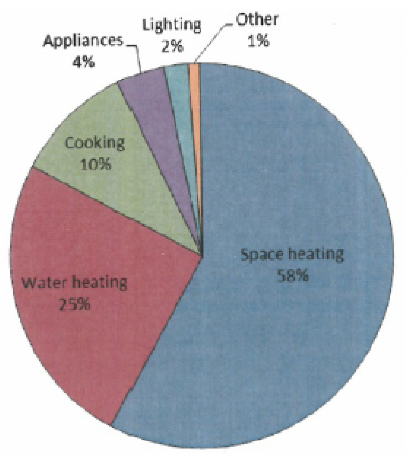
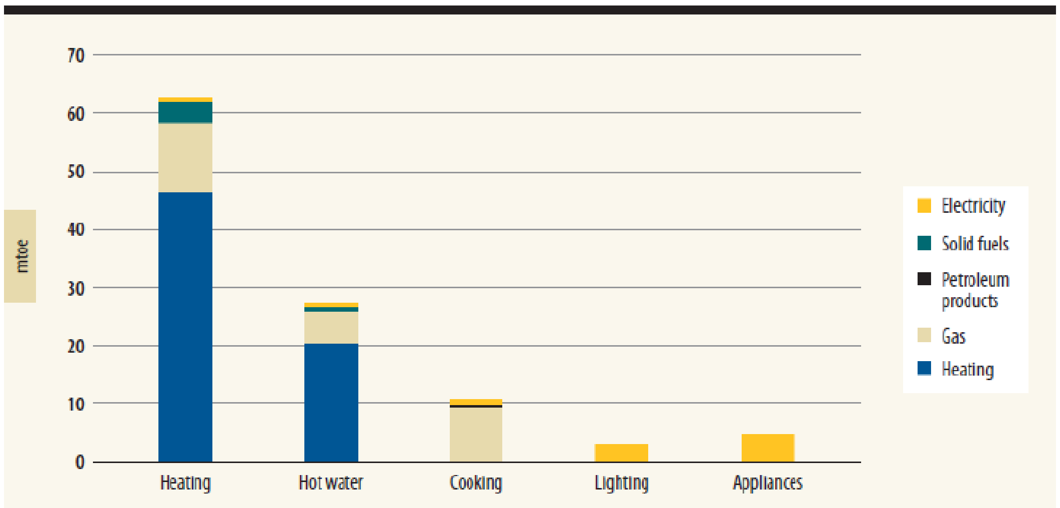


FIGURE 5-7. Residential energy consumption in Russia [40] (#cite-text-0-120) [50] (#cite-text-0-49)

District heating is the main heating system in 75 % of dwellings. According to IFC and World Bank, the district heating based space and water heating is inefficient, and by improvement approximately two thirds of the total energy saving could be achieved [46] (#cite-text-0-153) [40] (#cite-text-0-120).

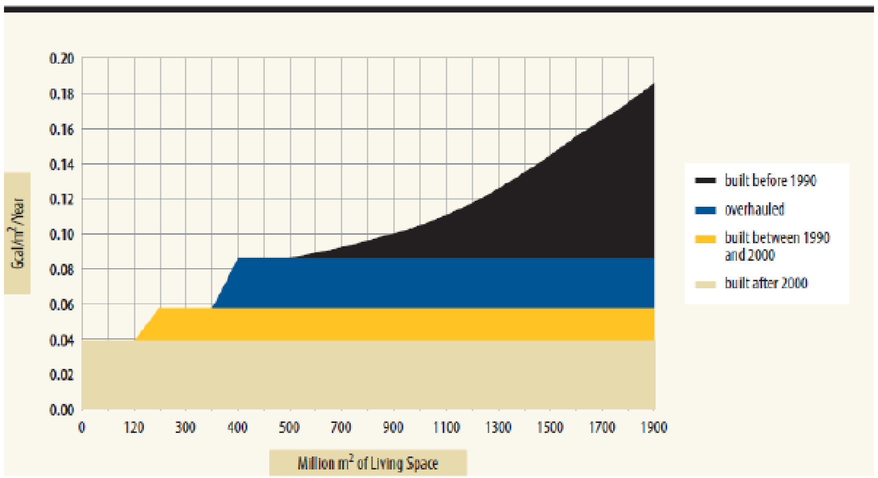
Although the significant share of energy end-consumption, more detailed level data is missing on the energy consumption of residential buildings. Some estimates by organizations such as CENEf, IEA, World Bank have been made, and these are utilized in this study.



Source: CENEf for the World Bank.

FIGURE 5-8. Residential energy consumption is shown grouped according to energy sources in Russia [51] (#cite-text-0-50)

Average heating energy intensity for multi-family apartment building is 229 kWh/m²/year. Refurbishment of existing building stock can result in energy intensity of 151 kWh/m² (World Bank 2008). Also the age of the building affects space and water heating energy intensity (Figure 5-9).

