Sustainable Buildings for the High North. Energy performance, technologies and challenges of new buildings in Russia and Scandinavia

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Metatiedot

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Tiivistelmä: Since 2019 and 2021 energy performance of nearly zero energy level is required from new residential and non-residential buildings by Energy Performance of Buildings Directive (EPBD). Currently, building sector consumes large 40 % share of the final energy usage. Pressures for energy saving efforts are created by legislation induced by proceeding climate change, national economies and healthy indoor climate. Growth rate of residential building sector is 1 % in many European countries. The modern-age buildings constructed in the period 1991-2010 form only 14-19 % of the entire housing stock. Although new buildings have lower energy consumption levels in comparison to old ones they may also have higher electricity use due to increased need for ventilation, cooling, lighting and office equipment. By quality assurance process, commissioning, the intended performance of new building is aimed to confirm before the operation phase. Optimal operation of mechanical, electrical and HVAC systems generate additional energy saving options for new buildings. The common aim is to produce best possible indoor climate with least amount of energy.

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1 Introduction

Present-day construction of new buildings have long-lasting impacts as age of hundreds of years can be achieved (e.g. [1] (#cite-text-0-0) [2] (#cite-text-0-1)). Correspondingly, the highest energy and carbon saving potential are estimated to be reached by retrofitting and renovating the existing building stock in 2030 [3] (#cite-text-0-2).

Improved energy efficiency of nearly zero energy level are required from new residential and non-residential buildings since 2019 and 2021 by Energy Performance of Buildings Directive (EPBD) and national level legislations. Technical solutions are already available to implement the low-energy targets in cost optimal way [4] (#cite-text-0-3).

In European residential building stock, the share of new buildings constructed in the period 1991–2010 is approximately 19 %. Forty percent are old buildings which have been established before 1960s. Annual construction rate of new buildings is around 1 % [2] (#cite-text-0-1). In construction, average growth of 1.8 % is expected to occur between years 2014 and 2016, and majority of the upturn is generated by residential buildings. Although the rate is relatively weak it is also a sign of increasing stability after turbulent years [5] (#cite-text-0-5).

The main phases of the construction project include design, construction, operation, maintenance and demolition stages. Initial investments in buildings constitutes less than 20 % of the life-cycle costs. Consideration of sustainable energy use already in the design and construction phases bring more energy saving potential than refurbishment or maintenance of old buildings [6] (#cite-text-0-6). The largest part of the long term costs are generated by operation and maintenance phases where majority of expenses are due to energy use [7] (#cite-text-0-7).

The goal of this report is to generate an overview of new building stock in Scandinavian countries and Russia for the purposes of international Sustainable Buildings for the High North (SBHN) -project. The work is based on the available literature, official statistics of involved countries and other information published by different organizations.

2 Energy saving potential in new buildings

New buildings have lower energy consumption levels than older ones, but may also have higher electricity use due to increased need for ventilation, cooling, lighting and office equipment (Figure 2-1) [8] (#cite-text-0-8). Simulation results indicate that already existing technology is adequate to achieve low-energy building requirements [9] (#cite-text-0-9). Still varying level of gaps have been observed between the actual market and the necessary future market to cover requirements induced by low energy buildings such as nZEBs [9] (#cite-text-0-9).

Quality assurance process called commissioning between design and operation phases confirms that building performs in intended manner, and that the personnel is educated to operate and maintain the systems (e.g. [10] (#cite-text-0-11). Optimal operation of mechanical, electrical and HVAC systems generate additional energy saving in new buildings. The sizing and installation of equipment are checked, as well as calibration for optimal performance to ensure that the usage corresponds to the settings. Commissioning ensures that least amount of energy is used to produce best possible indoor climate. Installation or addition of new systems cause changes in existing operation and maintenance systems which must be re-adjusted to sustain energy efficiency [10] (#cite-text-0-11).

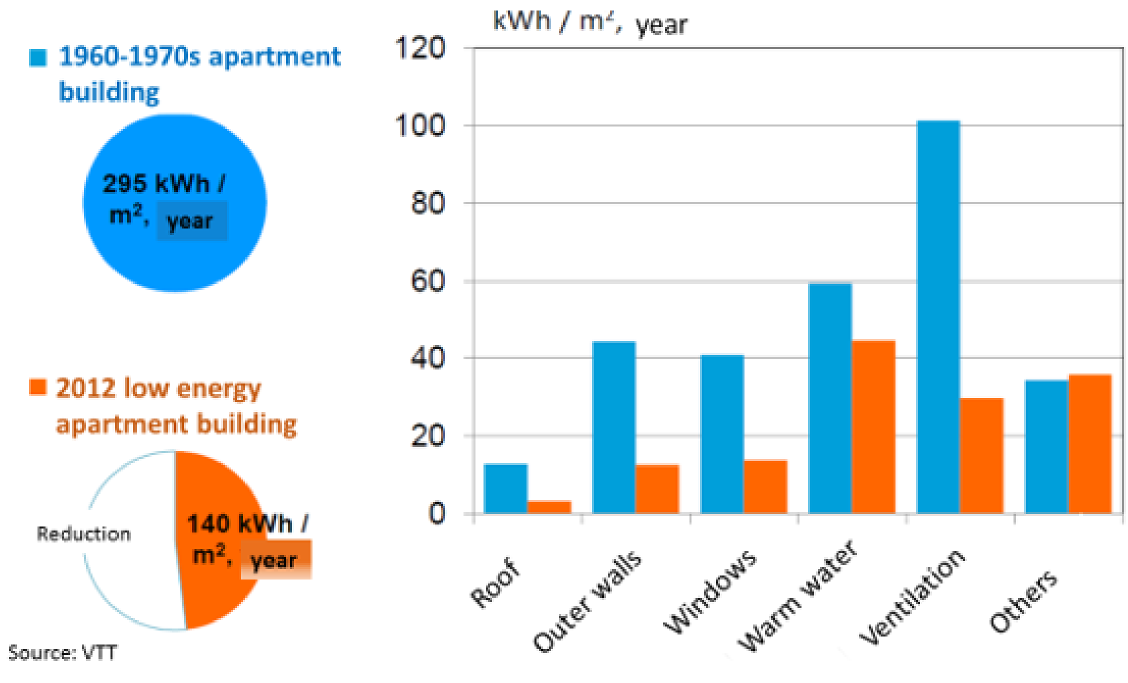


FIGURE 2-1. An example of the energy consumption differences between old and modern low-energy buildings [1] (#cite-text-0-0)

2.1 Standard new buildings

New buildings that comply only with minimum building standard energy efficiency requirements are called standard level new buildings (e.g. [11] (#cite-text-0-13)).

The common target in EU region is to have nearly zero energy level for new buildings by 2021. Construction of new buildings are guided by national building regulations. Generally step-wise tightening of building codes are proposed where intermediate targets are set to reach the ultimate goal. For example, in Finland an object is to achieve Passive House standards by 2015 and in Norway until 2017 for new buildings (e.g. [12] (#cite-text-0-14)). In Germany new buildings should be operating without fossil fuel by 2020 [13] (#cite-text-0-15).

2.2 Low energy level buildings

"Low energy buildings" or "Highly energy efficient buildings" have many concepts and voluntary standards throughout Europe that have changed in time. Various definitions may include different spheres; site energy, source energy cost or emission, and they may consider either new, existing, residential or non-residential buildings [9] (#cite-text-0-9).

In general, low energy level buildings refers to any building whose energy use is below the standards defined by national building codes. Often buildings that use energy half of the levels set in building regulations are called low energy buildings (e.g. [14] (#cite-text-0-17) [11] (#cite-text-0-13)). As standards differ between countries, low-energy developments of one country may mean normal practice in some other state (e.g. [9] (#cite-text-0-9)).

Low energy level is achieved by design, technologies and building products that use less energy. Often active or passive solar building design techniques are used to decrease energy consumption. Energy efficient landscaping and passive solar design exploit natural and passive methods to increase or reduce the heating effect of solar radiation (e.g. [15] (#cite-text-0-20)). The design of compact houses with reduced surface area and positioning of windows toward equator (toward south in northern hemisphere and north in southern hemisphere) enhance the passive solar heating. In reducing the solar heating, passive methods such as construction of Brise-soleil, green roof or planting trees and vines in pergolas provide shade for direct or indirect sunlight (e.g. [15] (#cite-text-0-20)).

Typically heating and cooling energy needs are lowered with improved insulation, energy efficient windows, air infiltration and heat recovery ventilation. Heat may also be recovered from hot water of dishwashers and showers by special recycling technologies (e.g. [9] (#cite-text-0-9)). Fluorescent lighting and efficient appliances are used in miscellaneous energy use. Also weatherization, special treatment against various weather conditions, is used to improve building energy efficiency. Additional cost of constructing low energy level building are not large, generally 3–4 % (e.g. [11] (#cite-text-0-13)). Typically, energy consumption for heating ranges between 50-60 kWh/m² for low energy houses [14] (#cite-text-0-17).

2.3 Passive houses

Passive or ultra-low energy house, is a construction concept that represents simultaneously high energy efficiency and indoor comfort with improved air quality (see Figure 2-1). The concept has been utilized for two decades. Although stringent quality criteria are set, the concept itself is adaptable as it suits for all building types, climates and countries, and is also affordable for constructors. Various definitions occur for passive houses. In these shared technical elements are; high insulation levels and airtight layers which are continuous, thermal bridge free-design, heat recovery ventilation and highly controlled air infiltration rates (e.g. [16] (#cite-text-0-25) [9] (#cite-text-0-9)). In the design process, energy modelling software are used to calculate the performance of designed building [14] (#cite-text-0-17).

Generally no separate heating system is installed because minimum amount of energy input is required as solar radiation energy and heat recovery technologies are efficiently utilized in the design. Energy sources inside buildings, such as heat from white appliances, lighting, occupants or entering solar radiation, are exploited in overall heating need. Also in cooling various kind of passive methods are exploited that reduce the energy consumption (e.g. [17] (#cite-text-0-28) [15] (#cite-text-0-20)).

Passive House building is extremely ecological and participates in reducing climate change. The concepts is used as worldwide standard in construction of energy efficient buildings as it requires only 10 % of the energy consumed by typical building stock in Central Europe (see Figure 2-2). Huge energy saving up to 90 % bring additional independency for the owners in relation to energy prices and production.

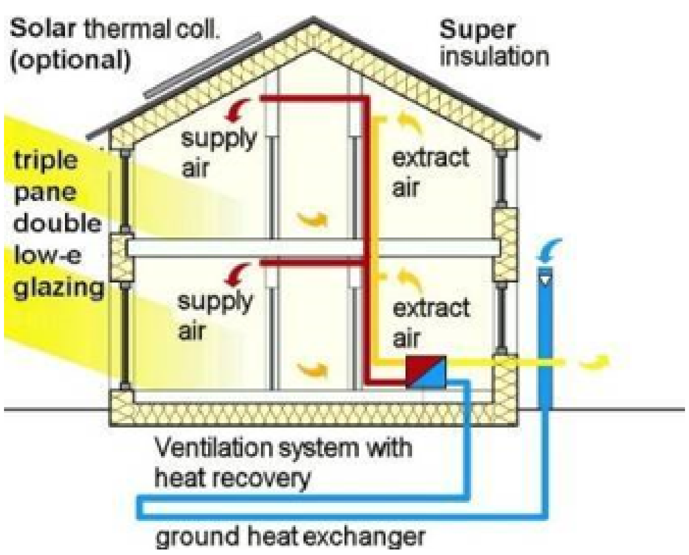


FIGURE 2-2. Illustration of passive house [2] (#cite-text-0-1)

When compared to average new building with low energy levels, only one quarter part of the energy is used; savings are up to 75

% in passive house. Less than 1.5 liters of heating oil is used per square meter of living space which is much less than in typical low-energy buildings. Equivalent energy savings have been observed for buildings in warm climate where energy is mainly required for cooling [17] (#cite-text-0-28). In comparison to data from average and low energy standards buildings large differences are observed (Figure 2-3).

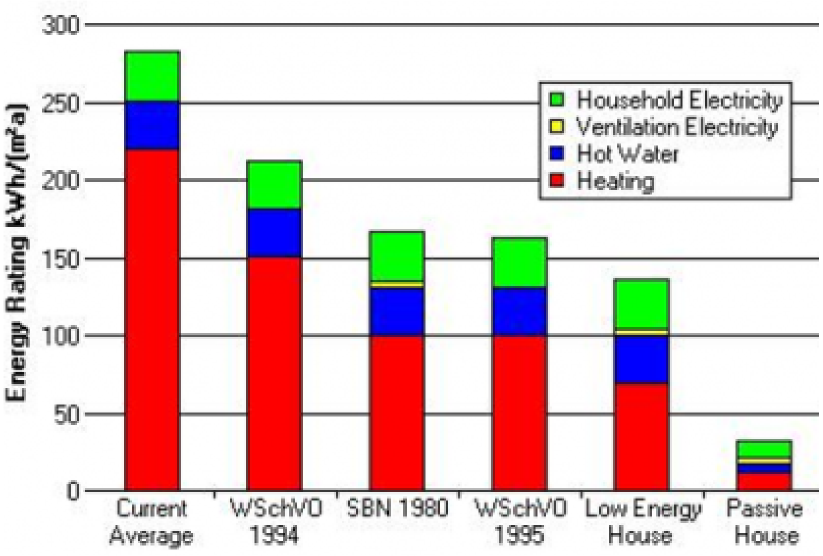


FIGURE 2-3. Difference in the energy use between building types (WschVO = German Heat Protection Regulation, SBN = Swedish Construction Standard) [3] (#cite-text-0-2)

The essential technical characters for Passive houses are listed in Table 2-1. Airtightness, annual heat demand, maximum heat load and primary energy consumption criteria must be fulfilled to achieve the Passive house standard. Ventilation and minimum surface temperature enable high internal air quality and thermal comfort which promote the health of occupants. Efficient heat recovery unit recovers the heat of the exhaust air for the re-use purposes.

TABLE 2-1. Technical characters for Passive house includes four major component (1–4) and two additional (5–6) that increase the indoor climate quality [16] (#cite-text-0-25)

Requirement	**Criterio**
1. Airtightness	0.6 air changes per hour at 50Pa (positive and negative) pressure
2. Annual Heat (Cooling) Demand*	15kWh/m².a (kWh per square metre per year needed to provide space heating to 20°C, or cooling in hot climates)
3. Maximum Heat (Cooling) Load*	10W/m² (maximum power needed to maintain 20C internally when it is -10°C outside)
4. Primary Energy Consumption	120kWh/m².a (kWh per square metre per year needed to meet all energy demands, energy defined as consumed at source, e.g. heat extracted from fuel at power station)
5. Ventilation	30m³ per person per hour (needed to provide fresh, healthy air to building occupants)
6. Minimum Internal Surface Temperature	>17°C (lower surface temperatures cause convection driven drafts; this target avoids this allowing all parts of the building, even those adjacent to windows to be used)

*either the Annual Heat Demand or Heating Load target must be met

Building shell and particular windows consist well insulated exterior walls, floor and roof that sustain the desired temperature in the house or undesired heat outside. Thermal envelope components; walls, roof and floor require U-values 0.14 W/m²K or better. Form of the building influence the U-values, less efficient form need thermal envelope with higher performance level to achieve the standard. With thorough design the number of thermal bridges is minimal. For windows, overall U-value must be 0.80 W/m²K. Here also window part must have certain features; spacers are of low psi-values, good frame U-values are required, g-values for glazing are high and double gasket are used for air-tightness [16] (#cite-text-0-25).

As air tightness is emphasized, requirement of passive house include that less than 15 kWh/(m²year) is used for heating or cooling of living space, and subsequent load is limited to a maximum of 10 W/m². Ventilation systems are in central role as replacement air is not flowing anymore through the cracks and holes between walls and windows to sustain healthy living environment. Passive house adapted quality ventilation systems can reduce operating costs significantly as supplied fresh outdoor air may be utilized in heating. Primary energy use can be uttermost 120 kWh/(m²a). Air change rate are limited to n50 =

0.6/h, meaning that building is not allowed to leak more air than 0.6 times the house volume per hour at 50 Pa (N/m²) when tested by a blower door test. During summer months or in warmer climates, highest temperatures are allowed to exist at most 10 % of the time [16] (#cite-text-0-25). In Germany 1 % of all new buildings were built according to passive house standard in 2011. In other part of the Europe the percentage is even smaller as Germany is regarded as forerunner in Passive House technology.

TABLE 2-2. Passive house related definitions in different countries [4] (#cite-text-0-3)

Country	**Space heating and cooling energy demand** **kWh/m²a**	**Primary energy demand** **kWh/m²a**	**Heating power demand** **W/m²**	**Air tightness 50 Pa** **exch/h**
Finland	20–30	130–140		0.6
Norway	15+3.5 (T-5) T = Annual Temperature			
Sweden	South 45 North 55 Total purchaced energy		South 10 North 14	~0.6 (0.3l/sm²)
Germany	15	120		0.6
Southern Europe	15+15=30	120		0.6

2.4 Nearly Zero Energy Buildings (nZEB)

Recast of EPBD (2010/31/EU) has set a target that all buildings must be of nearly zero-energy level since 2021. Two years earlier, target is filled with new buildings occupied and owned by municipal authorities.

Building with very high energy performance level that uses very low or almost zero amount of imported energy is called as “nearly zero energy building” [9] (#cite-text-0-9). Majority of the energy is produced on-site or in vicinity from the renewable energy sources. Annual primary energy consumption is 0 < kWh/m2. The requirement for primary energy is low due to advanced building technological solutions and large extent of utilized renewable energy sources on-site or nearby (EPBD). Best available technology is used together with best practices to achieve cost-optimal energy efficiency.

The research has shown that large differences occur in definition of nZEB between Member States regarding the selection of sphere to make basis (e.g. site energy, source energy, cost, emissions) on adequate means and techniques [9] (#cite-text-0-9).