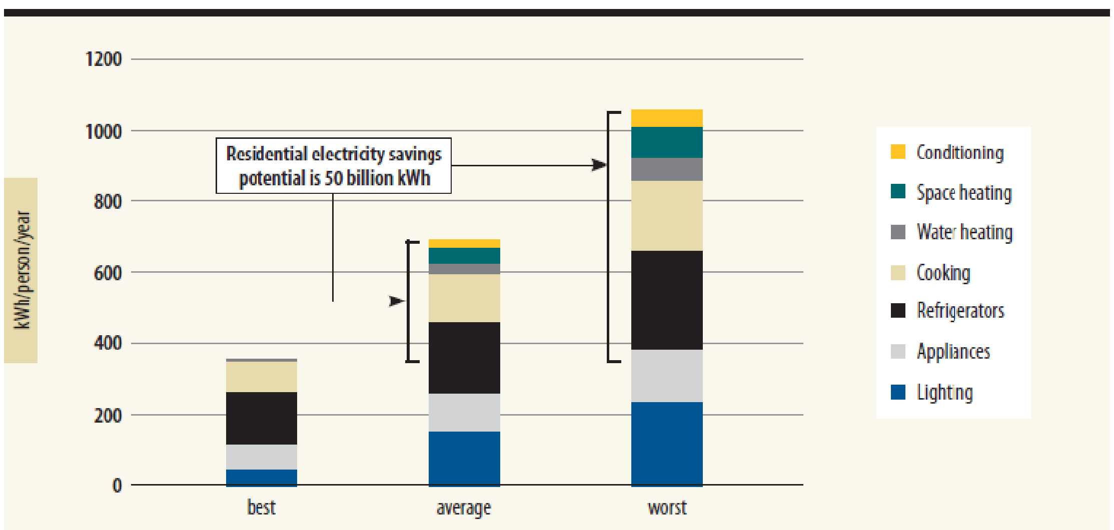


Source: CENEf for the World Bank.

FIGURE 5-9. Residential buildings constructed in different decades access the district heating network by hot water energy intensities [52] (#cite-text-0-51)

Small portion of the houses constructed after 2000 have insulation levels according to standards and have sufficient thermal performance and heating energy efficiency level. New buildings may have heating intensity of 77 kWh/m².

Significant technical potential could reduce space heating energy between 17-42 mtoe. This corresponds to 35-49 % of the final heat consumption in 2005. Overall, refurbishment of existing housing stock could save up to 60 % of heating energy consumed in 2005.



Source: CENEf for the World Bank.

FIGURE 5-10. Electricity saving potential in residential building [53] (#cite-text-0-52)

Improved technical efficiency of water heating could produce 13.4 mtoe savings, which equals to 35 % of the use in 2005. Renovation of hot water delivery system (e.g. regulation of water temperature, insulation of hot water pipes) produce 12 % of the 13.5 mtoe saving. Investments within individual apartments, e.g. installation of hot water meters, bring 38 % of the savings. Changes in consumer behavior can produce additional 30-40 % saving due to hot water installations when the water usage can be monitored [40] (#cite-text-0-120).

Age of the building determines partly the cost of energy efficiency investment. No energy-efficiency related incremental cost are needed for new buildings, rather the cost depends on the number of floors, building orientation and geometry, labor and material cost [40] (#cite-text-0-120). For existing buildings, numbers of options are available to save energy. In Figure 5-10 are shown electricity saving measures and results.

According to World Bank Report 2008, the major obstacles in hindering the improvement of energy efficiency in Russia are general awareness and lack of statistical data, little appreciation of energy efficiency, too mild incentives or split incentives, environmental externalities, tariff methodologies and tariffs, high transaction costs, lack of competition.

In the residential sector the specific barriers for new buildings are:

- No incentive to improve energy efficiency for developers and their contractors.

- Thermal performance standards became voluntary in 2010.
- Limited knowledge of energy efficiency developers and their contractors have.

For the existing buildings main hindrances are:

- Lack of monitoring the energy efficiency.
- Lack of information on the energy efficiency by apartment owners and building managers.
- Lack of incentives to invest in energy efficiency by the owners.

TABLE 5-3. Buildings and energy use in Russia

	Quantity / gross floor area m²	Number of occupants per dwelling	Average dwelling space (m² / inhabitant)	Ownership / annual need for renovation rate	Construction intensive years / Main construction material	Final energy consumption TJ / TWh	Heating energy consumption TJ / TWh	Final electricity consumption TWh
Russia						5338 TWh (1)	1 437 TWh (1)	927 (1)
Building stock				Priv 84 %		6,216 PJ / 165 mln TOE = 1343TWh	62 % of final energy	
Residential buildings	19.7 million / 3 345 million m² (14)			/ 4-5 %		4,666 PJ / 1372 TWh (1)	677.6 TWh (1)	131
Detached houses	16.4 mln / 975 mln m²			Priv 97 %				
Block of flats	3.2 mln m² / 2 237 mln m²				1960-1985 Precast concrete large panel	266 kWh / m² (4)	299 kWh / m² (5) 219 kWh / m² (3)	47 kWh / m² (3)
Dwellings	55 mln / 2 853 mln m² (2)	2.3 (2)	19.7 (2) - 23.4 (3)					
Detached houses				Priv 97 %				
Block of flats				Priv 76 %				
CO2	1 653.23 fuel combustion only (1)							

(1) [45] (#cite-text-0-151)

(2) Chapter III, statistics collected in a year 2002

(3) Calculated for the apartment built in year 2012, Russia Federal State Statistics.

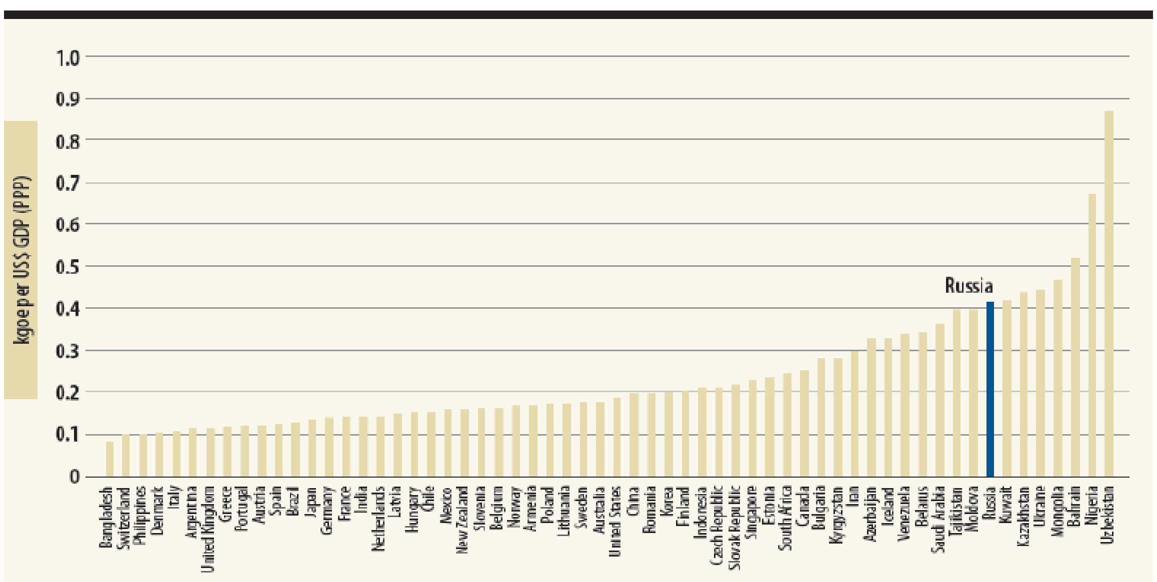
(4) [44] (#cite-text-0-137)

(5) [40] (#cite-text-0-120)

6 Comparisons between countries

The countries have strengths and developmental targets regarding energy efficiency in different economy areas, and especially among residential building sector. Here energy policies have significant role in implementation of measures. Finland and Sweden as EU member states are committed to follow EU-directives regarding energy use. Norway has also included requirements of energy related EU-directives into its national regulations. In Russia, the EU-directives have been acknowledged in recently updated legislation and are regarded as a guideline for energy use. For example, energy efficiency and conservation were defined as top priorities in modernization of Russian economy by the president Dmitry Medvedev in a year 2008 [40] (#cite-text-0-120).

Major findings of the energy production and consumption of the countries are gathered on Tables 6-1, 6-2 and 6-3. Generally, the proportion of residential and service sector of the final energy use is approximately 40 % in Scandinavia and Russia.



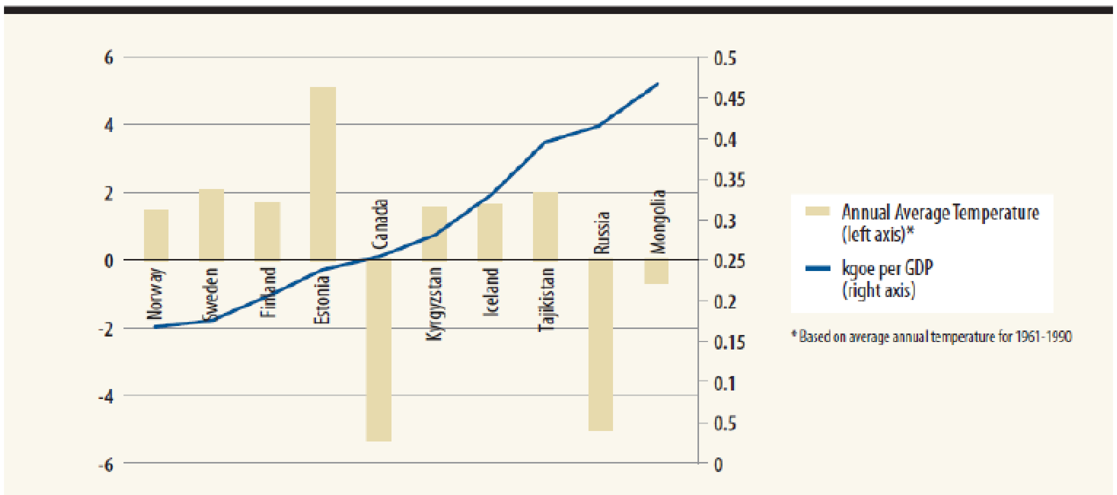
Source: Energy consumption data from the International Energy Agency (IEA), Energy Balances data set. GDP and PPP conversion factor data from the World Bank Development Indicators Database.

FIGURE 6-1. Global comparison of energy intensities per GDP (PPP) for Norway, Sweden, Finland and Russia [54] (#cite-text-0-53)

Energy intensities indicate the efficiency of energy use in economies of the countries. This is generally regarded as a ratio between the total amount of primary/final energy and gross domestic product. The unit allow performing comparisons between countries, as energy use often follows the level of GDP (e.g. [40] (#cite-text-0-120)).

Along the rise in economic circumstances, energy usage by housing tends to increase, e.g. dwellings are heated to more comfortable levels, larger dwellings, more appliances and lighting points are acquired. However, no explicit relationship between energy consumption and average household income are shown, and various exceptions can be detected across the country comparisons [16] (#cite-text-0-33).