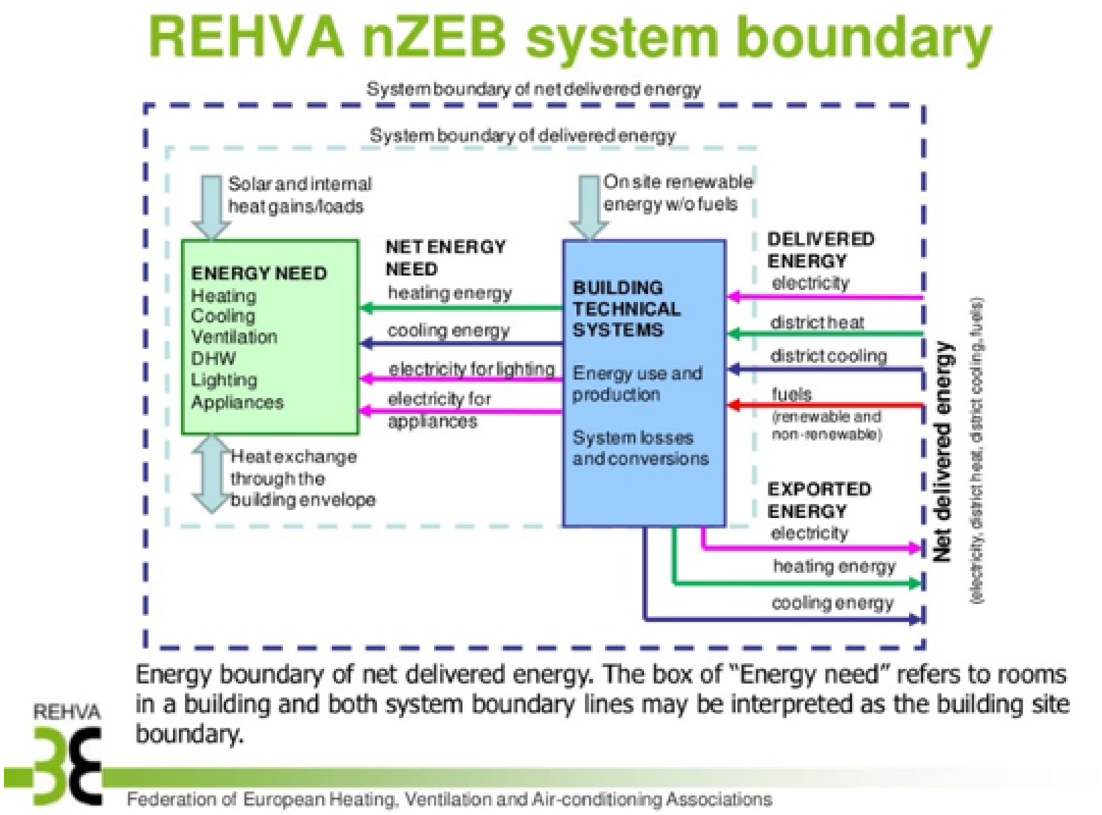


FIGURE 2-4. Scheme of delivered- and on-site-energy energy production and their influence on energy calculations [5] (#cite-text-0-4)

Nearly zero-energy building targets; energy saving, energy efficiency and renewable energy usage can already be reached with combination of current technologies [9] (#cite-text-0-9). Still, the actual market is partly underdeveloped in proportion to the future needs induced by nZEB sector, and investments on new energy efficient technologies have to be increased. For example, actual markets for ventilation systems with heat recovery and triple glazed windows are currently too minor in comparison to the demands generated by full implementation of nZEB (see Table 2-3).

TABLE 2-3. The overview of the actual market size in relation to future demand caused by nZEB [9] (#cite-text-0-9)

Markets	Required growth factor	Current market size	Unit
Insulation materials	2–3	2 010	MioEUR
Ventilation systems with heat recovery	8–10	130 000	units
Triple glazed windows	>10	1 500 000	m²
Heat pumps	2–3	185 000	units
Pellet boilers	2–3	43 000	units
Solar thermal systems	2–3	3 700 000	m²

With transition phases adaptation of new technologies are smoothed and here policies have important role in directing market toward the desired focus [4] (#cite-text-0-3). Cost optimality is often considered in planning phase of new buildings and in the extent of renovation.

In Northern circumstances, the design approach where emphasis of structural engineering on entities are often acknowledged. Requirement for insulation are defined on projects-scale calculations where the total energy balance is taken into account. Thicker insulation layers can compensate other solutions until the critical point is achieved. After the point further insulation layers are not growing anymore linearly with the thermal insulation capacity [15] (#cite-text-0-20). Structural thicknesses of walls can be 300–600 mm depending on the building principle and material. In roofs insulation thickness can be up to 700 mm, and in ventilated floors up to 500 mm. Corners are especially sensitive for frost. Freezing of foundation is mainly dependent on site and quality of soil and conditions. In energy efficient buildings, thermal loss through floor is so minor that it does not prevent freezing under basements without scaled frost shielding in low-base structures [15] (#cite-text-0-20). Majority of the moisture problems encountered in energy efficient houses could be avoided by ensuring the quality of design and implementation. Thick insulation alone is not causing moisture damages, rather multitude of factors in the construction phase; careless attitude together with wrong working habit and working schedule are the primary factors in inducing damages [15] (#cite-text-0-20). Necessarily, no distributed heat systems such as radiators and floor heating are required due to low level heating losses. Heating provided by air-ventilation system is often adequate. Appropriate ventilation level depends on the intended use of the room. Minimum ventilation level is set to be 0.5 [18] (#cite-text-0-42).

Construction costs are optimized to provide significant savings in the building lifecycle costs without excessively increasing investment costs (EACI Executive Agency for Competiveness and Innovation). Planning costs form only minor part out of the total costs, still it is the most critical phase where majority of the energy consumption-related decisions are made for the entire building life time [15] (#cite-text-0-20). The positioning of building in the lot, measurements, shape of the house, room plan, surface and location of windows and HVAC are crucial decisions. Consequently, efforts on making additional surveys or enhancing careful planning in the design phase can be the most cost-efficient investments of the whole building project. The management of entities and acknowledgement of energy efficiency in the planning along with appropriate usage and maintenance are starting points to reach successful outcome [15] (#cite-text-0-20).

2.5 Zero-Energy Buildings, ZEB

New building type was developed as an answer to growing energy resource shortage, worldwide reduction efforts of emissions and high share of energy usage by buildings. In 1979 passive solar heating and -cooling techniques were exploited in the first super-insulated airtight construction called Zero Energy Design Building (e.g [19] (#cite-text-0-45)). Buildings that produce on-site the same amount of renewable energy than is purchased from the grid during a year are called net zero-energy buildings [15] (#cite-text-0-20). However, common agreement on the exact definition is lacking and many countries have their own approaches. The direct energy usage value per square meter is not given in the Directive, rather each Member State defines the limits because climate, national costs of construction practices and availability of local renewable energy sources influence on the cost optimality (see [15] (#cite-text-0-20)).

Some correlation is observed between ZEB approach and utility grid characteristics of the country [20] (#cite-text-0-48). Because excessive amount of the on-site produced electricity are fed into the grid, special characteristics are required. For example two-way remote metering devices and maintenance of energy balance are prerequisites to enable distributed energy production by ZEB. The energy usage is minimized in ZEB-buildings by reducing electricity use in lighting and appliances, space and water heating and electricity use in estate.

Renewable energy sources can be wind-, solar or geothermal based or include combined production of heat and electricity from wood pellets. Especially solar radiation and efficient energy conservation technologies are utilized with varying proportions. District heating is classified as energy source in vicinity if the energy is derived from renewable energy sources. Variety of renewable energy sources and the lack of approved standards may result in diversity of energy usage profiles and environmental impacts. In one extreme are almost autonomous buildings that have minor space heating requirement even during the coldest season, whereas in the other extreme space heating requirements are mainly covered by imported energy in winter time. High in-take from the grid are balanced by high levels of renewable energy production during more advantageous times across the year.

Synergistic technology approaches are used in Passive House and ZEB where thermal energy transfer and storage are based on the same physics. Difference is observed in annual energy consumption which can be at lowest level 0 kWh/m² in ZEB when renewable energy sources on-site are used along with Passive House typical materials and methods. These include utilization of electricity efficient equipment and lightning, airtight envelope, exploitation of free and waste energy flows, internal heat sources such as heat produced from occupants and equipment. Preheating and -cooling of air in exchangers can be organized as geothermal and geocooling based. Passive awnings bring shadow during sunny periods.

2.6 Plus Energy Buildings

In architecture, buildings that annually produce more energy than consume are called Plus Energy Buildings. This is enabled by micro-generation technology and low-energy building techniques (e.g. [21] (#cite-text-0-49)).

Private residence called Heliotrope was the first Plus Energy house constructed in 1994 (see Rolf Disch Solar Architecture (http://www.rolfdisch.de/index.php?p=home&pid=276&L=1&host=2#a678)). Environmentally friendly houses can be regarded as integrated ecological and architectural concept. Diversity of techniques are used to provide characteristic energy levels. For example heat is captured during a day with large South and North directing window areas to decrease need to produce heat during a night and to reduce the use of electric light in daytime. Passive solar building technologies and high level insulation windows equipped with triple panes (U-value 0.7) store the solar heat in thick insulation layers framed interstitial space where it is maintained long in the evening thus reducing the heating need. Also phase changing materials in the walls and vacuum insulations are adopted to enable maximum amount floor space in certain sites. Importance of sustainable development in communities are also emphasized in relation to Plus Energy design. Community of 50 residential Plus Energy houses were established under the project Solar Settlement. After eight years of full occupancy, each house produced additional energy more than 5 000 euros annually which have been advantage for the house owners. No compromises are made in the living standards of occupants. First positive energy office building in the world, The Sun Ship includes retail, commercial and residential sections in the space of 5 600 m². Walls are vacuum insulated, ventilation has 95 % heat recovery, façade is covered by solar panels and windows are triple paned (see Rolf Disch Solar Architecture (http://www.rolfdisch.de/index.php?p=home&pid=276&L=1&host=2#a678)).

2.7 Renewable energy sources

Renewable Energy Directive, RED, was recast in 2009 (2009/28/EC). It stipulates that until December 2014, minimum levels of energy from renewable sources have to be required from new and existing buildings that are under major renovation, in the building regulations and codes by Member States.

Most potential renewable energy sources regarding their utilization technology are listed in the Table 2-4. In Europe, various renewable energy technologies are available although regional differences appear in the distribution. In Northern European market heat pumps are most popular although biomass technology is gaining growing importance. Solar thermal systems and reversible heat pump technologies have largest potential for heating and cooling purposes in Southern Europe. Mature market exist for diversity of technologies in Western Europe while underdeveloped markets occur in Eastern Europe (e.g. [4] (#cite-text-0-3)).

In Northern Europe the efficiency of photovoltaic systems is much less (average irradiation 1 000 kWh/m²) than in Southern regions (1 900 kWh/m²) due to long winter and rather low solar irradiation. For example installed thermal capacity per thousand capita is half or less than the European average level. Combined systems to provide heat for space and water heating have become standard in Northern Europe. Active solar thermal systems have relatively small market whereas air source heat pumps (ASHP) and ground-source heat pumps (GSHP) that operate at lower temperatures have grown the share above the European average (see [4] (#cite-text-0-3)). Also pellet market has matured during recent years where Sweden and Denmark are the main producers and consumers (see [4] (#cite-text-0-3)).

TABLE 2-4. Renewable energy sources in Europe and their estimated potential [4] (#cite-text-0-3)

Renewable Energy Technologies	Northern Europe	Eastern Europe	Western Europe	Southern Europe
Solar Thermal Systems	Need for more sophisticated systems. Higher abatement costs than in moderate climates. The market has a small size.	Installed systems present low capacity. The market is underdeveloped.	The installed systems present high capacity. The market is large and well developed.	Great potential due to high radiation levels; especially suitable for less sophisticated Solar Domestic Hot Water preparation (SDHW); and present a high efficiency of low-cost compact thermal storage systems. The market is large and still growing.
Photovoltaic Systems	Actually still low efficiency and high costs due to low radiation levels. The market has a small size.	The market is underdeveloped.	The systems have a high efficiency. The market is large and well developed.	Great potential due to high radiation levels and short payback times. The market has a medium size but is still growing.
Heat Pumps	Due to the cold climate, the efficiency of the systems is lower. However, the systems have a very good market penetration.	The main challenge for increasing the use of those systems is the difficult license procedures. However it represents a growing market.	The systems mainly operate in heating mode, since air conditioning is just rarely required. The market is large and it is still growing.	Reversible systems are economically attractive in this climate. Combisystems has the biggest potential for market growth. The market has a medium size but is still growing.
Biomass and Pellets	Main producers and consumers in Europe. The market has a large size, has been well developed in recent years and is still growing.	The market is in an initial development stage.	The market is large, well developed and it is still growing.	Raw materials are scarce and building just have a relatively low heat demand due to a warm climate. Thus, the market is still quite small but has considerable growing potential.

Renewable energy markets are rather small in Eastern Europe in comparison to other European regions. Capacity for solar thermal systems is low, below the average, ranging between 3 and 25 kWth per 1000 capita (see [4] (#cite-text-0-3)). Markets, especially for air and water heat pumps, are increasing although they do not exist for domestic hot water preparation, possibly due to license procedures. Pellet market has just begun to develop as the whole renewable technology market in general. Despite the availability of technologies, experience and education are missing among professionals, and prices are rather expensive.

The significance of envelope performance is emphasized in regions where access to renewable sources is limited (e.g. urban centres). On site, or nearby generation by offsite renewables may have more prominent role in the design of nZEB in the future than has today.

TABLE 2-5. Expected share of renewable energy use in the building sector in Norway in the period 2005–2020 [22] (#cite-text-0-55)

	2005	2010	2015	2020
Residential	75 %	78 %	81 %	84 %
Commercial	24 %	33 %	43 %	53 %
Public	N/A	N/A	N/A	N/A
Industrial	N/A	N/A	N/A	N/A
Total				

* Commercial building are not distributed between private and public buildings.

Norway has set ambitious target to have 67.5 % renewable energy use in 2020 in relation to Directive 2009/28/EC. Here, estimates are also given for building sector (Table 2-5). Almost 61 % of the general goal was already fulfilled in 2010, mainly due to abundant water resources and produced hydroelectricity. Hydrological conditions in becoming years bring some uncertainties in reaching the goal as multiple dry years in a row influence the normalization of the hydropower and development of energy consumption [23] (#cite-text-0-56).

TABLE 2-6. Expected use of renewable energy sources in building sector in Sweden [24] (#cite-text-0-57)

	2005	2010	2015	2020
Residential	55.9 %	60.3 %	64.7 %	69.1 %
Public	50.5 %	55.1 %	59.7 %	64.3 %
Commercial	50.7 %	55.0 %	59.3 %	63.6 %

In Sweden, the proportion of renewable energy is aimed to be 49 % until 2020, and the value already reached the proportion of 46.8 % in 2011 [25] (#cite-text-0-58). Targets are set for residential, public and commercial sectors (Table 2-6). Roughly 20 % reduction of final energy consumption until 2020 and 50 % until 2050 from the level of 1995 are the set targets to new buildings and existing stock undergoing major renovation. Heating and cooling use 122 593 GWh energy, and proportion of heat producing technologies are divided between biomass 90 %, heat pumps 10 % and solar energy 0.1 %.

TABLE 2-7. Renewable energy use in building sector in Finland [26] (#cite-text-0-59)

	2005	2010	2015	2020

Residential	40 %	46 %	58 %	68 %
Total service sector	15 %	18 %	26 %	38 %
Industrial	12 %	N/A	N/A	N/A
Total	31 %	N/A	N/A	N/A

Finland has set goals of reaching 38 % renewable energy use by 2020. In 2011 the share was already 31.8 % [26] (#cite-text-0-59) [25] (#cite-text-0-58). In residential building sector, majority of energy is planned to be derived from renewable sources (Table 2-7).

Advice, information and training regarding renewable energy use are provided mainly by Motiva. Small-scale use of bioenergy, energy entrepreneurship and usage of solar energy, wind power and heat pumps are the main priorities. Collaboration with other organizations are done to promote the use of bioenergy [26] (#cite-text-0-59).

In Canada where resembling climate with Northern parts of Russia and Scandinavia exist, photovoltaic systems represent one of the few clean technologies that has ability to meet electrical demand in buildings on-site. Sufficient roof-area and south facing wall area in residential and commercial buildings are able to support photovoltaic system that can cover full electric load of low energy buildings [27] (#cite-text-0-63).

3 New Buildings in Scandinavia

3.1 Finland

Building stock is formed of 1.5 mln units of which majority, 85 %, are residential buildings (Statistics Finland 2014). Annually, the share of new building construction of the total building stock is more than one percent. Depending on building type, average exclusion rate is 0.3–2 % per year. According to estimates, roughly 75 % of the current building stock exists in year 2050. Almost equal economical contributions are used for establishing new buildings and repair of existing stock. Target for the usage of renewable energy sources is set to 38 % of total energy consumption in 2020 [28] (#cite-text-0-64). In the published roadmap for energy requirements of buildings, multiple intermediate targets are set to reach overall energy saving goals in 2020 (see Table 3-1, [29] (#cite-text-0-65)). Here stepwise transfer to adopt nZEB are framed for residential and non-residential buildings especially through adaptation of best E-values in Energy Certificate and by following principles of low-energy houses. Finland is prepared to implement requirements of nZEB building a year earlier than is imposed by the directive EPBD, thus making new public and residential buildings of nearly zero energy level since 2018 and 2020 [30] (#cite-text-0-66).

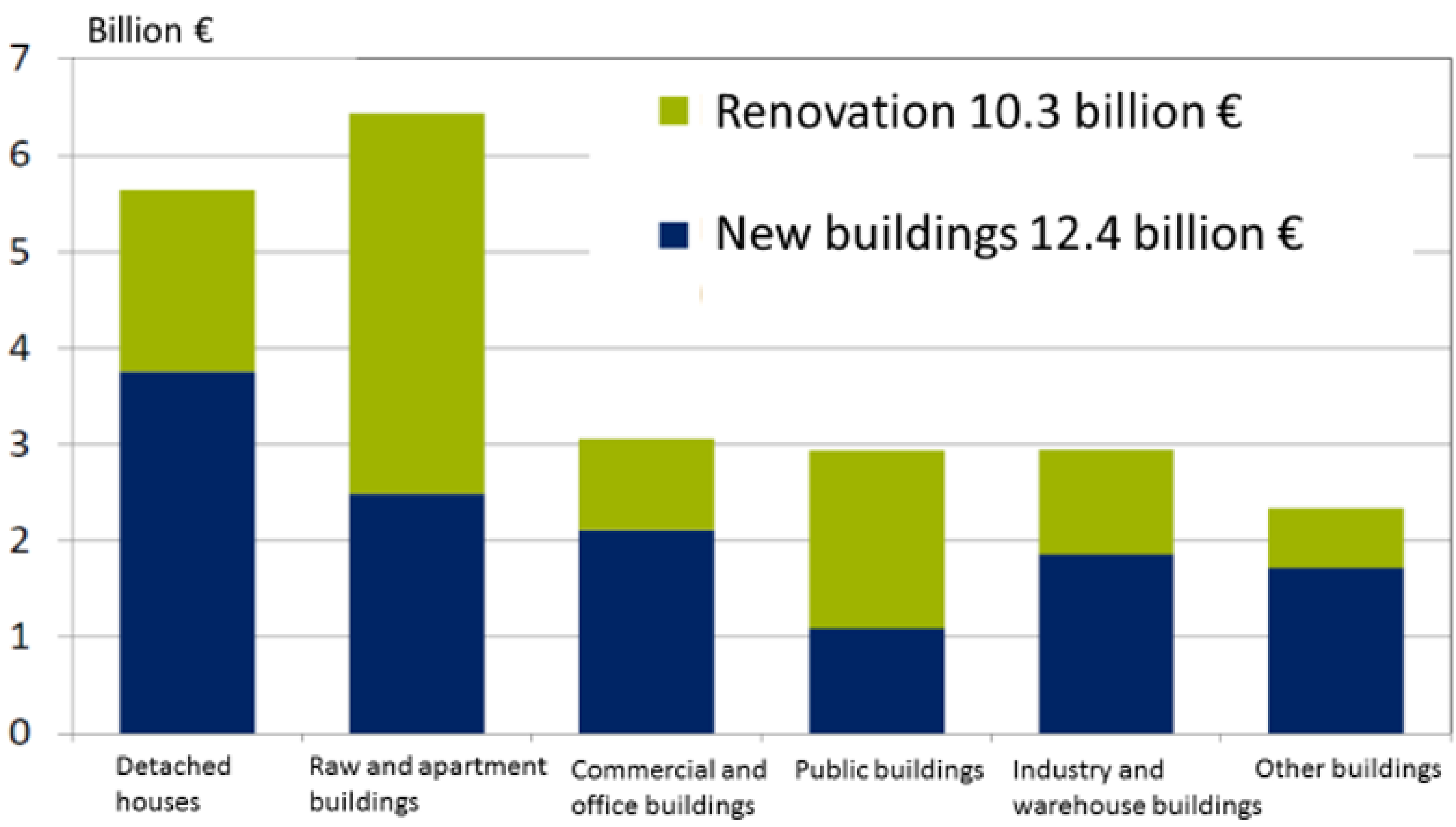


FIGURE 3-1. Construction market is illustrated for different building typologies in Finland in 2011. The value of end-products is 23

billion € [6] (#cite-text-0-5)

The most effective energy saving measures include tightening the energy efficiency requirements for new buildings, advice-based promotion of renewable energy usage (heat pumps of detached houses), energy subsidies in residential sector and agreement-based operation for improving energy efficiency in oil-heated single-family house Finland [28] (#cite-text-0-64). Until 2020, more than 15 % energy saving can be reached with these actions giving estimated energy saving potential of 18 566 GWh in the same year Finland [28] (#cite-text-0-64). Preliminary calculations based on real examples and simulations have shown that best results are achievable only with combination of different measures which produce significant fall in comparison to standards given in national building code [30] (#cite-text-0-66). Here the role of building technology is central. Depending on the building type the E-value described in Energy Certificate legislation can be reached easily whereas in others it is more challenging. Especially combination of measures that are categorized as effective but affordable have given promising energy saving results when used together with photo voltaic technology. In different sized apartment buildings measures include 80 % heat recovery from ventilation, specific fan power (sfp) of 1,5 kW/m³ which is reduced by 25 %, air leakage value 0.6 l, lighting 7 w/m² which is reduced by 36 %, and window U-values which are decreased by 20 % being of the level 0.8 W/m²K. With these operations, E-values range 99-107 and the quantity of annually purchased energy 95-105 kWh/m² in different sized apartment buildings where district heating is used [30] (#cite-text-0-66). For example, the limit for reaching the best A-class for apartment building in Finnish Energy Certificate is 75 kWh/m² per year.

TABLE 3-1. The rapid development of allowed U-valued in C3-part (insulation) and D3-part (energy efficiency and calculation of consumption) of national building code of Finland across the years [7] (#cite-text-0-6)

U-value	**C3/1985**	**C3/2003**	**C3/2007**	**C3/2010 D3/2012**
External wall	0.28	0.25	0.24	0.17
Upper (roof) or base floor against outdoor air	0.22	0.16	0.15	0.09
Base floor towards crawl space	0.22	0.20	0.19	0.17
Structure against ground	0.36	0.25	0.24	0.16
Window or door	2.1 (0.7)	1.4	1.4	1.0
Roofwindow		1.5	1.5	1.0
Surface area of windows	max 15 % of floor area, max 70 % of external wall area	max 15 % of floor area, max 50 % of total external wall area	max 15 % of floor area, max 50 % of external wall area	max 15 % of floor area, max 50 % of external wall area

In Finland approximately 335 000 heat pumps were installed in detached houses until 2010. Part of these were retrofitted on existing buildings as energy saving measures and the rest were installed as energy efficient basic heating system on new residential houses Finland [28] (#cite-text-0-64). The sales of heating pumps begun to increase in 2000 when the usage were started to promote by Motiva and Finnish heat pump association. Heat pumps are regarded as significant energy saving action in Finnish single-family houses.

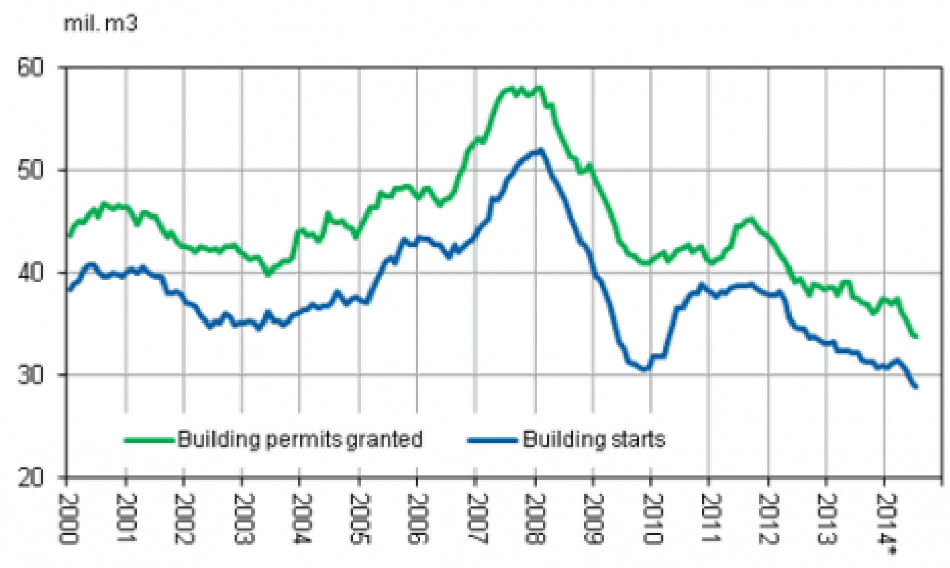


FIGURE 3-2. The quantities of granted building permits and started buildings in Finland between 2000 and 2014 [8] (#cite-text-0-7)

Preliminary data indicates that in August 2014 building permits were granted 8.5 % less than in previous year, resulting 1.9 million cubic meters (see Figure 3-2 [31] (#cite-text-0-72)). When inspected only residential buildings, the difference was even larger 12.5 % when compared to the rate year before.

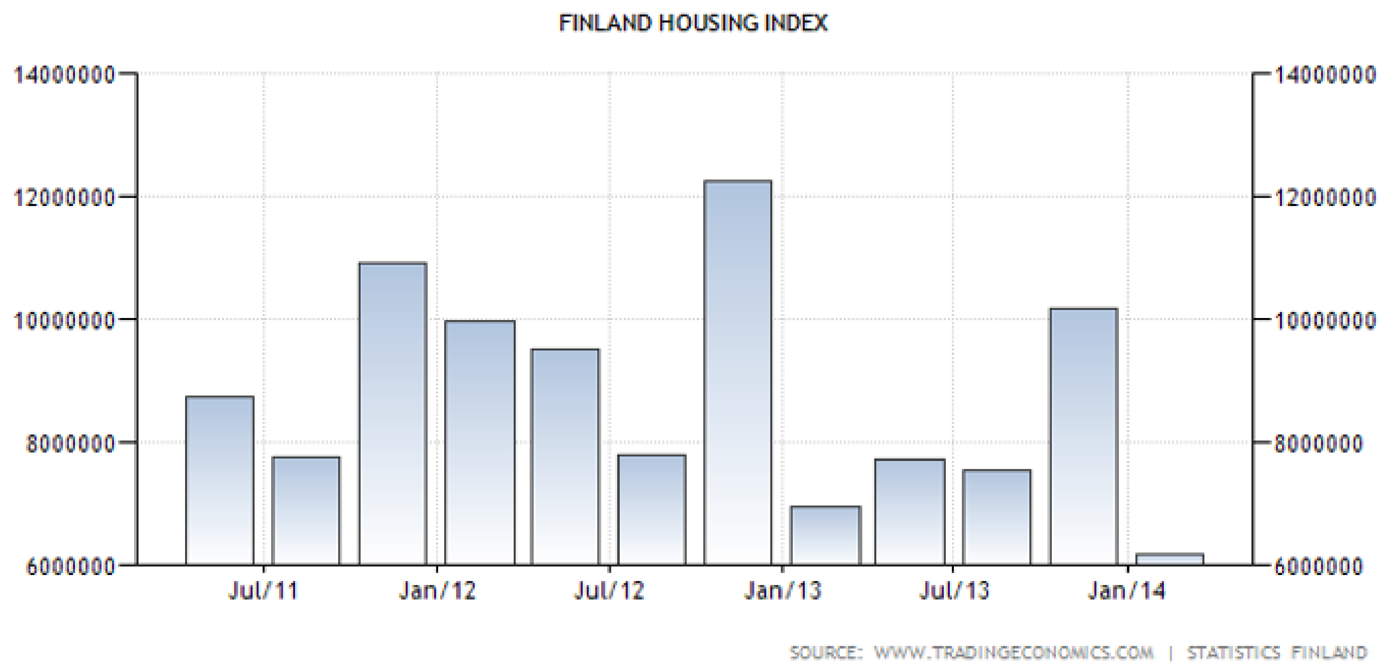


FIGURE 3-3. Quantity of all completed buildings in cubic meters in Finland [9] (#cite-text-0-8)

In Finland Housing Index is expressed as all completed buildings in cubic meters. It decreased by 3 991 605 m³ from the fourth quarter of 2013 to first quarter of 2014 (Figure 3-3). Average value is 9 345 905 m³ in the period 1985–2014. Highest value, 20 132 946 m³ was gained in the fourth quarter of 1990, and the lowest 5 031 052 m³ in the second quarter of 1995 (see [32] (#cite-text-0-73)).

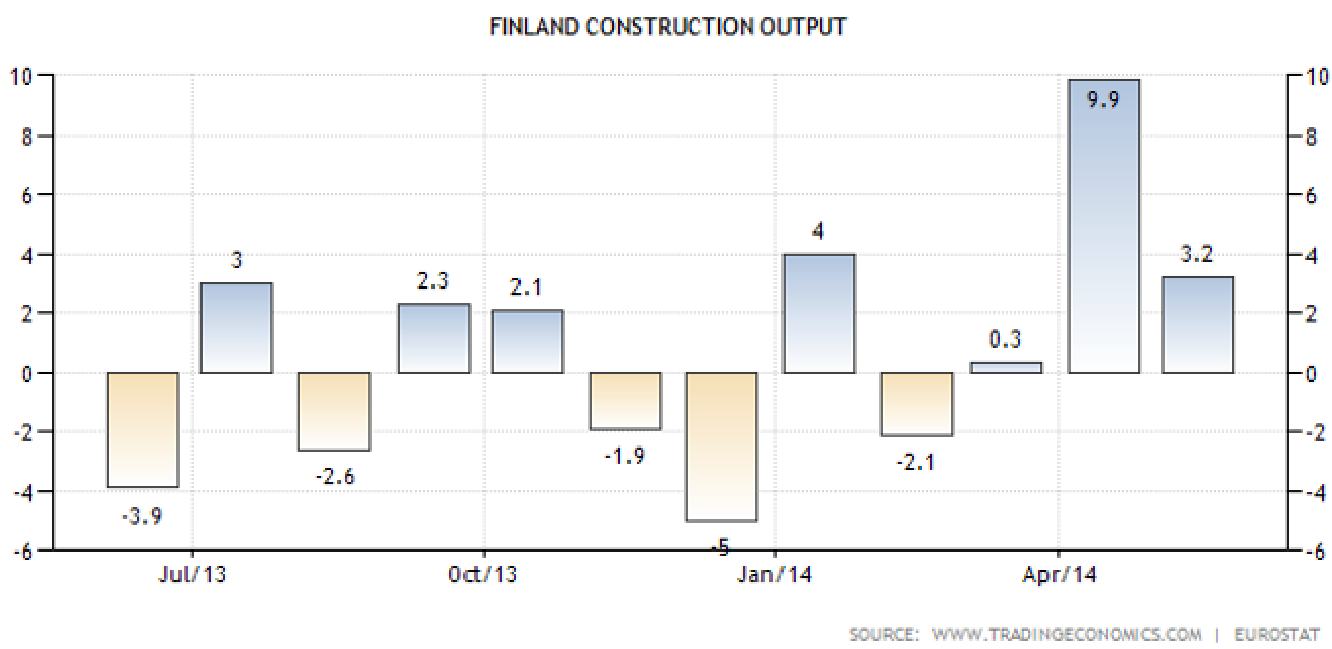


FIGURE 3-4. Construction output in percentages in Finland for the period July 2013-May 2014 [10] (#cite-text-0-9)

Increase of 3.2 % in construction output occurred from May 2013 to May 2014 (Figure 3-4). For years 1996–2014, average value of 4.6 % was gained. Highest value 24.6 % was peaked in June 2010 and lowest -21.8 % in May 2009 [33] (#cite-text-0-74).

Pilot targets have been established for nearly zero energy buildings. For example in 2011 five floors high and 6500 m² energy efficient office building Viikki located in Helsinki aims to reach 70 kWh/m² annually (Figure 3-5). The limit for best energy class A is 90 kWh/m². The energy level of building is 50 % below the requirements of national building code. Usual energy consumption of standard office building is 150 kWh/m². In addition environmental friendly material and construction manners have been acknowledged in the building. Part of the energy is covered by solar energy, surface of panels on the roof and on the double façade is 572 m² which produce 60 kW of energy. This corresponds to 20 % of the electricity need of the building. Also a few windmills are installed. Space and water heating is covered by municipal district heat system whereas cooling in summertime is organized by 25 drilled wells of depth 250 meters [34] (#cite-text-0-75).

FIGURE 3-5. Viikki-environment friendly house located in Helsinki [11] (#cite-text-0-10)

In residential sector the example case, wooden detached house named "Lantti" has primary energy E-value of zero. The building has optimal surface/volume-ratio, optimally placed and sixed openings, good 450 mm thermal insulation in walls, and 510 mm in roof and base floors where the range of U-values is 0.07-0.09 W/m²K. Air tightness and avoidance of heat bridges and thermal leakages are emphasized where n_{50} is 0.3 l/h. Windows are of best quality and have U-value of 0.7 W/m²K. Ventilation machine is equipped with circulating heat recovery system that has annual efficiency of 80 %. The supply air is warmed by district heating. Lighting is based on LED-lamps where smart control systems are utilized together with maximum amount of natural light. Generally the most energy efficient equipment and machines are installed, and also adjustment of energy levels is organized according to presence/absence of occupants. Solar collectors cover 40 % of the need for warm service water and municipal heating the rest 60 %. Water-based floor heating system are utilized where the temperature of rooms can be separately adjusted.

FIGURE 3-6. Finland´s first net-zero energy building was constructed in 2012. After implementation the house turned out to produce more energy than consumed and thus can be regarded as representative of also plus-energy house. [12] (#cite-text-0-11)

Photovoltaics produce 11 934 kWh/a which is more than electricity consumption per year.

Low initial energy need, careful execution of construction work, utilization of district heat and own energy production resulted in calculated purchased energy value, or E-value of -1, which was of lower level than the set target (E=0). This corresponds to net zero energy level of buildings when inspected annually and different energy sources are calculated with coefficients [35] (#cite-text-0-76).

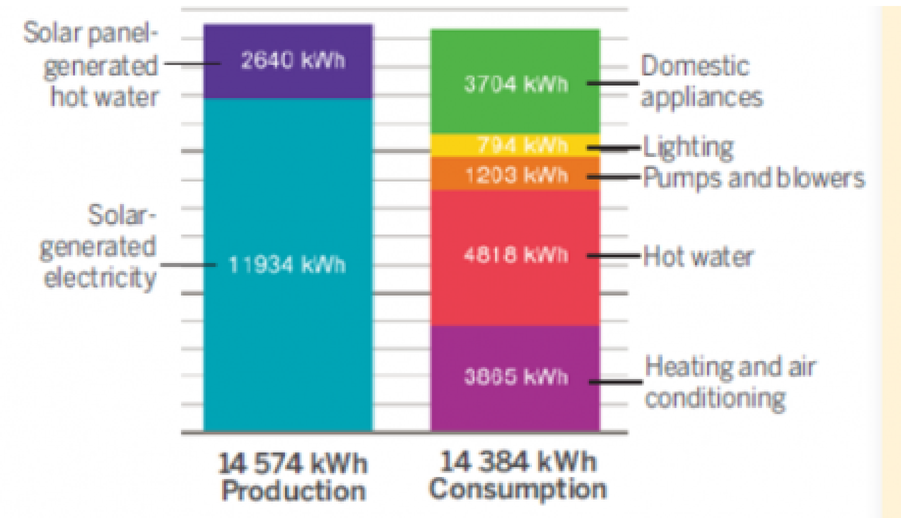


FIGURE 3-7. Illustration of solar energy production and consumption of Lantti-wooden detached house [13] (#cite-text-0-12)

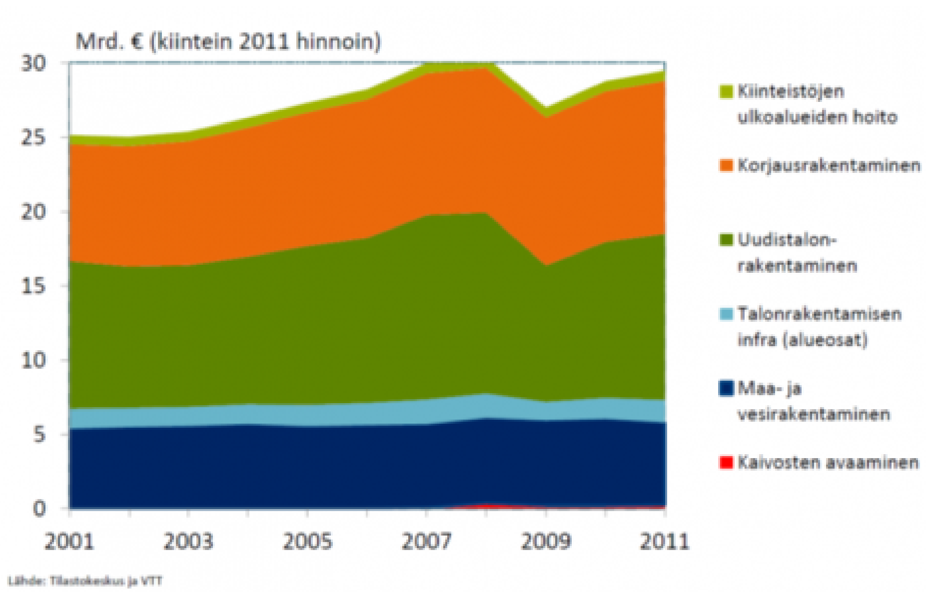


FIGURE 3-8. Development of construction markets (in billions euros) in Finland across the years according to subsectors. Light green color: maintenance of building outdoor areas, orange: renovation, green: new buildings, light blue: infra-areas of house construction, dark blue: civil engineering, red: opening of mines [14] (#cite-text-0-13)

In 2011 the total value of construction market was 29.5 billion euros. Of all the construction projects largest share was formed by new buildings with 38 % in Finland although the share of renovation (35 %) has been increasing in recent years (Figure 3-8). The proportion of all infra-related construction product was 27 % [36] (#cite-text-0-77).