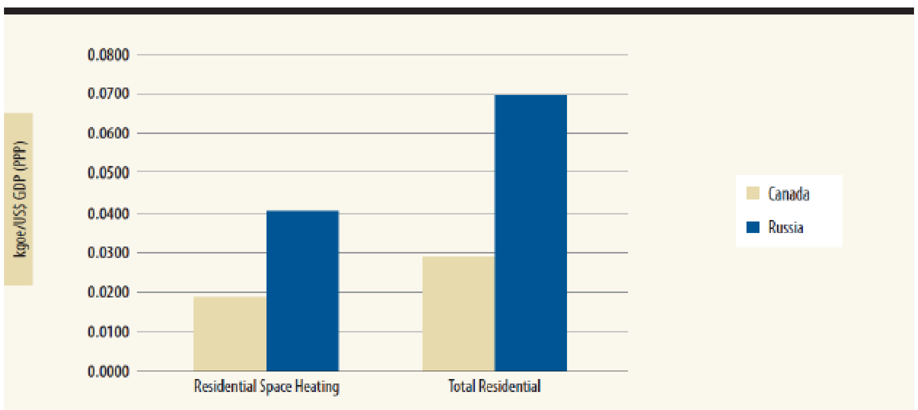
In 2010, the average primary energy value for EU was 0.15 koe/€2000. The corresponding values for Finland, Sweden and Norway have been close to EU-average during many years. Energy intensity of Russia has often departed from the EU-average (Figure 6-1, Table 6-3). According to set decree in Russia, energy consumption per unit of GDP will be reduced at least by 40 % until the year 2020 from the level of 2007.



Source: Energy consumption data from the International Energy Agency (IEA), Energy Balances data set. GDP and PPP conversion factor data from the World Bank Development Indicators Database. Temperature data from data set TYN CY 1.1, Mitchell, T.D., Carter, T.R., Jones, P.D., Hulme,M., New, M., 2003: "A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100)". *Journal of Climate:* submitted.

FIGURE 6-2. Energy intensities of countries with similar average temperatures, including Norway, Sweden, Finland and Russia [55] (#cite-text-0-54)

High energy intensity of major Russian economic sectors, measured in global categories has emphasized the need to improve energy performance (see Figure 6-1). Long heating season and inefficient design are named to be factors behind energy intensiveness of Russian buildings. On average Russia is one of the world´s coldest countries which explain partly the high energy intensity. Other countries that have average temperature close to Russia, including Finland, Norway, Sweden, do not show that clear association to energy intensity. For example in Canada the temperature is even lower than in Russia, still the energy intensity is much less in Canada. Smaller energy quantities are consumed per square meter in Canada than Russia (Figures 6-1, 6-2, 6-3).



Source: IEA Energy Balances, CENEf for the World Bank, and Natural Resources Canada.

FIGURE 6-3. Energy use in residential sectors in Canada and Russia [56] (#cite-text-0-55)

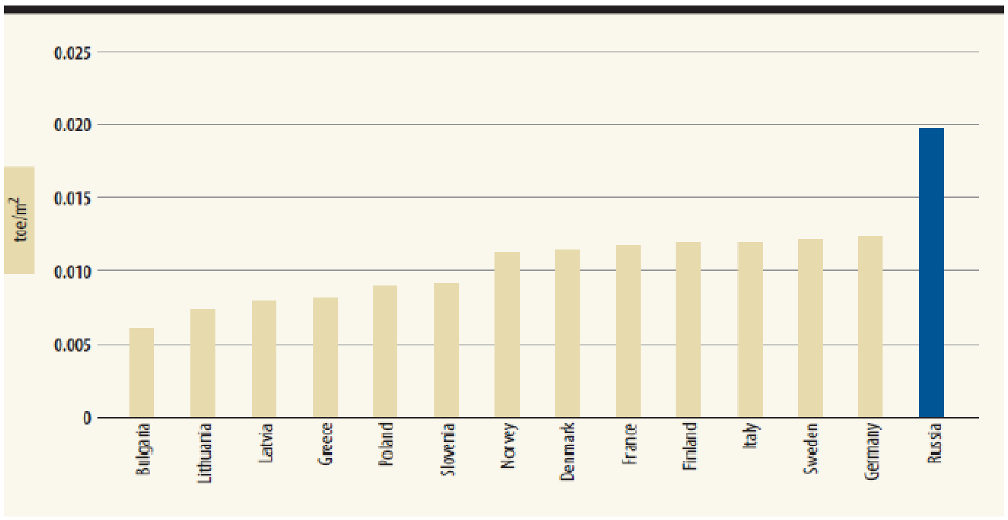
The structure and age of existing building stock vary between countries, although common characters are found. The construction of detached houses has dominated the building in every decade in all countries. Especially periods of 1970s and 1980s have been intensive regarding the erection of single-dwelling houses.

The shares of detached houses as units of the building stock are 44-77 % in Scandinavia and 30 % Russia. When investigated as floor area, Norway has exceptionally high, 86 % proportion of single-dwelling apartments in residential building stock (see [1] (#cite-text-0-0)). The corresponding values are 65 % for Finland and 55 % for Sweden [1] (#cite-text-0-0).