3.2 Sweden

In 2012, the total amount of dwelling stock is 4.5 million. The share of apartment buildings is 2.5 million that is 25 % higher than the proportion of detached and semi-detached buildings. The quantity of one and two dwelling houses comprises 2 million units. Approximately 80 % of the current housing stock was built before 1980 [37] (#cite-text-0-78). The average floor space for newly-built detached and semi-detached houses was 122 m² in 2003 which has increased 12 % in ten years, explaining part of the growing energy consumption. In the 1990s the average floor space per capita was 43 m² in residential sector.

Swedish construction industry provide employment for approximately 500 000 people which corresponds to 11 % of working-age population. Gross value-added growth in construction industry reached peak in 2010 with annual rate of 9.5 % [38] (#cite-text-0-79). In the following years 2011, 2012, 2013, rates of more normal levels were observed; 3.4 %, 4.3 % and 4.6 % [38] (#cite-text-0-79). In the end part of 2013 signs of recovery in industry growth were acknowledged as residential apartments, shopping malls and transport infrastructure were constructed (see Figure 3-9). New buildings increased by 46 % (29 225 units) of the level year before (21 249) [39] (#cite-text-0-81). Growing population size and income rates have created strong demand for new housing which is also reflected as increased housing prices [38] (#cite-text-0-79).

Another commonly used indicator, Swedish Housing Index, describes the total number of established housing projects in thousands. For the period 1970-2014 average value was 10.02 Thousand. Highest value is 35 Thousand in the fourth quarter of 1971 and lowest 1.54 Thousand in the first quarter of 1997 (Figure 3-10, [39] (#cite-text-0-81) [32] (#cite-text-0-73)). Since 2013 mainly positive trend in the development of value has occurred.

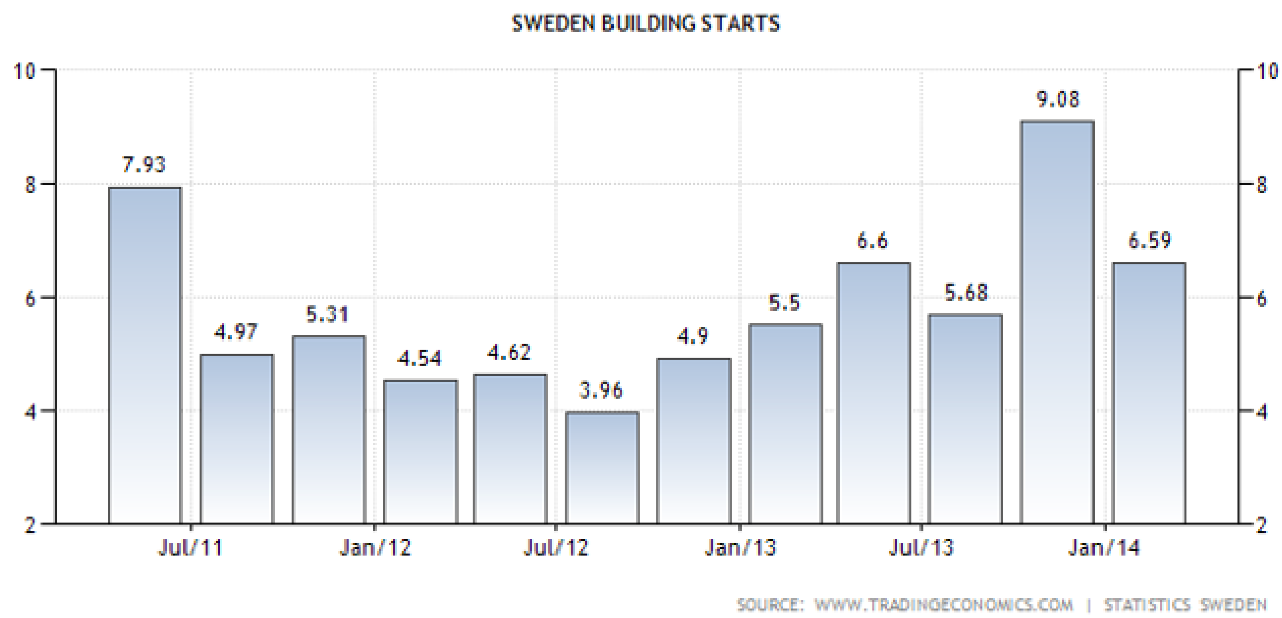


FIGURE 3-9. Total number of housing starts in Sweden in the period July 2011-January 2014. Units are in Thousands [15] (#cite-text-0-14)

Average value for construction output is 2.70 % in the timespan 1995–2014. Highest value 22.10 % was recorded in November 2000 and lowest -14.30 % in February 2009 [33] (#cite-text-0-74) [32] (#cite-text-0-73). Increase of 4.9 % occurred from July 2013 to July 2014 (see Figure 3-10).

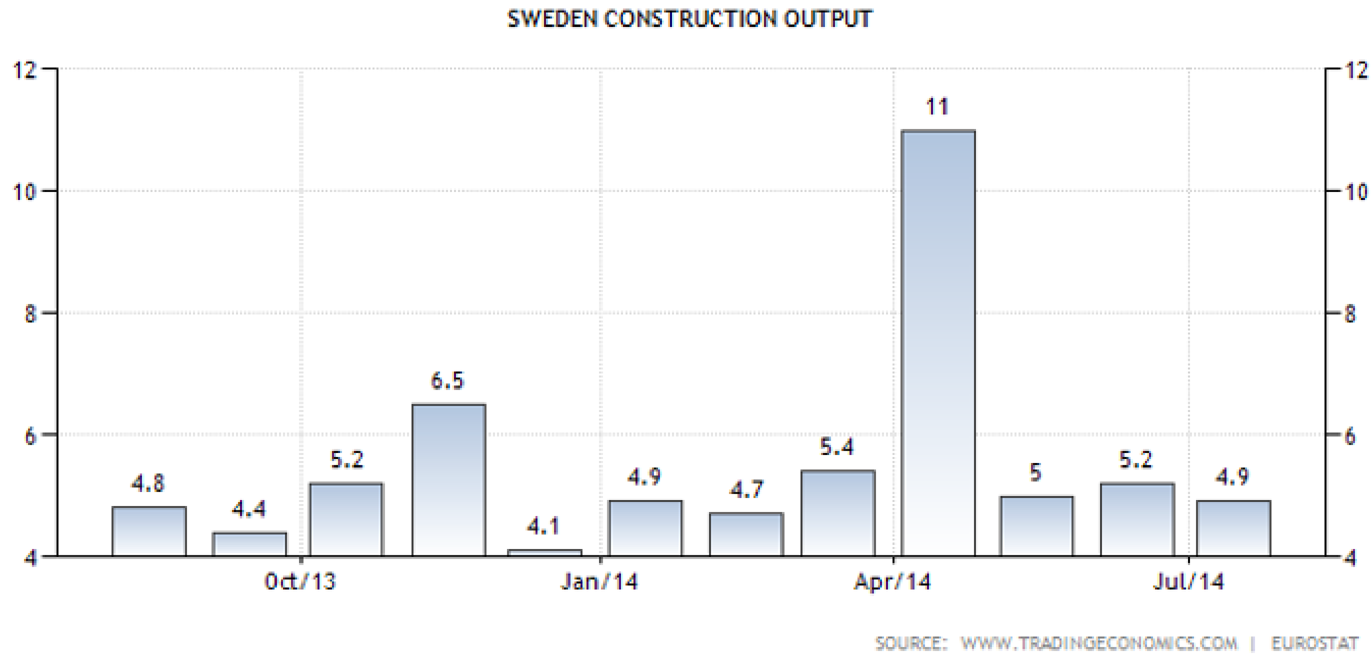


FIGURE 3-10. Construction output expressed in percentages in Sweden in the period July 2013–July 2014 [16] (#cite-text-0-15)

CAGR, Compound Annual Growth Rate, that expresses the constant rate of return for certain period, was 4.16 % between years 2008–2012 [40] (#cite-text-0-87) and 4.21 % in 2009–2013 [38] (#cite-text-0-79). Lower construction volumes encountered in 2009 was short-termed, and particularly residential sector is expected to grow strongly in the near future. Altogether, construction output of 4.8 % is forecasted during the period 2014–2018 [38] (#cite-text-0-79). Large budget of SEK522 billion admitted to infrastructural development ensures the field to be most rapidly growing construction market in the period 2014–2025. Among the set goals are also enhancement of employment and inducement of long-term economic growth Timetric. 2013. Construction in Sweden – Key Trends and Opportunities to 2017. [40] (#cite-text-0-87).

Despite of the initial slow progress, market for low-energy buildings has notably increased in recent years likewise is the overall construction rate. Totally 72 apartment buildings (including 3200 apartments) and 100 detached houses were established as low-energy level (Figure 3-11, [41] (#cite-text-0-91)). This corresponds to 11.2 % share of low-energy apartments out of all newly built flats and 1 % of detached houses.

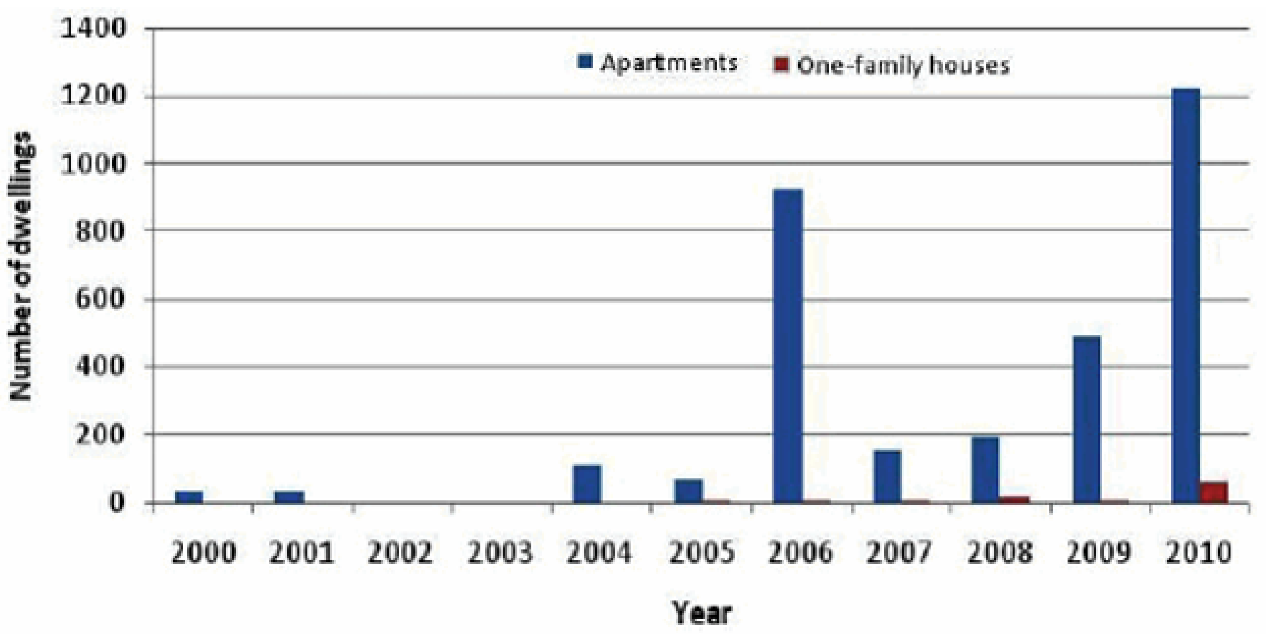


FIGURE 3-11. Construction of low–energy residential dwelling units have been strongest in the latest years in Sweden [17] (#cite-text-0-16)

In 2010, proportion of low-energy commercial premises reached 8 % of the total built area which corresponds to 700 000 m² or 78 construction projects (see Figure 3-12). Roughly 76 % of these buildings have 25 % higher energy performance than stated by building regulation, and 20 % reaches performance 50 % higher than defined in regulations [41] (#cite-text-0-91).

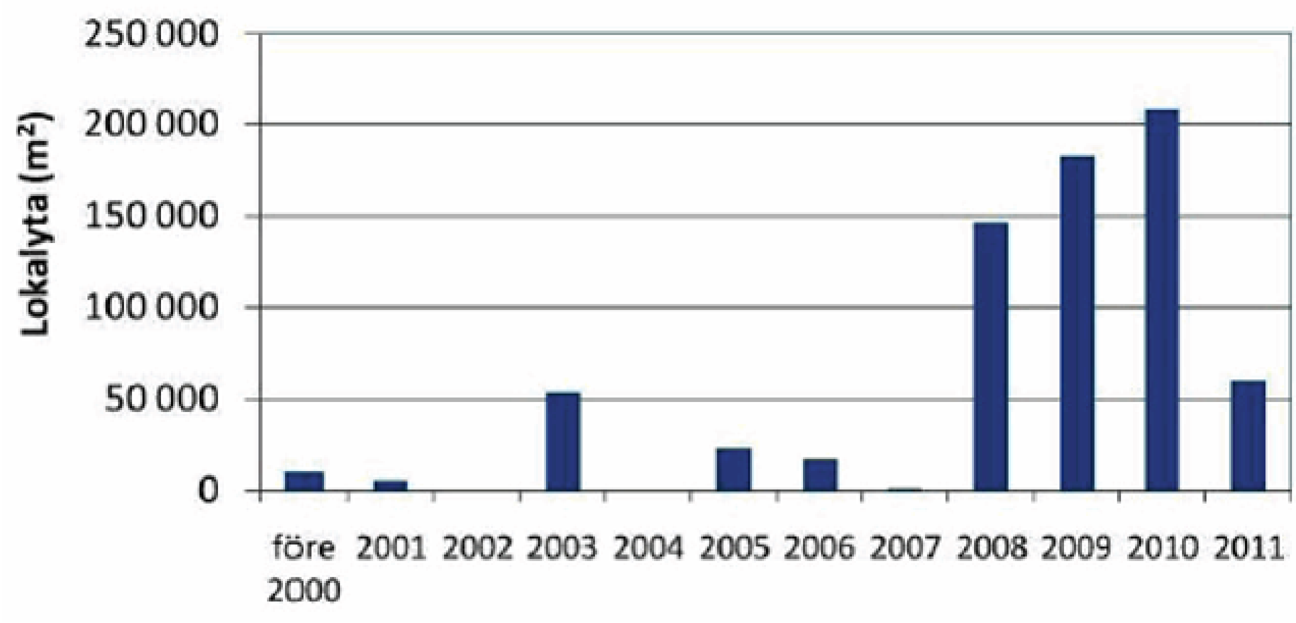


FIGURE 3-12. Commercial and similar premises built with low-energy technology per year in Sweden [18] (#cite-text-0-17)

In 2012 residential sector formed the biggest construction market. Government is facing two-sided role; in one hand it is supporting high housing demand by providing credit and increasing supply, but on the other hand setting limits for the rise of house prices, indebtedness of households and inhibiting the burst of property bubble [40] (#cite-text-0-87). In larger cities, e.g. in Stockholm requirement for office spaces of good quality is highly emphasized. Sweden aims to strengthen its competitiveness by increasing budget reserved for research and innovation by SEK4 billion until 2016, when at the same time other European countries are decreasing their share for RDI [40] (#cite-text-0-87).

()3.2.1 Energy use

Majority of the electricity is produced from hydro and nuclear sources. In the period 1970–1985 the share of hydroelectricity grew constantly and since that has been on the level of 60-80 TWh. In 2012 approximately 160 TWh of electricity was produced where the proportion of domestic consumption was 140 TWh. Sweden also imports electricity, and the amount of import highly depends on the weather conditions; in dry years more electricity is purchased from international electricity markets such as Nordic pool [42] (#cite-text-0-95). After 2000, the installed production capacities for wind power stations have steadily risen and reached quantity of 2000–3000 MW in 2011. Two years later the capacity was almost doubled, being value of 4470 MW [43] (#cite-text-0-96).

The most popular heating energy carriers were electricity, district heating and biofuels (logs, wood chips, sawdust and pellets). Between years 1970 and 1990 the share of electricity use for heating grew almost six-fold and reached value 29 TWh in residential and service sector. After 1990 falling trend has been experienced and in 2010 heating consumed 20 TWh of electricity [42] (#cite-text-0-95). Since 1990 district heating has mainly been based on renewable energy sources such as biofuels, waste, peat, waste heat and heat pumps. At present the usage of oil and coal are only marginal [39] (#cite-text-0-81).

District heating has become popular option also among detached houses that traditionally have been heated with electricity and biofuels. In 2012 the supply of district heating accounted for 6 TWh in single family houses, whereas electricity 16 TWh and biofuels 12 TWh [42] (#cite-text-0-95). In apartment buildings totally 25 TWh of district heating, 1 TWh of electricity and 0.4 TWh of oil heating were used in 2010 [44] (#cite-text-0-100). District heating covered 85 % of the apartment area in multi-dwelling apartments. Only 2.7 % of heating energy was oil-derived in detached and semi-detached houses, and 1-3% in multi-dwelling houses and premises [39] (#cite-text-0-81).

Usually, different combinations of heating systems are used, for example electricity-heat pump or oil-air source heat pump systems are used concurrently with other heating technologies. Dwellings have more than one million heating pumps and the largest proportion of these are in attached and semi-attached houses [45] (#cite-text-0-102). Detached houses have approximately 46 % share of heat pumps [42] (#cite-text-0-95). The most usual types are geothermal-, lake-, water- and air-source heat pumps.

In 2012, the average quantities of space and water heating energies were 121 kWh/m² for dwellings in detached houses and 140 kWh/m² in apartment houses [39] (#cite-text-0-81).

In 2000 century, the average energy efficiency has improved by 20 % in newly built detached and semi-detached buildings when compared in buildings of 1980s and 1990s. As indication of development, detached and semi-detached houses consumed 120 kWh/m2 when constructed in 1996-2001, 146 kWh in 1990–1995, 159 kWh/m² in 1980–1989 [46] (#cite-text-0-105). In the Table 3-2 slightly different values are presented [47] (#cite-text-0-106).

TABLE 3-2. The quantity and energy consumption of Swedish detached houses constructed in different decades [19] (#cite-text-0-18)

Construction	Number of permanently	% of houses with only	% of houses with electricity +	Measure final

Construction year	used houses in 2010 (1000s)	electricity heating system installed	biomass heating system installed	energy use (kWh/m²)
–1940	534	11 %	31 %	153
1941–1960	279	12 %	21 %	144
1961–1970	273	21 %	16 %	122
1971–1980	414	35 %	25 %	107
1981–1990	203	38 %	25 %	109
1991–2000	94	37 %	26 %	104
2001–	99	29 %	28 %	91

Based on annual surveys of several thousand households by Swedish Energy Agency.

Within one year period, energy use decreased by 18 kWh in apartment buildings. Roughly, heating energy consumption in single and multi-dwelling buildings are 23 200 kWh and 10 200 kWh, values varying due to temperature zones [39] (#cite-text-0-81). As expected, the most extreme values are observed in northern (for detached houses 26 700 kWh) and southern counties (21 000 kWh).