In quantities, Finland and Norway have relatively low proportions of attached and apartment houses, 11 % and 23 % of residential buildings. Highest share of apartment houses are in Sweden and Russia, with 56 and 70 percentages (Table 6-2 (http://www.oamk.fi/epooki/files/7814/2986/7661/Table_6-2.pdf)).

In floor areas, the proportion of attached-apartment houses in Norway is 14 %, Finland 35 %, Sweden 45 % [1] (#cite-text-0-0) and Russia 68 % (2.2 mrd m² of apartment floor area is divided by total floor space of all buildings 3.2 mrd m²).

Construction of apartment houses has focused especially in 1970 decade. In Norway block of flats are constructed more in 2000 century than in earlier decades.



Source: ODYSSEE for all countries except Russia. Russian data from CENEf and Rosstat, "Residential Sector and Consumer Services to Population in Russia", 2007.

FIGURE 6-4 Heating energy intensities for Norway, Finland, Sweden and Russia [57] (#cite-text-0-56)

Differences in the usage of energy sources and consumption by residential buildings are detected between countries.

Majority of the energy, generally around 60 %, is used for heating the space and water. In Norway, the electricity is the main heating energy source also in apartment houses. In Sweden and Finland, electricity heating prevails in detached houses, whereas district heating is the most popular among block of flats. In Russian apartment houses district heating is practically the only heating form. The heating energy per square meter is roughly 1.5 times higher in Russia than elsewhere (Figure 6-4, Table 6-2).

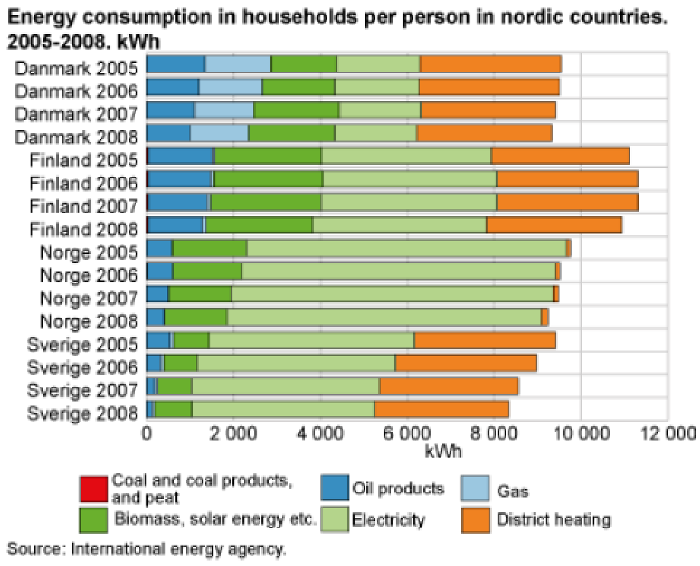


FIGURE 6-5. Energy consumption in households per person in Nordic countries in years 2005-2008 [58] (#cite-text-0-57) [19] (#cite-text-0-37)

In Norway, hydroelectricity is the main energy product. This can be seen when electricity production of Nordic countries and Russia are compared (Figure 6-4, Table 6-3). Norwegian houses are mainly heated with electricity and by minor percentage of wood-fuels. Generally, consumption of heating oil and solid fuels have decreased in Europe. This can also be seen in energy use of Sweden and Finland (Figure 6-5). Partly, this is due to replacement of oil-boilers with biofuel-boilers and connections made to district heating network.

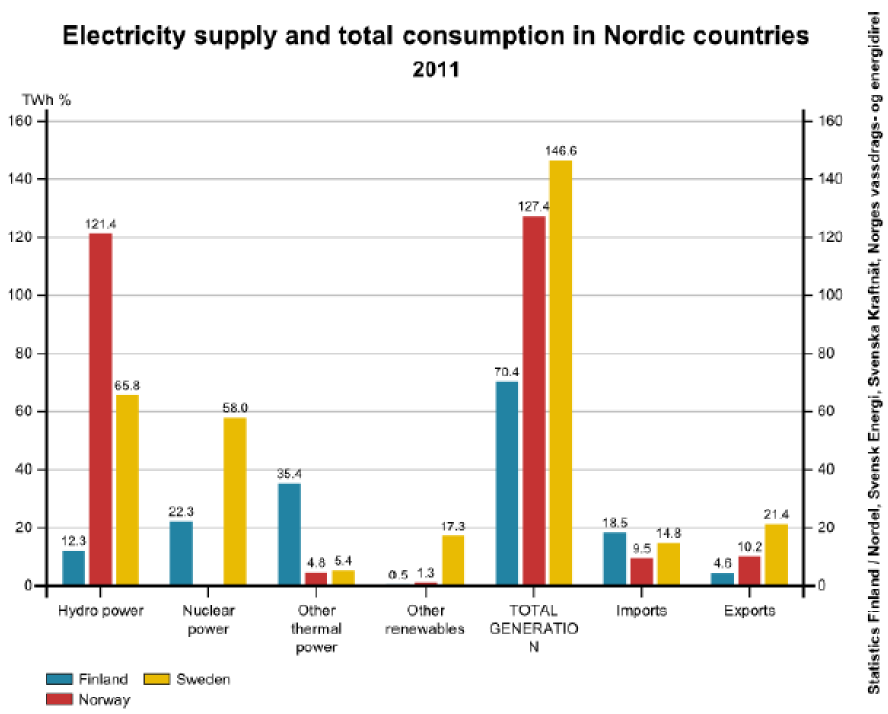


FIGURE 6-6. The supply and consumption of electricity in Nordic countries [59] (#cite-text-0-58)

Despite of the continuous growth of the building mass, the energy and electricity consumption per apartment area has flattened during 20 years. This is primarily due to energy-efficient measure, better heating systems, milder climate since 1980, urbanization that has increased the construction of apartment houses, flattened increase of per capita square meters, increasing trend in housing prices in Scandinavia.

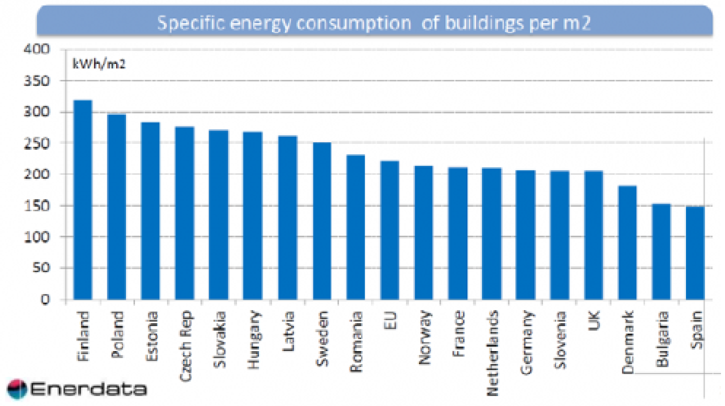


FIGURE 6-7. Energy consumption of buildings per square meter as presented by Enerdata and IEA-report [60] (#cite-text-0-59)

In Europe, the energy consumption per square meter for buildings range between the values 150 kWh/m² and 310 kWh/m². In 2009 the average was 220 kWh/m². Residential and non-residential buildings energy use differs largely, by values 200 kWh/m² and 295 kWh/m² [16] (#cite-text-0-33).

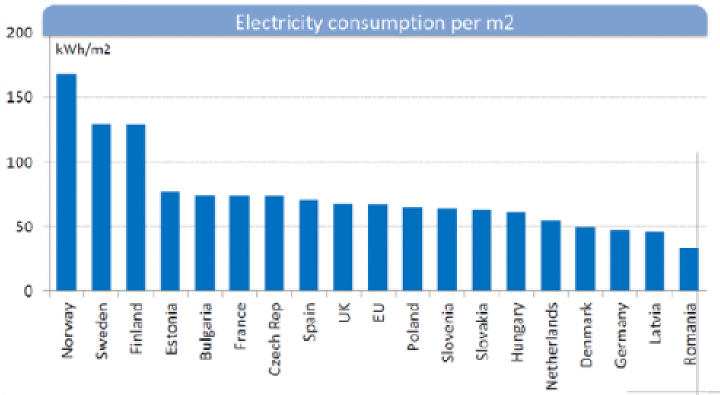


FIGURE 6-8. Electricity use in European buildings is shown for the year 2009. Studied Scandinavian countries are ranked as the highest electricity consumers [61] (#cite-text-0-60)

Type of buildings and countries have high influence on the variation of the electricity consumption per square meter. The studied Scandinavian countries; Norway, Sweden and Finland are ranked on the top because of the electricity use for space heating [16] (#cite-text-0-33). In Russia, district heating is the major energy carrier to warm apartment buildings.

TABLE 6-3. Energy consumption in typical apartment houses before and after renovations of different level in Scandinavia and Russia

	Typical apartment house	**Heating consumption (kWh / m², a)**	**Electricity consumption (kWh / m², a)**	**Cost €/ m²**
Finland				
- before nenovation (1a)		225	70	
- after Advanced renovation	City: Oulainen	139	52	61 (462) (6)
- before renovation (1b)		188 - 255		
- after renovation		82 - 138		payback time 10 years
Sweden				
Norway (2)	Modelled	160 (5)		
- after moderate renovation		130 (5)		
- after ambitious renovation		90 (5)		
Russia (3)	II-18 (4)	219	47	
- after Basic renovation		134	37	125
- after Improved renovation		104	35	155
- after Advanced renovation		71	39	200

(1a) [47] (#cite-text-0-169) apartment house constructed in 1971 with floor area of 1833 m²

(1b) [48] (#cite-text-0-170) three apartment houses constructed 1950, -60 and -70.

(2) [21] (#cite-text-0-39)

(3) [49] (#cite-text-0-172)

(4) Total floor area 4 911 m², number of floors 12

(5) [21] (#cite-text-0-39) Specific useful energy consumption for apartment houses constructed 1946-1970.

(6) a cost 61 € indicates the proportion of energy efficiency renovation out of the total cost 462 € of renovation per square meter.

Large share of buildings are constructed before 1960, when only few or no requirements existed for energy efficiency (except in Sweden that had requirements for energy efficiency already 1948). Only small portion of these buildings have experienced major retrofitting, thus old and inefficient heating systems and low insulation levels prevail [1] (#cite-text-0-0). Low performance level among the oldest buildings consumes the highest amounts of energy in the entire building stock. Lack of insulation standards at the times of construction have resulted in the shortcoming of proper insulation among old buildings.