Restrictions for electrically heated buildings were announced in 2009 by National Board of Housing, Building and Planning. Maximum allowed energy use per square meter, permitted installed electric power for heating and a mean coefficient of thermal transmittance of the building envelope were defined. Additionally, within two years of completion measurement of energy performance must be performed [41] (#cite-text-0-91). Specific energy use (kWh/m² Atemp) per temperature area, is defined as an area bordered by inside of the building envelope on all floors that are heated to more than 10 °C.

Some post-construction measurements are in progress and additional are in the planning stage. Less than half of low-energy residential buildings are measured for their energy performance. Larger-scale measurement for airtightness of building envelope and interviews of occupants about the indoor climate are done for quarter part of apartments and only for a few detached houses. In non-residential sector, the follow-up of energy use and other characteristics is even less frequent than in housing sector [41] (#cite-text-0-91).

The enhanced monitoring would be important to enable collection of experience and development of appropriate technical design and system improvements. The Swedish building code require the measurement of new buildings within two years of completion. Buildings energy certificate is normally based on monitored energy performance unless it is sold within one year after completion. Then energy certificate is formed of calculated energy performance [41] (#cite-text-0-91).

Positively, changes in the attitudes are observed in the construction and property sectors. Large-scale voluntary based initiatives have been adopted to erect new building with lower energy use than is determined in building regulations [41] (#cite-text-0-91).

3.3 Norway

Norwegian building stock consists 3.9 million units. Largest building category is formed by residential buildings with 1.48 mln units or 38 % share. Detached houses comprise majority with 1.14 million units. Of the residential buildings the proportion of apartment buildings is only 2.4 % [48] (#cite-text-0-112).

Due to high share of single family houses, also average dwelling area per household is relatively high, ~120 m². Similarly, dwelling are per person represent the higher extreme in the European scale, and was more than 50 m² (see [49] (#cite-text-0-113)). However, the rise of floor area per person has lately been decreasing due to urbanization and increasing prices. This has reduced per area energy consumption. New buildings built since 1990 are the outcome of dwelling standards and energy requirements and have lower energy consumption levels. It has been estimated that on average 2–3 TWh of energy in Norwegian households have been saved due to milder climate since 1980 [50] (#cite-text-0-114). Average energy use per square meter is 170–180 kWh depending on the number of years included [48] (#cite-text-0-112). In 2005 approximately 85 % of energy consumed by housing stock were due to detached and attached houses in 2005. Majority of the energy used by buildings established between 1990 and 2005 were consumed by detached houses which account roughly 3.1 TWh annually [49] (#cite-text-0-113).

The number of started constructions is expressed by Housing Index (Figure 3-13). Average value was 2055 in the period 1983–2014.

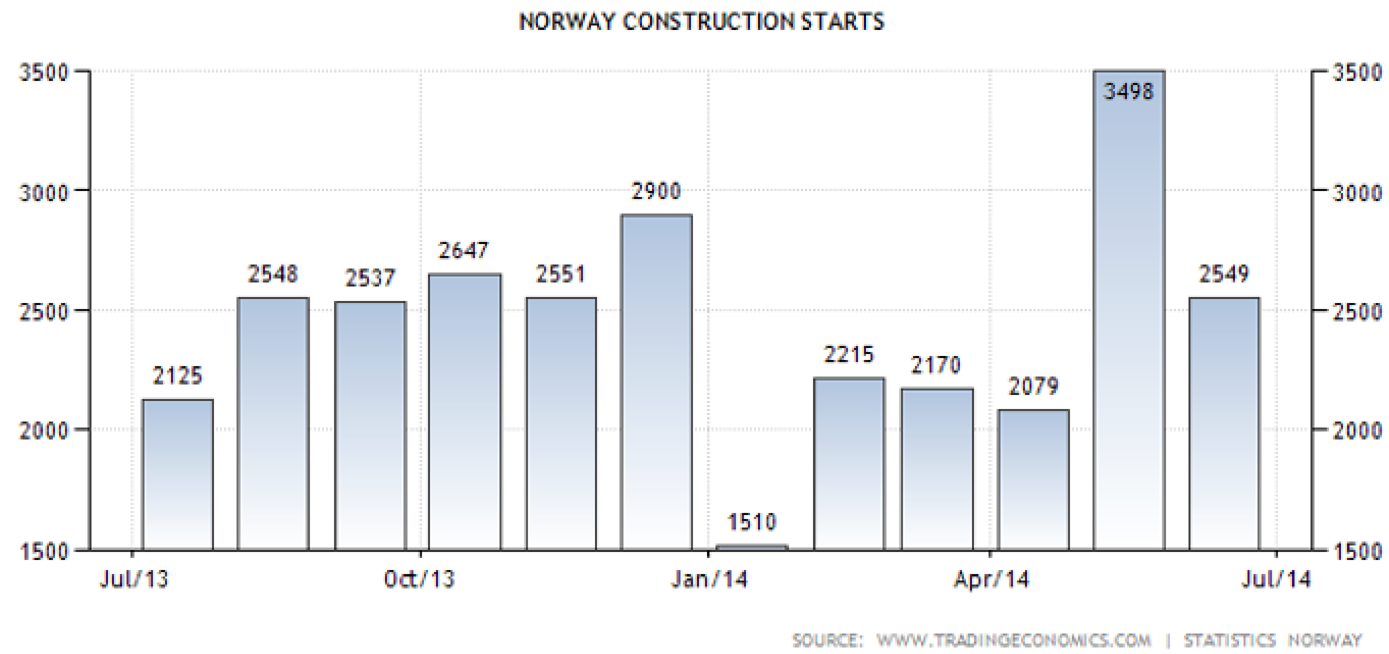


FIGURE 3-13. Number of started constructions are shown in Norway [20] (#cite-text-0-19)

Highest value 4157 was acknowledged in December 2006 and lowest 1081 in April 1993 [48] (#cite-text-0-112).

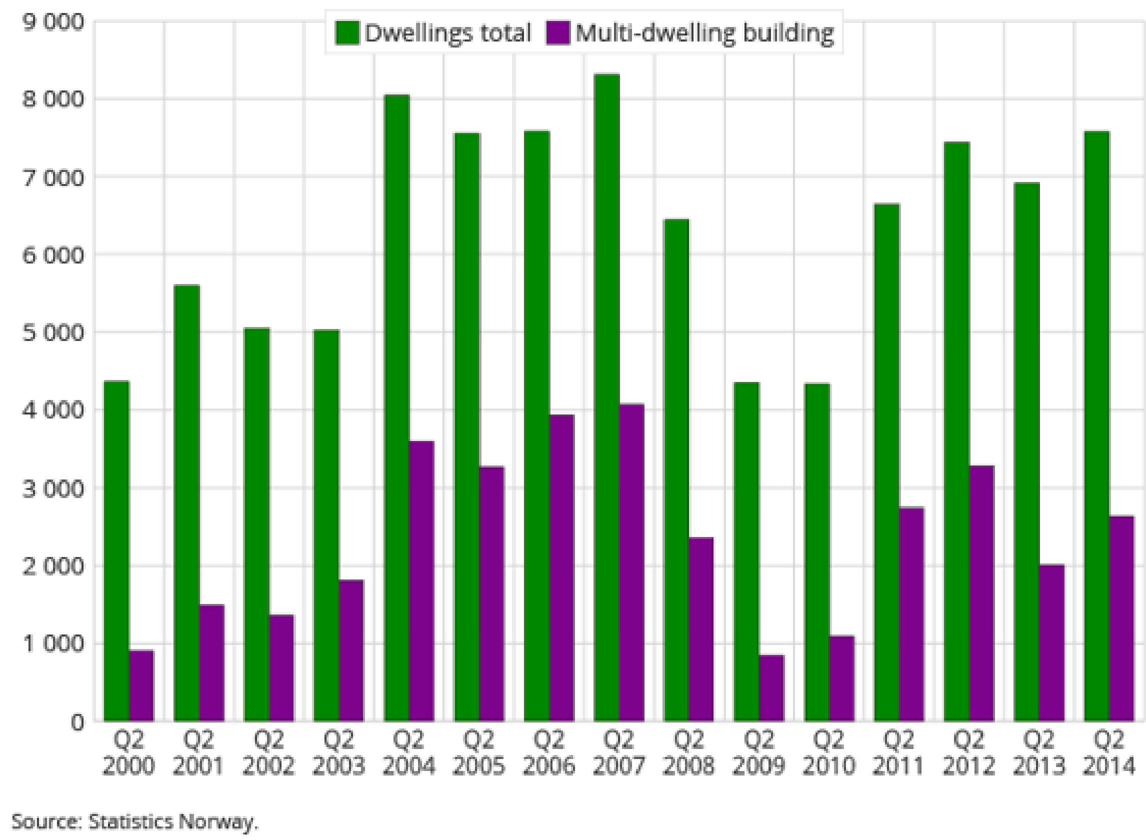


FIGURE 3-14. Building permissions for all dwellings and multi-dwelling buildings registered in Norway over the years [21] (#cite-text-0-20)

Upward direction between 2003 and 2007 were expressed in building permission granting which was followed by rather sharp decrease until the lowest value of 2000 century was reached in 2009. Since then higher number of dwelling have been constructed. Flattened trend curve that begin in 2013 has been increasing modestly in the beginning of 2014 (Figure 3-14, Table 3-3). Number of permits for non-residential buildings has grown since 2013, although occasional between-months reductions in quantities occur.

TABLE 3-3. The total number of dwellings and corresponding utility floor space are shown also for other than residential buildings [48] (#cite-text-0-112)

Year	Dwellings	Utility floor space to dwellings	Utility floor space to other than dwellings
	Number	(1 000 m²)	(1 000 m²)

2013	30 450	4129.7	5273.7
2012	30 189	4039.5	5504.6
2011	27 735	3804.6	5491.0
2010	21 145	3059.1	5726.8
2009	19 748	2748.5	5042.9
2008	25 950	3379.5	6205.2
2007	32 520	4025.2	6023.7
2006	33 314	4080.6	4969.4
2005	31 608	3848.7	4601.6
2004	29 999	3543.4	4239.3
2003	23 177	2956.8	3779.9
2002	22 980	3043.7	3754.9
2001	25 266	3408.7	3922.0

Statistics of buildings rely on registration date of building permits which does not necessary mean that construction is started immediately.

In 2013, building permission was granted for 30 450 dwellings which corresponds to 4.1 mln m² of utility floor space (Table 3-3). Since 1988, this is the highest value. However, the total quantity of utility floor space is lower than in 2006 which was the peak year (Table 3-3). In 2013, other than dwelling floor space was 4.1 % less than a year before. In the business sector totally 3.8 mln m² were started and of the value more than half were formed by industrial and office buildings [48] (#cite-text-0-112). Approximately 1.5 mln m² is due to holiday houses, garages of residential buildings etc.

4 New Buildings in Russia

Roughly 19.65 million buildings account for total area of 177 million m². In floor space this corresponds to 3.2 milliard m² [51] (#cite-text-0-120). The number of block of flats is 3.2 million that consist 2.2 milliard m² of floor space (see [52] (#cite-text-0-121)). In 2002 approximately 73 % of the total housing stock located in urban area with majority of multi-storey buildings [53] (#cite-text-0-122). In rural areas single-family houses are the most common residential building type. Estimated average age of Russian buildings is 42 years [53] (#cite-text-0-122).

The most construction intensive years were in the period 1960–1985 which resulted in the establishment of three basic residential building categories. These are called First, Second and Third generation buildings which at present create rather uniform appearance of urban housing stock [53] (#cite-text-0-122). In 2009, on average 90% of buildings were constructed before 1995 (see Figure 4-1).

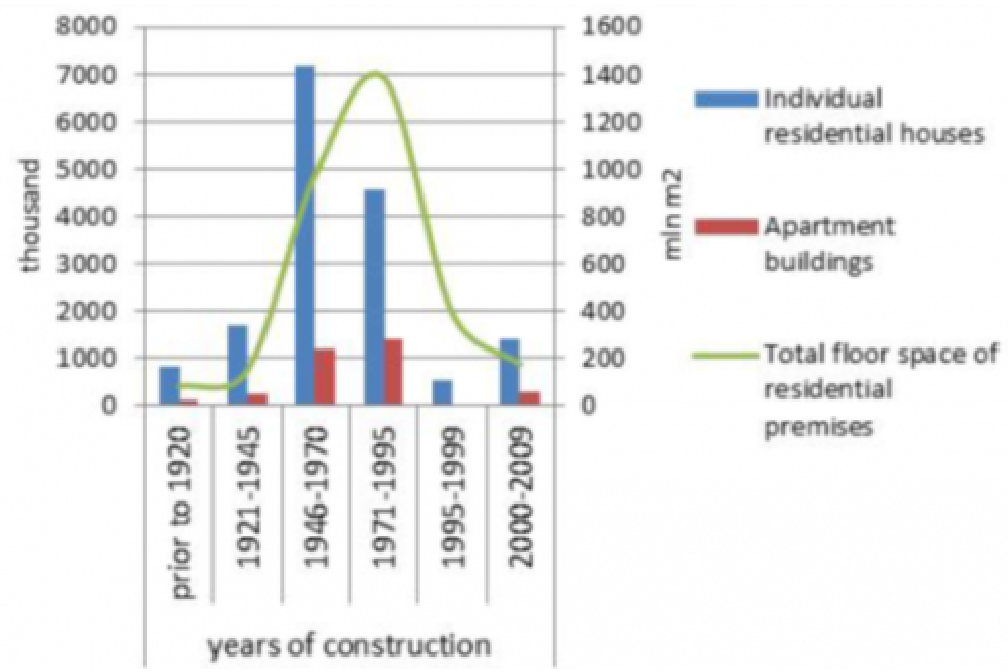


FIGURE 4-1. Distribution of units and area in residential sector according to construction year in the period prior to 1920–2009 [22] (#cite-text-0-21)

Due to inadequate maintenance and renovation the condition of housing stock is continuously weakening. Roughly 150 000 flats become non-suitable for living every year. Not too much statistics and data are available about the renovation efforts. Simultaneously the construction rate of new buildings is low which may be interpreted as lack of increase in the total housing stock in years preceding 2003 [53] (#cite-text-0-122).

FIGURE 4-2. Growth rate of Russian housing stock floor space and evolution of dilapidated housing in different years [23] (#cite-text-0-22)

Between years 2000–2009 the quantity of residential stock increased by 14 %. In general, the growth rate of housing stock area was significantly lower in the period 1990–2005 than in 1980th [51] (#cite-text-0-120). Construction of new residential buildings slowed after 1990, and in 2001 it was only 40 % of the level in 1990 (see Figure 4-2). In the beginning of 2000 century, approximately 380 000 new dwellings or 32 mln m² dwelling floor space were produced annually. This corresponds to 2.6 dwellings per 1000 Russians, when the average number for Western European country is 5–5.5 dwellings/1000 people [53] (#cite-text-0-122).

In 2008–2009, the growth rate of housing stock was higher than in the first years of the 2000 century; rate grew from 0.6 % to 1.7-1.8 % which corresponds to 54–55 mln m² per year. Average housing occupational rate per person was 22.4 m² in 2009 which increased 17 % from the level in the beginning of the 2000 [51] (#cite-text-0-120). The increase is partly explained also by the population decline. Privatization of residential buildings begun in the beginning of 1990s and is currently around 90 %.

In October 2009 around 5.3 mln m² of residential area were constructed, which is 9.8 % lower share than a year before [54] (#cite-text-0-129). According to published plan of Russian Government, volume of housing construction should be increased up to 90 million m² until 2015 (see [52] (#cite-text-0-121)). For example, comfortable city living place is constructed by NCC-company according to European city standards that includes large apartment block areas with parks, playgrounds, sport facilities, shops and parking in St. Petersburg. Multitude of new construction technologies such as energy efficient materials are used. In project designed by Setl City energy efficient technologies such as collector heating and water supply system, energy efficient insulation and windows are implemented. Project is estimated to last for 15–17 years (see [54] (#cite-text-0-129)).

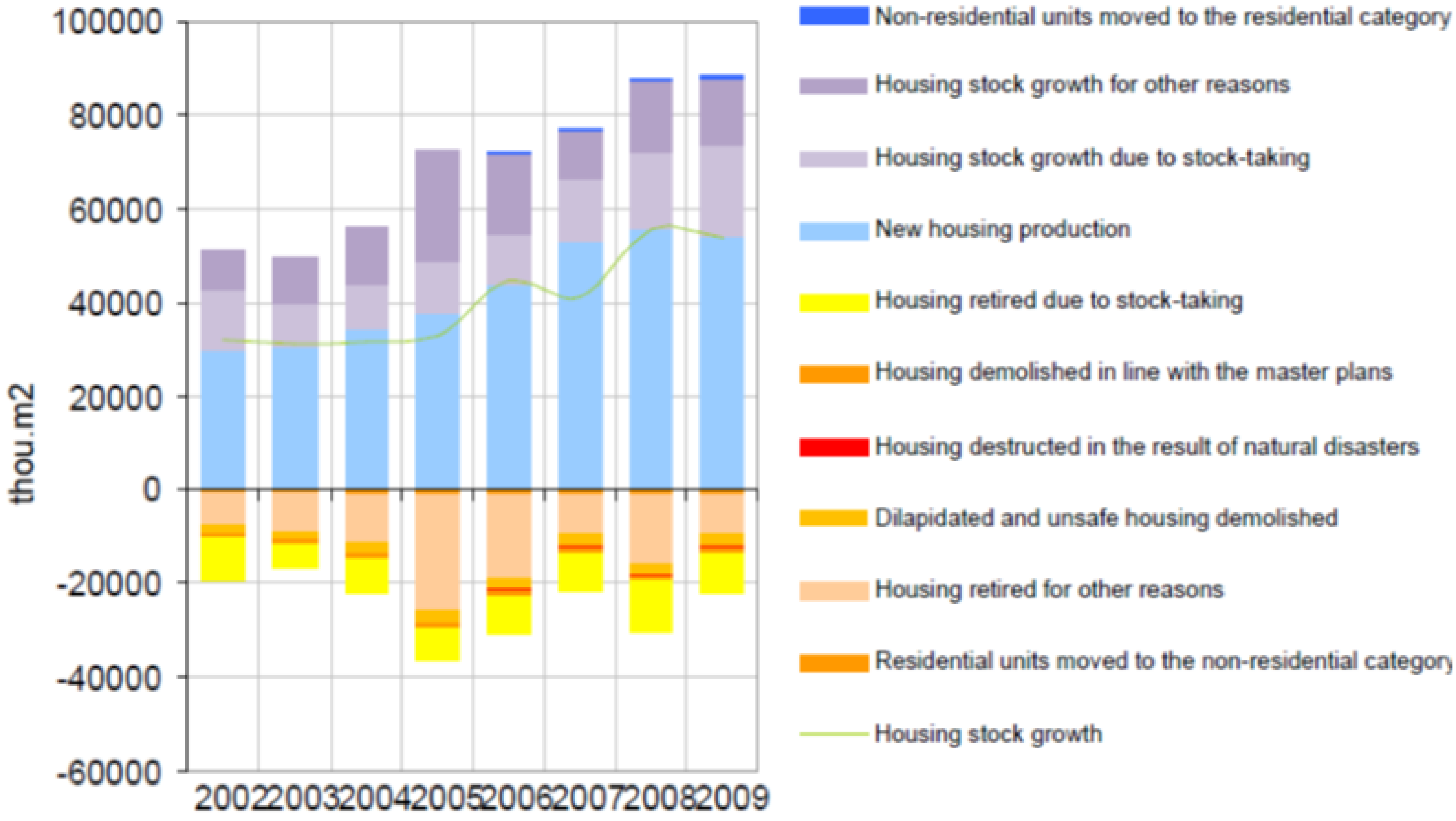


FIGURE 4-3. Housing stock dynamics is presented subdivided to different factors [24] (#cite-text-0-23)

The growth of housing stock is due to construction of new units and due to other reasons, such as modification of non-residential premises to residential ones and stock-tacking (see Figure 4-3). The rate by which non-residential estates are changed to residential is 0.1-0.4 % per year. Thus, the main dynamics that influence the growth of housing stock are housing production and demolition [51] (#cite-text-0-120). Annual increase rate of housing stock was 3 % in 2009 (Figure 4-2). The new act that entered into force in 2009 determines that new private buildings have to be equipped with energy meters. Improvements have been observed in Murmansk area where energy use is measured with high-quality instrument in multiple places [55] (#cite-text-0-133).

FIGURE 4-4. Volume of started constructions in Russia in the period July 2013–July 2014. Units are in millions of square meters. [25] (#cite-text-0-24)

In Russian Housing index, expressed as millions of square meters, gain from 4.60 mln to 6.90 million occurred from May to June in 2014 (Figure 4-4). Average value of 3.92 mln m³ was recorded for the period 1996–2014. In comparison, highest value 18.40 mln m³ was achieved in December 2008, and lowest 0.40 mln m³ in January 1996 [56] (#cite-text-0-134).

Many large buildings projects have just been finalized and others will be established. For example buildings for 2014 Olympic Games in Sochi, 2018 FIFA World Cup and Skolkovo Innovation Center-technology park in the area of Moscow. Plenty of hotels and shopping centers are planned to be constructed on the areas of larger cities, such as Moscow, St. Petersburg, Omsk, Kemerovo and Rostov. According to announcement of Moscow city government 343 hotels with 92 700 rooms are planned to be constructed (see [52] (#cite-text-0-121)). Also retail space development is intensive as one fifth part (400 000 m²) of European´s developmental total were completed in Russia during the first six months in year 2011. Approximately 36 % of the new space were located in Moscow where AFIMALL City and two shopping centers were opened (see [52] (#cite-text-0-121)). A modern office building of 2000 m² will be built in St. Petersburg that meets the requirement of LEED building (BTK).

Various challenges are encountered in the construction phase of new buildings. Part of these are of generic levels (see Figure 4-5), and part are specific barriers that can be overcome with recommendations. The need for holistic design approach where interdependence and shared responsibility are encouraged in the building value chain are emphasized [57] (#cite-text-0-137). Integrated design and usage of advanced energy technology together with incentives to perform whole building actions rather than single elements are required. Here motivation of involved people is one of the essential targets.

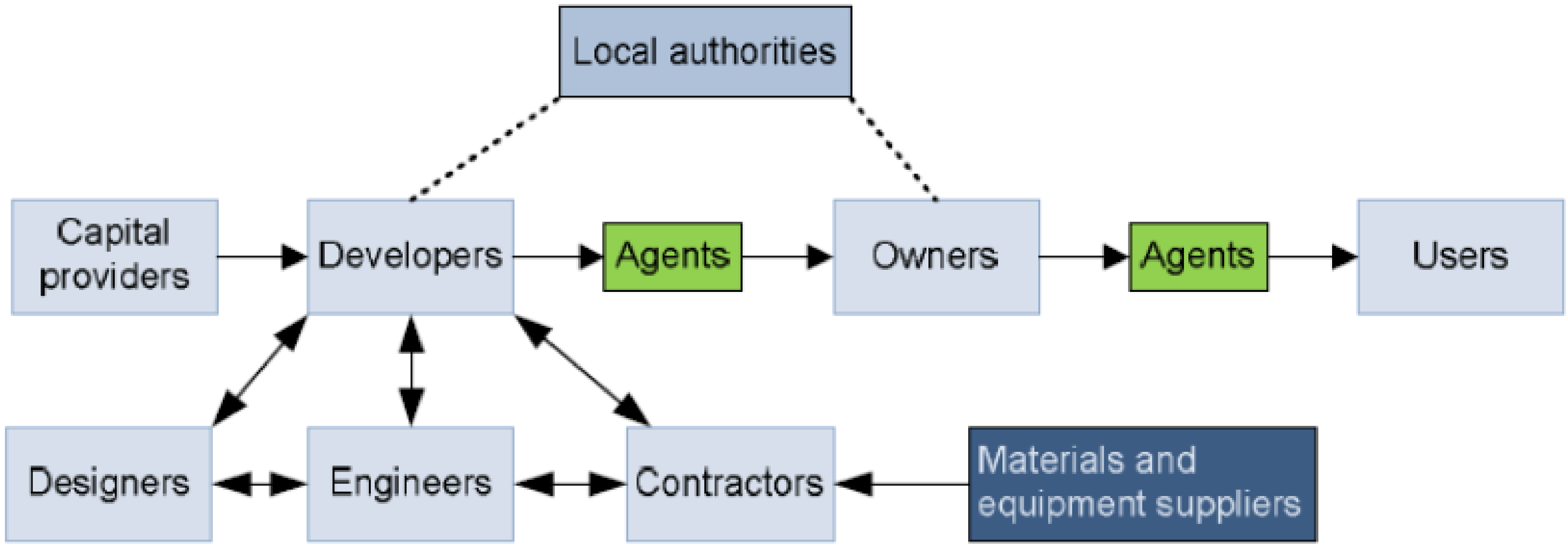


FIGURE 4-5. Complexity of commercial relationships in the supply chain is considered as one of the barriers to achieve energy efficient buildings [26] (#cite-text-0-25)

Some recommendations are given to surpass general level barriers. Especially important are the strengthening the usage of building codes and labelling, generation of incentives to energy efficiency investments, usage of integrated design approaches, innovations and advanced technology to strengthen energy saving behavior of users. In addition, education of personnel to energy saving aspects is crucial as well as the general level sharing of energy knowledge [57] (#cite-text-0-137).

4.1 About new building markets

In 2008, proportion of working population related to construction sector was 8.1 %, real estate 7.3 % and retail sales and service sector 17.7 % [58] (#cite-text-0-139). Investments of 366.2 mln RUR made in the period January-October 2009 were evaluated to be inadequate by the Builders' Association of Russia (BAR). Opportunities in green markets depends on economic trends and national construction programs [52] (#cite-text-0-121). Generally, as the economy is rising also the quantity of construction projects are increased.

Roughly 70–80 % of Russian construction companies were having critical economics and requirement for large scale investments. Vast market opportunities exist in public buildings construction area for foreign companies. Demand for construction equipment and buildings materials will be growing and often Russian companies rely more on quality of Western manufacturers. In addition to quality, also price is important. Often cheaper products are favored, such as Chinese ones which induce severe price competition. It is expected that retail purchases will increase in the market as Russians prefer "do it yourself" approach. On retail market roughly 20 % of buildings material were sold to individual customers in 2011 (see [52] (#cite-text-0-121)). The price of building materials has experienced reduction of 8.5 % in the period 2008–2009. Also sales of window and doors production sector encountered negative impacts along the heavy construction sector [54] (#cite-text-0-129).

The percentage of unfinished construction has generally been rather high. In the third quarter of 2009, volume of production in manufacturing and building sector was reduced by 18.4 % in comparison to the level in previous year. Of all the areas of Russian economy, construction sector has severed most of the world credit crisis [54] (#cite-text-0-129). Along the reduction of demand for real estate and building services, banks have not given credits with same condition and scale as previously. This influences majority of construction-related companies, as minor proportion is directly financed from the government budget [54] (#cite-text-0-129).

Generally, the level of insufficient investments and the rise of construction costs have caused delays, or total inability to complete the buildings [53] (#cite-text-0-122). Building statistics of Russian Federation reveals the unfinished work that was started in previous years. More than 50 % of unfinished projects had been launched much earlier, and also regional differences are observed. For example, the ratio of uncompleted to completed new dwellings can reach the ratio 10:1, as was the case in Murmansk in 2001 [53] (#cite-text-0-122). However, 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 4-1, [52] (#cite-text-0-121)).

TABLE 4-1. Information on uncompleted construction of Russian residential buildings. The table is originally presented by [52] (#cite-text-0-121)

Year	1995	2000	2005	2006	2007	2008	2009	2010
Total area (million m^2)	90.1	45.2	35.0	36.1	39.2	39.5	33.9	29.7

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 were increased and the number of completed projects was risen by 5.2 % when compared to the value of in 2011 [52] (#cite-text-0-121). In 2013 the quantity of new homes increased to 912 100 which is highest amount within two decades. This corresponds to 69.4 mln m² which is ultimate value since 1989. Highest annual housing completion value 72.8 mln m² was recorded in 1987. After this the quantity of population has been reducing by nearly 2 million people. The main drivers for development of increased construction have been insufficient housing space per capita, increased household income, decline in mortgage rates and enhanced business atmosphere. Especially the construction of economy class housing have been supported in recent years in the form of more affordable mortgages. This enable low income families to purchase new homes. Also less expensive residential projects are embraced by people as a consequence of need for housing and limited buying ability. At least 71 mln m² of housing space will be commissioned across the Russia in 2015 and 92 mln m² in 2020, as is stated by the Provision of Affordable and Comfortable Housing Programme 2013–2020. Of these amounts, largest part (60 %) is formed of economy class housing. In the beginning of 2014 total of 22.3 mln m² of this housing type were under construction or awaiting necessary documentation. Major increase has occurred as in previous years 2010–2013 the value was only 2.3 mln m² [59] (#cite-text-0-150). The cost of new buildings depends on the number of floors, building orientation and geometry, labor and material cost rather than energy-efficiency related incremental cost [60] (#cite-text-0-151).

TABLE 4-2. Completed buildings in Russia in the period 2005–2011 [61] (#cite-text-0-152) [62] (#cite-text-0-153)

	2005	2006	2007	2008	2009	2010	2011
Total number of buildings	141.6	159	209.9	224.6	233.3	216.5	223.8
• residential	131.0	148.7	194.6	208.9	217.2	201.7	210.8
• non-residential	10.6	10.3	15.3	15.7	16.1	14.8	13.0
Total volume of buildings (million m^3)	265.4	304.2	414.1	446.2	423.6	397.4	407.7
• residential	202.2	234.4	282.1	310.9	280.8	271.8	305.6
• non-residential	63.2	69.8	132.0	135.3	142.8	125.6	102.1
Total floor space of buildings (million m^3)	66.3	75.6	98.1	102.5	95.1	91.5	94.8
• residential	54.8	62.3	74.5	79.2	72.5	70.3	77.1
• non-residential	11.5	13.3	23.6	23.3	22.6	21.2	17.6

Housing stock is estimated to have reached 23.8 m² per capita in 2013 which is still below the level of 30–40 m² of most European countries [61] (#cite-text-0-152) [2] (#cite-text-0-1). A series of residential construction and housing support programs have been launched by the government and regional administrations to expand the figure to 25–27 m² until 2015 and 28–35 m² until 2020. This is observed as strongly growing trend of construction in recent years (Table 4-2, Figure 4-6).

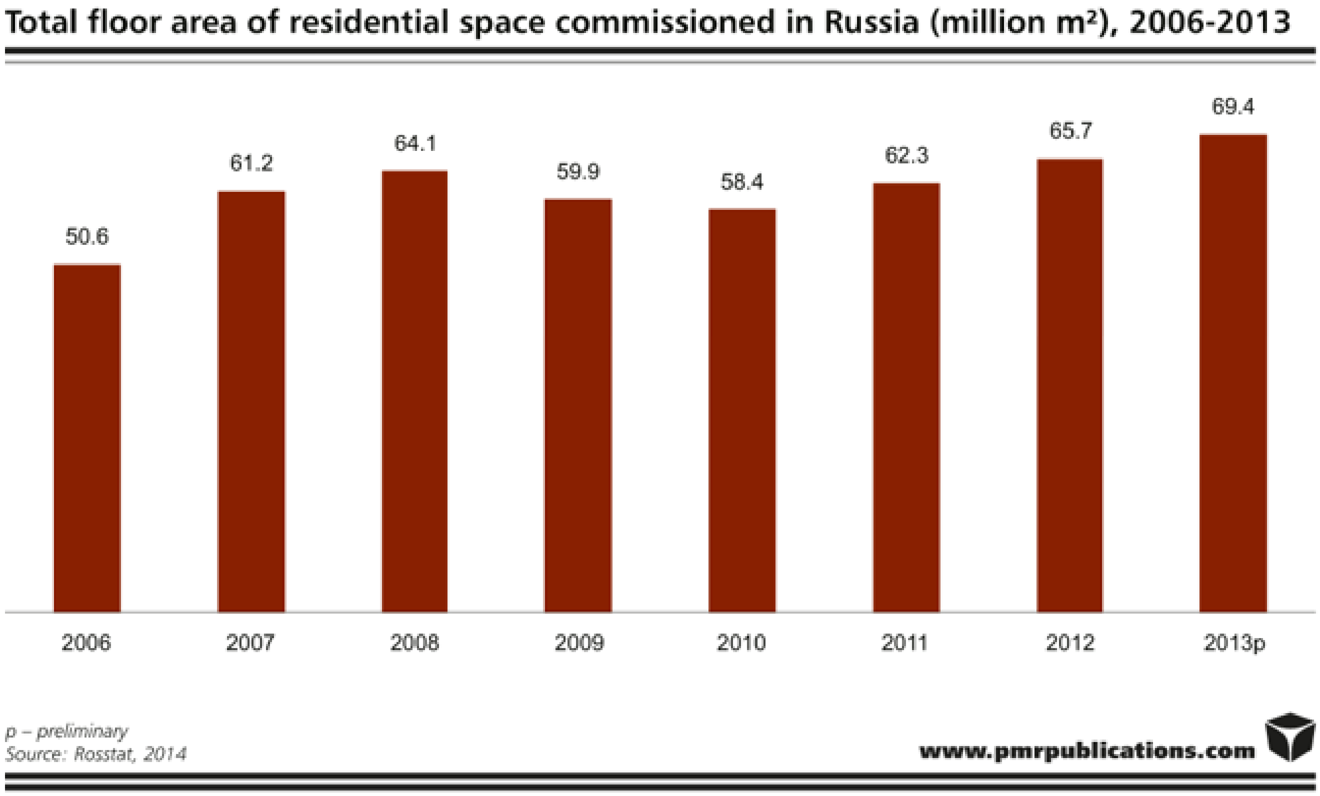


FIGURE 4-6. The development of total floor area in residential sector [27] (#cite-text-0-26)

4.2 Energy use

Russia is third largest energy consuming state in the world. Challenges in attempts to improve the level of energy efficiency are posed by extensive domestic energy supply and inefficient technologies that are used in cold climate. This influences all the sectors of economy [52] (#cite-text-0-121). Reduction target of 56 % for energy intensity has been set for 2030 when compared to level of 2005 by The Energy Strategy of Russia in 2009 [63] (#cite-text-0-157). Legal and economic frameworks for advancing the energy efficiency were adopted in November 2009 by Energy Conservation and Increase of Energy Efficiency-Federal Law [64] (#cite-text-0-158). The main emphasis is on the building efficiency where compulsory meters are required to be installed and establishment of energy efficiency certificate and information network. “Energy saving and energy efficiency improvement until 2020”-state program adopted in 2010 and implemented in 2011 aims to reduce energy intensity in relation to GDP by 40 % until 2020 when compared to the level in 2007. Of the saving, 26.5 % will be gained from structural changes in the economy and 13.5 % from new energy efficiency measures. New standards for construction were accepted in 2011.

Between years 1997–2011, energy production has increased from the level 910 mtoe to 1300 mtoe. In 2011 the total production of electricity and heat were 91 Mtoe (1055 TWh) and 549 Mtoe (6381 TWh) [65] (#cite-text-0-159). For long time heating has accounted for major portion of energy consumption. For example in 1999 it consumed 136.3 Mtoe (5706 PJ) and formed 33.2 % of the final energy use [66] (#cite-text-0-160). Usually heat and electricity sectors are issued together, as third part of electricity is generated as a side-product of heat. The heating energy is mainly produced from gas (67.3 %), coal-peat (19.9 %), oil (5.6 %) and other sources [65] (#cite-text-0-159). Largest consumers are residential 47 %, industrial 38 % and commercial-public service 11 % sectors.

Although the significant share of energy end-consumption, more detailed level data is missing on the energy use of residential buildings. Some estimates have been made by organizations such as CENEf, IEA, World Bank which are utilized also in this study. Residential energy consumption has grown by 20 % in the period 1990-2006, and roughly half of this is formed of energy use in appliances. Energy usage in large appliance has decreased from 47 % to 28 % but concurrently the ownership of small appliances (computers, mobile phones) has increased which have raised the electricity use in housing stock [67] (#cite-text-0-162).

Residential sector used 28 % of the total final energy and generated 20 % of the emissions. The shares of space and water heating are 58 % and 25 % of the overall residential energy consumption (see Figure 4-7). Proportion of cooking is 10 %, appliances 4 %, lighting 2 % and other 1 % (see [60] (#cite-text-0-151) [52] (#cite-text-0-121). In modern apartment buildings where energy efficiency measures are implemented these proportions are a bit lower (Figure 4-7). Generally long heating season and inefficient design of buildings in Russia 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 [67] (#cite-text-0-162).

District heating is the main heating system in 75 % of Russian dwellings. The district heating based space and water heating is inefficient, and by improvements approximately two thirds of the total energy saving could be achieved [51] (#cite-text-0-120) [68] (#cite-text-0-167).