Various renovation projects are done for existing building stock in the studied countries. Table 6-3 presents some main energy intensity estimates for typical apartment houses before and after the refurbishment. Overall view of the energy consumption and costs of achieving energy saving in apartment buildings of different countries can be gained. After advanced renovation, the heating energy consumption was reduced by 38 % and 56 % in Finnish residential apartment building whereas in Russian building the saving was huge 68 %. The yearly energy saving of 158 MWh in district heating energy generated 60 040 € cost saving in Finnish building in the period of ten years. This corresponds to 50 % of the total payback-time for the energy efficiency part of the Advanced level renovation [47] (#cite-text-0-169).

In case of Russian building type II-18, the different level renovation concepts decreased the heating energy demand 61-40 % and electricity 79-82 % when compared to current situation [49] (#cite-text-0-172). Because of the type of district system network, the sole renovation of buildings does not lead to sustainable energy savings. The whole district should be treated at once, including both the renovation of buildings and surrounding district energy and water infrastructure. For example, the replacement or renovation targeted at main district heating system with the distribution pipe-, main pipe- and water distribution pipes, district heating substations, water sewage main pipes, electricity- and main grid, and replacement of light bulbs of street lighting bring more energy and cost saving when performed together with the energy efficient renovation of building. According to estimations, electricity demand can decrease up to 34 % and heating demand 72 % for different district renovation scenarios [49] (#cite-text-0-172). The costs of district level renovation scenarios which included also the costs of building renovations, were 3 360€ (Basic), 4 090 € (Improved) to 5 200€ (Advanced) per inhabitant. Payback times were more than 12-14 years for additional investment into implementing other than basic renovation.

In Russia, 83 % of residential buildings, 70 % of water boilers, 66 % district heating network, 90 % of capacity of power stations and 70 % electric grid technologies were constructed before 1990 (Government of the Russian Federation 2010, [42] (#cite-text-0-125)). Calculations of net present value performed for different building and district level renovation scenarios for 20-year period with varying interest rates and annual energy price growth rates, indicated that Improved renovation package was most profitable [49] (#cite-text-0-172).

TABLE 6-4. Cost estimates for different renovation types. Costs are total installed costs for the measure. Slightly modified from [1] (#cite-text-0-0)

BPIE 2011 Report	Final energy saving(% reduction)	Indicative saving(for modelling purposes)	Average total project cost (€/m²)
- minor renovation	0 - 30 %	15 %	60
- moderate renovation	30 - 60 %	45 %	140
- deep renovation	60 - 90 %	75 %	330

Energy performance renovations can be implemented in various ways. Different outcomes are expected if building façade (e.g. walls, windows), building envelope and all its energy systems (e.g. HVAC, lightning) or renewable technology installations are done. By categorization different levels of renovations, better comprehension can be obtained on the energy performance level renovation produces [1] (#cite-text-0-0). On basic level, implementation of a single measure (e.g. new boiler plant/insulation of the roof space) can save up to 30 % of energy. In the other extreme is the holistic approach where package of renovation measures operate together to produce up to 90 % energy savings (Table 6-4). Modelling where essential parameters; carbon dioxide emission reduction targets, investment considerations and positive employment effect, were let to vary, most promising estimates were derived for two-stage renovation scenario [1] (#cite-text-0-0).

Generally, comprehensive information is missing on the prices and saving of buildings renovations. Also information regarding the number of ongoing and completed renovations, the extent or trends in renovation rates are scarce. Available estimates on renovation rates regarding other than single energy saving measures are annually between 0.5 % and 2.5 % of the building stock [1] (#cite-text-0-0). However, these estimates are based on recent years and can be due to certain circumstances, e.g. implementation of renovation programs, and may not necessarily reflect the normal rate. In Finland approximately 1-1.5 % of the whole building stock is estimated under yearly renovation. The estimated annual renovation rate in residential and non-residential buildings in Norway is 1.5 %. [1] (#cite-text-0-0)

Building energy performance level and the used energy mixes affect the carbon dioxide emission levels produced by buildings. The extent of the usage of renewable energy, district heating, co-generation and the sources of electricity production influence the building-related emissions [1] (#cite-text-0-0).

Approximately 36 % of the carbon dioxide emissions originate from buildings in Europe, the average emission is 54 kgCO2 /m². National carbon dioxide emissions vary from 5 to 120 kgCO2 /m². Norway has the lowest value 5 kgCO2 /m², followed by Swedish and Finnish values 17 kgCO2 /m² and 49 kgCO2 /m² [1] (#cite-text-0-0). The low value of Norway can be explained by the high percentage of hydroelectricity. Sweden is dependent on hydroelectricity and nuclear energy which reduce the level of emissions. Building-derived emission value for Russia was not available.

7 Conclusion and future challenges

By improving building energy performance the overall energy demand can be reduced concurrently with the carbon dioxide emissions. Various factors affect the energy performance of buildings. External factors include the climatic circumstances, social conditions and building envelope with the insulating layers. Internal factors comprise the building technology; e.g. heating system, air ventilation and plumbing [1] (#cite-text-0-0). The space heating is the most energy consuming system in the buildings. Improvements, for example updating the adjustments of heating system, replacement of systems to more green options, e.g. by changing fossil fuels to renewable energy sources, enhance the building energy use with more sustainable manner.

Energy performances of residential buildings and commercial premises are the target of various policy measures to influence energy use in the sector. Concerted actions appear for the implementation of the Energy Performance for Buildings (EPBD) and Energy Efficiency Directives (EED) by EU-Member States, Norway and Russia. The main policy driver Energy Performance of Buildings Directive (2002/91/EC, EPBD recast 2010/31/EU) imposes requirements for energy certification, training, renovation and inspections.