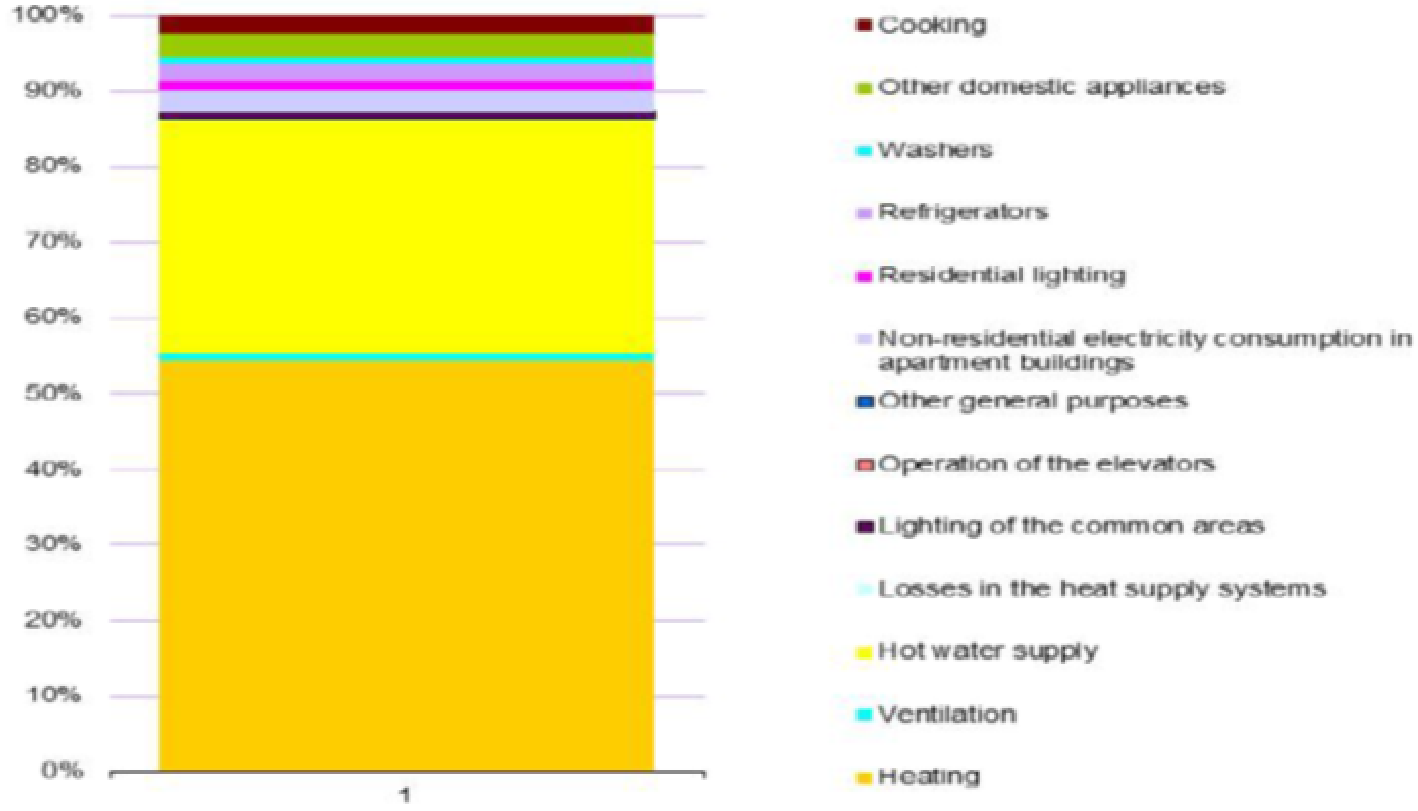


FIGURE 4-7. Energy usage pattern in apartment buildings in energy efficient residential area [28] (#cite-text-0-27)

Average heating energy intensity for multi-family apartment building is 229 kWh/m²/year. Refurbishment of existing building stock could result in energy intensity of 151 kWh/m² World Bank. 2008. Energy efficiency in Russia: Untapped reserves. World Bank, Moscow. Hakupäivä 24.11.2015. http://documents.worldbank.org/curated/en/2008/12/10123872/energy-efficiency-russia-untapped-reserves. The age of the building affects space and water heating energy intensity, and three-fold lower consumption can be observed in residential buildings constructed between years 2000–2010 than in buildings of 1960s (see Figure 4-8). Small portion of the houses established 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 [60] (#cite-text-0-151).

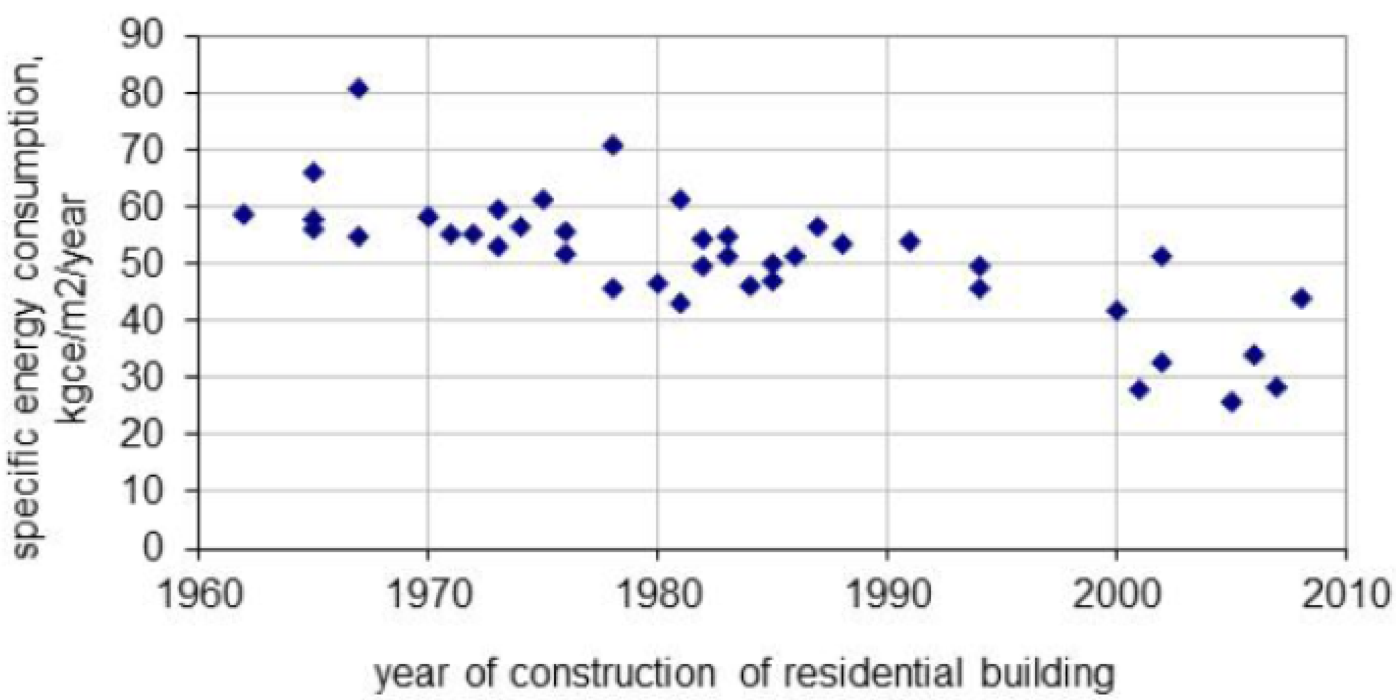


FIGURE 4-8. Correlation between building specific energy consumption and construction year are depicted [29] (#cite-text-0-28)

5 Comparisons

In general, Scandinavian countries are on different level regarding ZEB-related discussion and practical measures. Research centers are already established in Norway and Denmark whereas the development is on rather early stage in Finland and Sweden [20] (#cite-text-0-48). Shared goal is to adopt into the national strategies definition of ZEB with energy reducing measures and related use of renewable sources. Although the concept of ZEB is challenging due to cold Northern climate, shared efforts are done in Scandinavia for the implementation [20] (#cite-text-0-48).

Despite of the continuous growth of the building mass, the energy and electricity consumption per apartment area has flattened during 20 years. Detailed data for 19 IEA member countries show that energy requirement for space heating per capita has increased moderately. Concurrent trend where fewer occupants live in larger, more energy consuming dwellings, is offset by the efficiency improvements. Also urbanization has increased the construction of apartment houses which has on the other hand flattened the increase of per capita square meters. For example in Norway and many other European countries, number of occupants per room is 0.6, whereas two-fold value was observed in Russia in 2003 [53] (#cite-text-0-122). It is estimated that approximately 19 % improvement in efficiency is gained so far due to energy-efficient measures, better heating systems, and milder climate since 1980.

TABLE 5-1. Insulation requirements in building envelope in Scandinavia and Europe [30] (#cite-text-0-29)

	MT	CY	PT	GR	ES	IT	LV [1]	FR	BG	BE	NL	IE	HU	SI
HDD [5]	560	782	1 282	1 663	1 842	1 907	1 970	2 483	2 686	2 872	2 902	2 906	2 922	3 053
Roof	0.59	0.85	0.9-1.25	0.35-0.5	0.45-0.65	0.32-0.65	0.2κ-0.35κ	0.2-0.25	0.3	0.3	0.4	0.25	0.25	0.2
Walls	1.57	0.85	1.45-1.8	0.4-0.6	0.57-0.94	0.33-0.62	0.25κ-0.5κ	0.36-0.40	0.35	0.4	0.4	0.37	0.45	0.28
Floor	1.57	2		0.45-0.5	0.62-0.69	0.29-0.38	0.2κ-0.35κ	0.37-0.40	0.5	0.6	0.4	0.37	0.45	0.9
Window/ Door	5.8	3.8		2.6-3.2	3.1-5.7	1.3-3.7	1.8κ-2.4κ	1.7-1.9	1.8	2.5	4.2	2.2	1.6	1.1 -1.6

	UK [3]	RO	DE	SK	CH [2]	DK	CZ	AT	PL	LT	EE	SE [4]	NO	FI
HDD	3 115	3 129	3 239	3 453	3 482	3 503	3 571	3 573	3 616	4 094	4 444	5 444	5 646	5 850
Roof	0.2	0.2	0.24	0.19	0.17 or 0.2	0.2	0.24	0.2	0.25	0.16	0.15-0.2		0.18	0.09
Walls	0.3	0.56	0.24	0.32	0.17 or 0.2	0.3	0.3	0.35	0.3	0.2	0.2-0.25		0.22	0.17
Floor	0.25	0.35	0.3		0.17 or 0.2	0.2	0.45	0.4	0.45	0.25	0.15-0.2	0.4-0.6	0.18	0.16
Window/ Door	2	1.3		1.7	1.3	1.8	1.7	1.4	1.7	1.6	0.7-1.4		1.6	1.0

NOTES

(1) Depending on type of building (residential, public, industrial etc.) where κ is a temperature factor, κ = 19/(Tin-Tout), Tin and Tout denote indoor and outdoor temperatures, respectively.
(2) Depending on evidence of thermal bridges
(3) For England & Wales
(4) Depending on type of building (residential and non residential) & type of heating (electric and non electric). These represent overall U values
(5) Mean HDD values for period 1980-2004 based on Eurostat data

LEGEND
HDD: Heating degree days.

In Europe the percentage of Passive Houses was estimated to be less than 1 % in 2011. As Passive House and nZEB resemble each other in respect to energy use, the factor by which implementation of nZEB across Europe should increase is assumed to be beyond 100. The turnover of the building industry for residential and non-residential stock in the EU was roughly 1 trillion in 2009. Half of the amount is caused by new buildings [2] (#cite-text-0-1). According to calculations, nZEB principles stimulate construction activity and overall job creation. When turnover potential per employee is used, basis mandatory requirements of nZEB would generate roughly 345 000 additional jobs (see [2] (#cite-text-0-1)).

Differences appear between Member States in prescriptive element-based requirements for building energy codes (see Table 5-1). The most common thermal performance requirement for buildings is limited thermal conductivity of main construction elements, expressed as U-value (W/m²K). Diversity in values are met within some countries due to variation in climatic conditions (e.g. Spain, Italy), differences in building types (e.g. Latvia) and heating types, such as in Sweden. Generally, sole U-values of single elements do not necessarily reveal the overall energy performance of building, and is regarded as worst energy-standard in expressing the performance [2] (#cite-text-0-1).

In Sweden, study on large array of residential buildings has indicated that technically the energy use of current new buildings could be reduced by 50 % of the level defined in applicable building regulation. Notable is that economic potential varies between building types. For low-energy apartment buildings, allowed additional investment cost for improvement of energy efficiency must not exceed that of 7 % [41] (#cite-text-0-91). Generally, the energy consumption per square meter ranges between values 150 kWh/m² and 310 kWh/m² for all building types in EU. The average quantity was 220 kWh/m² for 2009. Energy use of residential and non-residential buildings differ largely, values being 200 kWh/m² and 295 kWh/m² [69] (#cite-text-0-176).

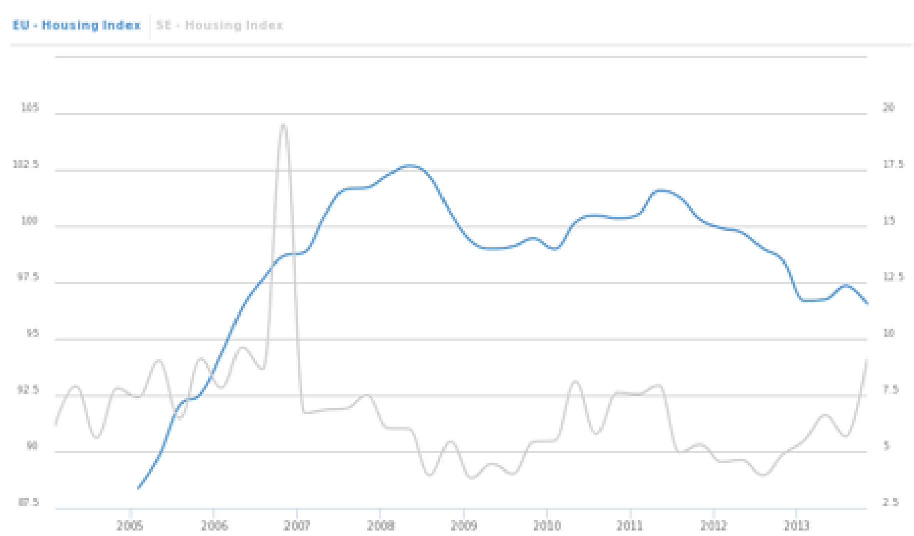


FIGURE 5-1. Housing indexes of Sweden and EU-area are shown in respect to each other [31] (#cite-text-0-30)

In Europe, construction output increased rather firmly until the end of 2006. After that economic and financial crisis have declined the total construction although some positive signs were observed between years 2010–2012 (Figure 5-1). In Sweden, high growth was experienced in the Housing Index (show the number of started construction in Thousands) in the end of 2006. This was followed by steep reduction in subsequent years, and again mainly positive curve between years 2009–2011. Since 2013, growing percentages of new buildings, including also low-energy residential and non-residential properties, have been constructed in the country (see Figure 5-1). Importantly, also positive attitude toward energy-saving measures are observed among professionals [41] (#cite-text-0-91).

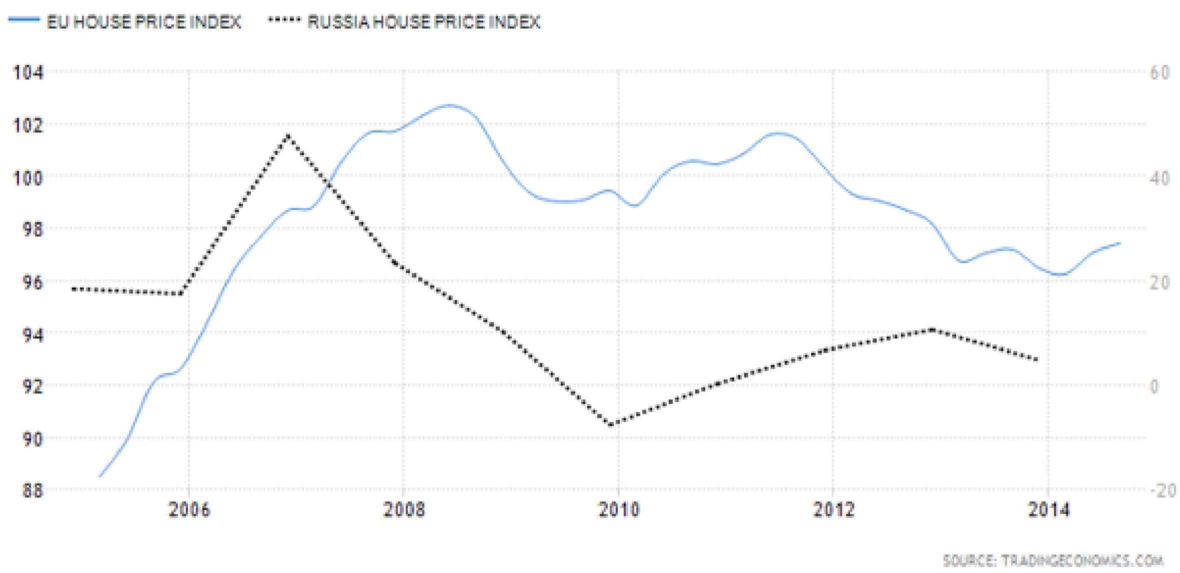


FIGURE 5-2. The evolution of Russian Housing Index in relation to that of the Euro area [32] (#cite-text-0-31)

Housing Index in Euro Area (EA-18) is formed of price changes in residential estates. The development of construction in the EU-28 and Euro Area (EA-18) resemble each other. In EU-28 Area, the construction of buildings, including both residential and non-residential, accounted for 78 % of the total construction. The rest 22 % were covered by civil engineering works such as construction of roads and bridges. The effects of financial and economic crisis were more minor in the civil engineering field than in building sector. Among EU-28 countries, variation appears in the decline level of building production. The most extreme situations are met in Lithuania where -54.4 % reduction occurred in 2009, and in Germany and Austria, where almost static activity levels prevailed. In many other countries construction growth rates were already decreasing before 2009, or the changes in activity occurred more quickly and lasted for shorter period [33] (#cite-text-0-74).

Russian Housing Index describes the volume of started construction. When Euro Area Housing Index based on price changes in residential estates and Russian Housing Index are compared for the last 10 years some shared patterns are observed (see Figure 5-2).

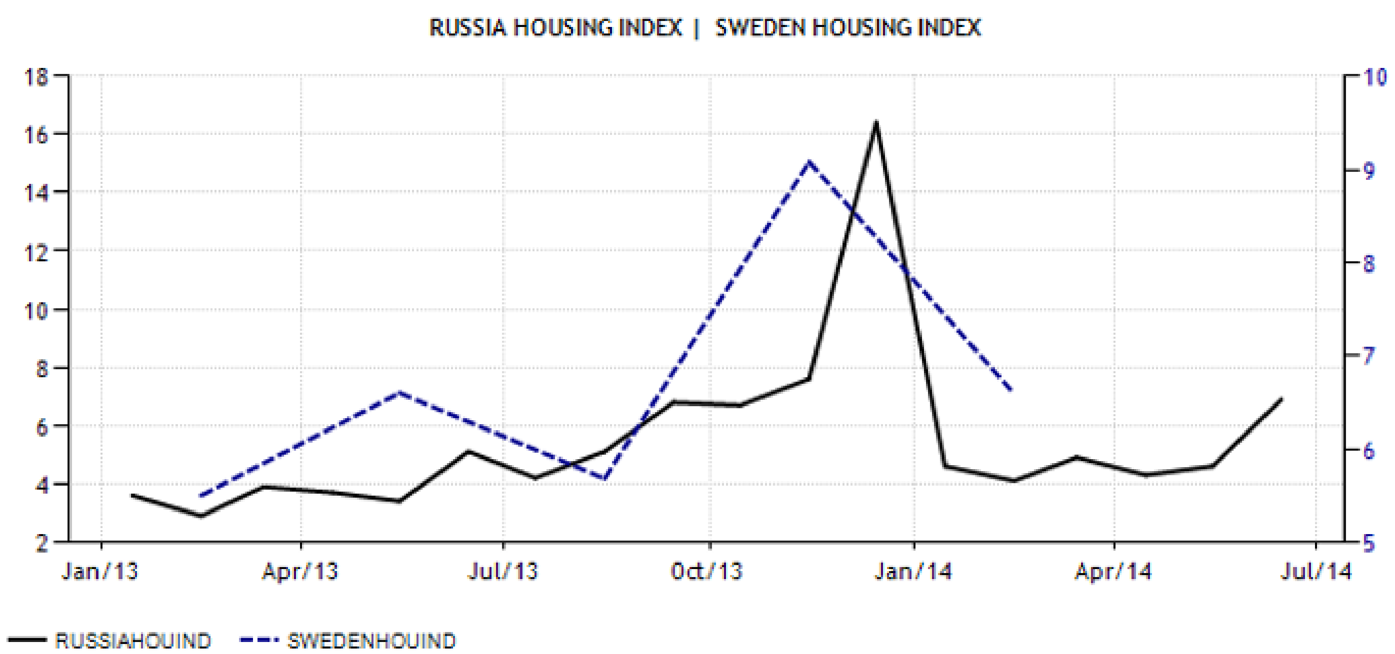


FIGURE 5-3. Russian values are shown as in millions of volume meters and Swedish values in real numbers of housing starts in Thousands [33] (#cite-text-0-32)

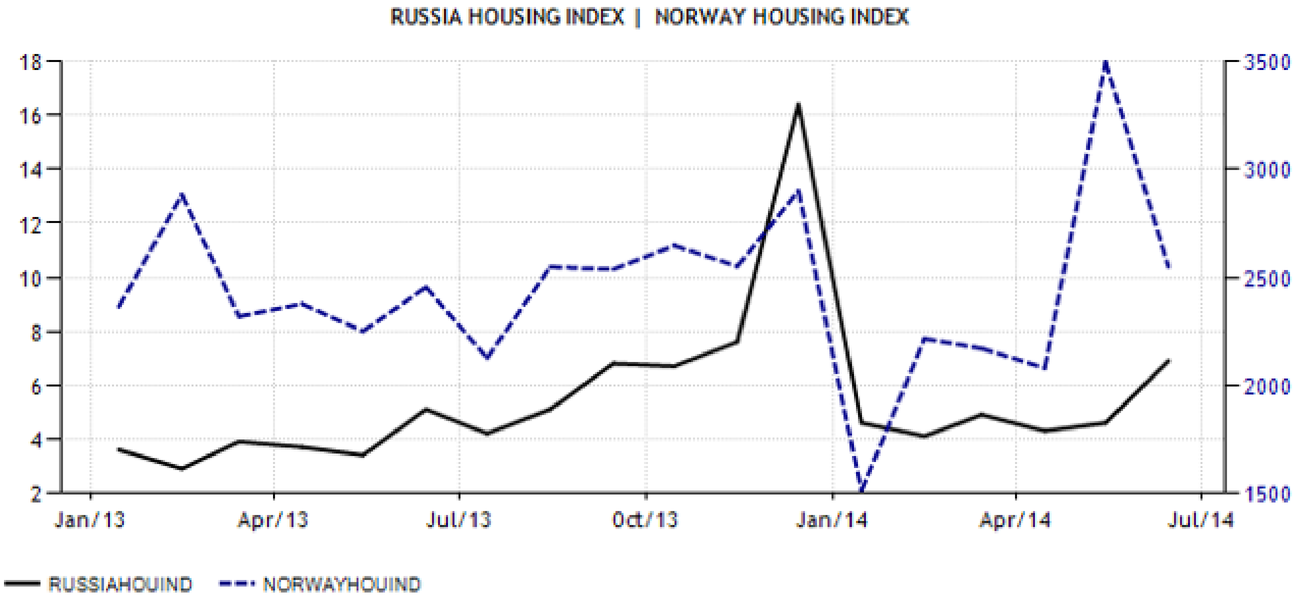


FIGURE 5-4. Russian value in millions of square meters and Norwegian values in real number of started construction work [34] (#cite-text-0-33)

Russian Housing Index is compared to Scandinavian values for the shorter timeframe between 2013 and July 2014 in Figures 5-3, 5-4 and 5-5.

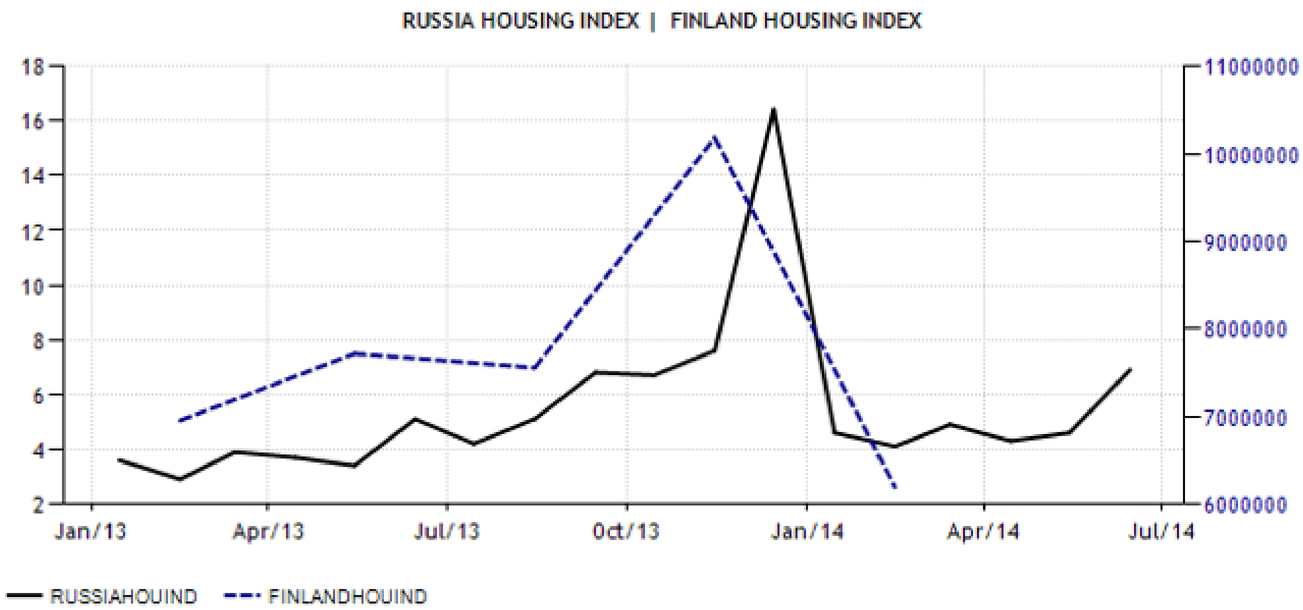
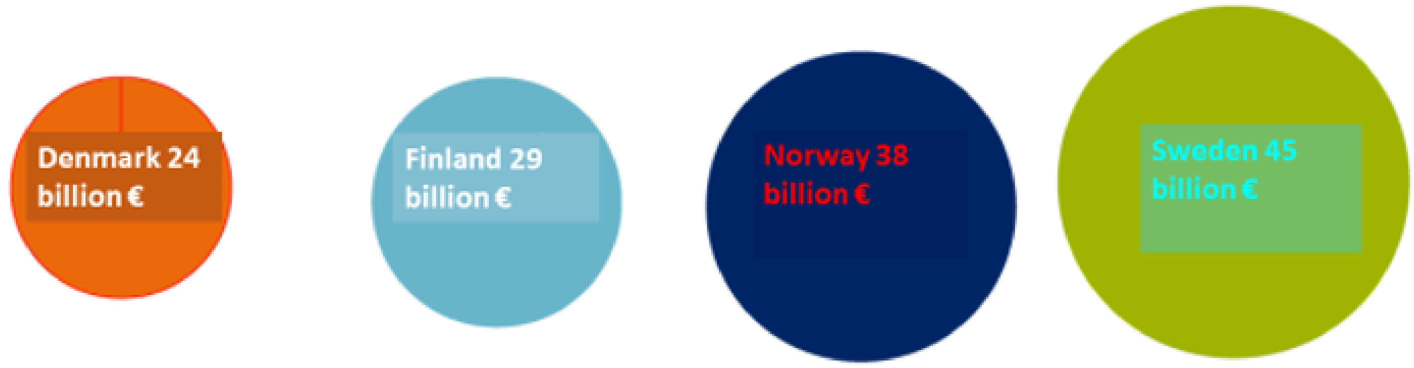


FIGURE 5-5. Russian housing index expresses number of started construction projects in millions of square meters whereas Finnish housing index is based on cubic meters [35] (#cite-text-0-34)

In Russia, new building construction has been intensive during the recent years. Growth rate is 3 % [51] (#cite-text-0-120). Building are equipped with meter devices according to requirements of new legislation. Although the proportion of low energy buildings is rather low, encouraging pilot cases have been constructed both on residential and non-residential sector. In residential sector the specific barriers for new buildings include the lack of incentives for developers and their contractors to improve energy efficiency, voluntary based thermal performance standards valid since 2010 and limited energy efficiency related knowledge among professionals. Also missing statistical data, commonly shared low appreciation of energy efficiency, environmental externalities, tariff methodologies and tariffs, high transaction costs and missing competition belong to the list of preventing factors.



	Rev. mln €	% of empl.
MT Højgaard	1080	4 %
E. Pihl & Søn	630	3 %
Aarsleff	565	2 %
NCC	585	2 %
Arkil	270	1 %

	Rev. mln €	% of empl.
Lemminkäinen	1500	4 %
YIT	1225	2 %
Skanska	1015	2 %
NCC	905	2 %
SRV	630	0,5 %

	Rev. mln €	% of empl.
Skanska	980	2 %
Veidekke	819	1 %
YIT	497	2 %
AF Gruppen	483	1 %
NCC	461	1 %

	Rev. mln €	% of empl.
Peab	3588	5 %
Skanska	3108	4 %
NCC	2918	4 %
SVEVIA	890	1 %
JM	847	1 %

Source: VTT

FIGURE 5-6. The Scandinavian construction markets in billions euros and the biggest construction companies are shown for each country. “Rev. mln €”= Revenue in million euros, “% of empl.”= percentage of employees of the sector. [36] (#cite-text-0-35)

In Sweden, new housing stock is built at increasing rate. Of the Scandinavian countries Sweden has the largest construction markets (see Figure 5-6). Strongly expanding population size and higher income have promoted the growth. Post-construction evaluation of energy performance and other technical characters of new low-energy building should be better emphasized to enable improved design and collection of experiences [41] (#cite-text-0-91). With adjustments and appropriate co-operation between technological equipment the desired energy-savings are achievable.

In Norway locates the second biggest construction market of the Scandinavian countries (see Figure 5-6). In 2013, totally 30 450 dwellings were constructed corresponding to 4.1 mln square meters (Table 3-3). The country is characterized by relatively high share of single-family houses where only 2.4 % of the residential buildings are multi-family buildings. In recent years, construction of apartment houses has increased. Exceptionally, electricity is the main energy source in Norway, due to high hydropower production and windmill capacities. Thus the usage of renewable energy sources is already high in buildings.

In Finland relatively large share of the buildings are new when compared to stock of other countries [9] (#cite-text-0-9). In Russia, new buildings are constructed at frequent rate but concurrently the rate of demolition is rather high for constantly growing share of dilapidated buildings. Thus the rate of new construction is not able to counteract the operations in the other extreme of the building project phases. Additionally, new legislation that bring thermal standards voluntary for new buildings is creating additional challenge for the establishment of energy efficient housing stock.

6 Discussion

Currently, buildings consume 40 % of final energy and produce almost the same share of emissions in Europe [9] (#cite-text-0-9). Tightening international and national level regulations aim to reduce the energy use, and the major emphasis is on new buildings and renovation. Enacted by EPBD, nearly zero-energy level non-residential buildings become obligatory since 2019 and residential buildings in the beginning of 2021. Due to diversity of building culture and climate across the Europe, elaborate national definitions and plans are set by Member States where specific national and regional conditions are taken into account in the form of feasible and robust measures [9] (#cite-text-0-9).

Growing proportion of energy efficient measures are currently implemented to facilitate the change. Although the annual growth rate of new residential buildings are rather low, approximately 1 %, the energy saving influence extends for relatively long period as buildings may reach the age of hundreds of years [2] (#cite-text-0-1). The major part, 42 %, of the existing housing stock in North-Western part of Europe and 35 % in Central-Eastern part were established before 1960. In comparison, shares of modern housing stock constructed 1991-2010 are 19 % and 17 % in the former and latter areas [2] (#cite-text-0-1). As building can be regarded as outcomes of building regulations of past eras, the ages and energy consumptions are highly correlated (e.g. [2] (#cite-text-0-1)). Roughly 25 % of the building stock of the year 2050 is still to be built. By general principles, guidance and quality confirmation effective implementation of low energy buildings are obtainable for the future (see [9] (#cite-text-0-9)). The reduction target of greenhouse gas emission of EU is 80 % until 2050 in comparison to levels of 1990, and here buildings are in central role as they produce majority of the emissions.

Diversity of acknowledged solutions exist to achieve the nearly Zero-Energy targets. Especially cost reduction in investments, enhanced component and system performance and increase of energy storages are among the most potential ones [4] (#cite-text-0-3).

In construction of new buildings most critical phase is the planning where majority of the decisions are made regarding building energy consumption during the lifetime. This is important to consider as expenses of planning phase are only minor of the total costs of building projects [15] (#cite-text-0-20). In fact, the most cost-efficient investments of the project can be the additional efforts directed on reporting and careful planning. Here the sustainable basis are created by good entity-based management and acknowledgement of energy efficiency in all the planning.

With integrated design principles even 80 % of the operational expenses of standard new buildings could be saved along with reduction of emissions [9] (#cite-text-0-9). Still, none or minor amount of additional costs are induced during the lifetime of the measures. The growing proportion of low-energy buildings is expected to strongly alter the market of construction sector where deployment of energy efficient technologies are required. Current energy efficiency technology-market is partly underdeveloped in relation to future demands posed by the nZEB sector. In addition to market barrier also know-how and quantity of professionals are recognized as barriers in the EU region in implementation of nZEB [9] (#cite-text-0-9). This will create employment opportunities for hundreds of thousands people across Europe.

The role of environmental factors vary between countries in reaching nZEB-targets. In simulation studies residential single family house and non-residential block building of high energy performance levels were evaluated in different locations characterized by varying climate zones; cold (Copenhagen), moderate (Stuttgart) and warm (Madrid). In all cases building shells were well-sealed and insulated, and ventilation system were highly efficient to confirm minimum level of residual energy demand. Indicators of achieving principles of nZEB; a share of renewable energy (energy production/total energy demand) and carbon dioxide emissions were estimated. Results show that basically, for residential buildings of the climate zones, it is possible to achieve a 90 % share of renewables by using combination of recommended technologies; biomass fired systems, heat pumps, off-site green electricity, on-site PV-systems or district heating largely based on renewable sources. Generally, in office buildings green electricity is advantageous way to achieve 90 % share of renewables as due to lighting electricity consumption in non-residential sector is higher than in residential. Exception is formed by fossil-fired variants where the share of RES remains lower [9] (#cite-text-0-9). As buildings are among the major carbon dioxide emission producers in the world, the climate target is set as low as possible or to maximum amount of 3kgCO2 /m²yr in nZEB principles [9] (#cite-text-0-9). Simulation results show that off-site green electricity alone effectively reduces also the level of emissions in both residential and non-residential example cases. Still, combinations of different technologies generate the best results where implementation also PV, bio solutions or heat pumps reduce the emission outcome (see [9] (#cite-text-0-9)).

EPBD defines that principles of nZEB have to be achieved with cost-effective manner. When compared to reference cases, financial investigations reveal that in general level the most cost-effective technologies are district heating and gas boiler-systems for residential building. The most expensive solutions are biomass and CHP in all the regions. The higher the north, the harder is the achievement of requirements of nZEB in cost-efficient manner. In non-residential sector the similar kind of observations have been made, except that cost differences and additional expenses are smaller than in residential detached house [9] (#cite-text-0-9).

In 2011 it was evaluated that official definition for low or zero energy buildings is lacking in half of the EU Member States. In the cases when definitions are given those are based on describing annual maximum primary energy per square meter as percentages in proportion to limit given in existing building codes Approximately 80 % of the operational costs of standard new buildings could be saved by following integrated design principles. This induces no or minimum amount of additional expenses when inspected through the lifetime of the measure [9] (#cite-text-0-9).

According to EPBD, principles of nZEB will be implemented in all new buildings since 2021. This will have only limited influence on the reduction of emission and energy demand set for year 2020 where emissions are reduced by 20 %, energy efficiency increased by 20 % and usage of RES by 20 %. Therefore, effects that nZEBs will have since 2021 extends much further in the future reaching the targets defined for 2050, as lifecycles of buildings are relatively long; at least 30–40 years. International goals set for 2050 should be regarded as guideline when the ambition level are defined for nZEBs being just about to construct (see [9] (#cite-text-0-9)). Currently, no specific targets are given for energy efficiency or RES share for building sector regarding the year 2050.

7 Conclusions

Since 2019 and 2021 energy performance of nearly zero energy level (nZEB) is required from new residential and non-residential buildings by Energy Performance of Buildings Directive (EPBD). It is also defined that principles of nZEB have to be achieved with cost-effective manner. Although the annual growth rate of new residential buildings is rather low, (1 %), the energy saving influence extends for relatively long period, as buildings may reach age of hundreds of years.

Germany is regarded as a forerunner in Passive House technology as 1 % of all the new buildings in country were built according to passive house standard in 2011. In other parts of the Europe the percentages are even smaller than in Germany. In construction, most critical is the planning phase where majority of the decisions are made regarding building energy consumption for the entire lifetime. Sustainable basis are created by good entity-based management. Still expenses of planning stage form only minority of the total costs. In fact, most cost-efficient investments of the project can be additional efforts directed on reporting and planning. Albeit new buildings have lower energy consumption levels in comparison to old ones they may also have higher electricity use due to increased need for ventilation, cooling, lighting and office equipment. By quality assurance process, commissioning, the intended performance of new building is aimed to confirm before the operation phase. Optimal operation of mechanical, electrical and HVAC systems generate additional energy saving.

In general, Scandinavian countries are on different level regarding ZEB-related discussion and practical measures. Research centers are already established in Norway and Denmark whereas development is on rather early stage in Finland and Sweden. Although the concept of nZEB is challenging due to cold Northern climate, shared efforts are done for the implementation. In Russia, new building construction has been intensive during recent years. Annual rate has been 3 %. Although the proportion of low energy buildings is quite low, encouraging pilot cases have been constructed both on residential and non-residential sector. Specific barriers for new building constructions have been identified. In Russia these include lack of incentives for developers and their contractors to improve energy efficiency, voluntary based thermal performance standards since 2010 and limited energy efficiency related knowledge among professionals. Growing proportion of low-energy buildings is expected to strongly alter the market of construction sector where deployment of energy efficient technologies are required. Current market is partly underdeveloped in relation to future demands posed by the nZEB sector. Also know-how and quantity of professionals are recognized as barriers in implementation of nZEB. This will create employment opportunities for hundreds of thousands people across Europe.

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Picture References

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