Still, the field of buildings renovation is only partially covered by EU legislation. Measures are emphasized in cases of deep renovations but the depth of measures are not well defined [1] (#cite-text-0-0). Although EPBD lays foundation for functional whole building focused building energy codes, considerable variation may appear in the national and applied requirements set by states.

The Nordic countries and Russia extends over many landscapes, cultures and climate zones. Constantly growing building stock consist various building types and thermal qualities, which show considerable differences between countries. Energy performance of the building e.g. insulation and type of windows, determines to a large extent the amount of energy needed for heating. Generally, the older houses constructed 1940s and 1950s require considerably more energy than the ones built in 1990s and 21st century [1] (#cite-text-0-0).

Aging and inefficient energy infrastructure of geographically large Russia provides increasing opportunities for the products and services to improve energy efficiency [42] (#cite-text-0-125). Major fields of Russian economic activity; agriculture, forestry, construction, manufacturing, transport, storage and services are globally scaled to be among most energy intensive in their respective categories. Enhancement of energy efficiency is defined to be as one of the five top priorities to modernize Russian economy by the leaders of the country [42] (#cite-text-0-125).

Some major barriers have been recognized in countries for the improvement of energy efficiency. The ones affecting the existing buildings could be categorized as financial, institutional and administrative, awareness/information and split incentives [1] (#cite-text-0-0). Improvement of the awareness and expertise of energy efficiency financing parties; authorities, building owners, construction companies, local banks and end borrowers is one of main targets. Recognized investment barriers include high initial investment costs, long pay-back time, credit risks associated with energy efficiency investments which lead to limited availability of funding.

The private ownerships predominate with 80 % share the occupancy of residential building stock in Europe [1] (#cite-text-0-0). In dwellings of Finland, Sweden, Norway and Russia the shares vary between 60 % and 90 %. This has consequences on the ability to perform renovation [1] (#cite-text-0-0). Insufficient demand for energy efficient investments from building owners is categorized as one challenge. In Russia, despite of importance, energy issues are not regarded as top priority among individual building owners [49] (#cite-text-0-172).

Generally, full implementation of energy efficiency regulations is suffering from the lack of enforcement (commission staff working document). Need for better coordination between different policy areas and among policy makers prevails. More stable support measures could be provided, e.g. state aid and public procurement mechanisms to promote energy savings. Energy efficiency measures and services can be promoted by the usage of taxation and broader taxation regime. Financially attractive projects and technical assistance could be provided as well as the provision of loans of attractive terms. Especially standardized monitoring of energy savings, education and training are potential channels for the implementation [1] (#cite-text-0-0). Single EU-wide calculation and certification scheme for energy efficiency of buildings is recommended to promote more standardized measures (Commission staff working document).

Residential building and service sector consumes the largest, or second largest, share of the final energy use in many countries, accounting generally to 40 %. Of the current stocks, buildings constructed in 1950-1970 exist at high percentages. To reach set international energy requirements residential buildings provide the largest potential. Due to relatively low annual rate of new dwelling production, renovation of older residential buildings is energetically the most productive approach.

Generally, best advantage is derived when improvement of energy efficiency level of building is performed in liaison with the planned renovation (e.g. [49] (#cite-text-0-172)). Better targeted measures of the implementation of the deep renovation are required to promote the forthcoming renovations of the prevailing building stock. Different scenarios where the performance and the depth of renovations, investment costs, energy and economy savings, the reduction of CO2 emissions were allowed to vary gave comprehension on the ideal measures in studied countries. In Russia, most promising results were obtained for renovations implemented in two stages [49] (#cite-text-0-172).

Large-scale renovation in apartment house sector is rather selective. Typically targets of renovations are repair of in-house electricity supply, heating, gas- and water supply and sewage systems. Also old lifts, lift shafts and lift facilities are commonly repaired or replaced. Roofs, basements and facades are repaired and/or insulated. Foundation structures of apartment houses are generally repaired. Often shared metering devices are installed to monitor the consumption of heating energy, cold and hot water, electricity and gas to be able to analyze energy efficiency.

Modernization programs often may face resistance due to several reasons. Commonly shared property in apartment house sector may not be well registered by municipalities because of the lack of institutional, infrastructural and organizational experience. This is prerequisite to be able to perform repair and renovation for block of flats. Major parts of households have low level of income. Money saving by dwelling owners to finance deep renovations of the shared property in apartment buildings is not successful due to attitude, organizational and financial level obstacles. Legislative and regulatory base and methodology are lacking similarly than the experienced personnel. Competition may be weak, and professional training of municipal managers and utilities companies may be insufficient. Relatively high risks are involved in saving, managing and spending the gathered finance for renovation (e.g. [1] (#cite-text-0-0)). Often, regional level large-scale campaigns are missing in the housing sector to increase the level of energy efficiency renovations.

As to summarize, in order to comprehend the energy performance of buildings, information of consumption levels over the years and the used energy mix are required. In relation to climate change, performance level is also associated to the produced carbon dioxide emission levels. By this study, mainly residential buildings in Scandinavia and Russia were overviewed to gain basic level conception of the building quantities and typologies in relation to energy use and production in each country. This enables targeting the renovation business-related focuses to desired objects in climatically cold and high energy-intensive North to promote also global-wide energy savings.

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