ERA-NET Eracobuild project

One Stop Shop - "From demonstration projects towards volume market: innovations for one stop shop in sustainable renovation"

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Project Report WP 1 – Definition Phase
Residential Building Typologies in Project Partners' Countries

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Project Website: www.one-stop-shop.org

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Project description

European and national ambitions for renovation lead to the prescription of increasing energy performances, including objectives such as reaching the passive house standard, zero-energy building or CO2 neutral. By doing this, the awareness grows that, considering energy-efficient renovations, the market will drastic change, both in volume and necessity for the execution of more thoroughgoing renovations. These renovations include innovative solutions to reach different target groups and to find solutions for technical bottlenecks. At present throughout all European countries (to higher or lesser degree) advanced renovations of residential buildings is an emerging market, implemented in demonstration projects only (typically financially supported by subsidies). SMEs that are involved are the front-runners on the market /trend setters in renovation activities of the residential sector. One of the existing barriers is on one hand, in fragmentation of the renovation process that is shared between many SMEs doing fraction of a number of renovation measures. On the other hand, a house owner lacks a possibility to find in a structured way for all information concerning decisions on renovation solutions, examples, contacts with building companies and quality assurance, and financial support opportunities. These two problems are the core that we want to address in this project, by specific actions towards clustering innovative technologies to reduce the fragmentation of the renovation process for single-family houses, and increase competences, knowledge and innovations by SMEs; and development of the one stop shop (tool) as platform for both house owners and companies offering holistic renovation solutions.

Objectives

The overall project aim is to facilitate market penetration (volume market) of housing renovations for single family houses of very high energy standard while providing superior comfort and sustainability to occupants. Following hypotheses will be investigated within the project: By clustering the different innovative technologies, the client receives a less fragmented renovation process. The clustering also assures a structured transfer of innovations to SME’s. The development of a ‘one-stop-shop’ tool as platform for both client as company, gives the opportunity to create demand and offer for holistic and integrated retrofit solutions. The clustering of innovative technologies can give SME’s the opportunity to develop skills, knowledge, capacity and a competitive marketing formula for holistic and cost-effective retrofit solutions. A ‘one-stop-shop’ tool for sustainable renovation can give house owners the opportunity to form a well-informed investment decision. It simplifies the access to quality-oriented constructors and companies. Together these companies offer integrated retrofit solutions. The communication about project results and the dissemination of these results can convince clients and SME’s to implement innovations.

Project partners

PHP, Passiefhuis-Platform, Belgium, non-profit organization.

www.passiefhuisplatform.be

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VCB, Vlaamse Confederatie Bouw, Belgium (Flanders), federations of constructors.

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1. Introduction

European[1] and national ambitions for renovation lead to the prescription of increasing energy performances, including objectives such as reaching the passive house standard, nearly zero-energy or CO_2 neutral buildings on the short to mid-long term.

In the field of policy, on the EU level, the legislation to enhance energy efficiency of the built environment, the **Energy Performance of Buildings Directive** (EPBD) was recently updated as EPBD – Recast (Directive 2010/31/EU, published in Official Journal 18 June 2010), with required implementation by Member States in two years.

Relating to the existing building stock, the re-casted EPBD requires from all Member States to fix and implement a level of minimum energy performance requirements for new **and for existing buildings that undergo major renovation.** In addition, benchmarking to achieve cost-optimum levels has to be investigated and minimum energy performance level for **technical buildings systems and building elements** - when installed, replaced or upgraded - have to be defined with a view to achieving cost-optimal level and encouragement of the use of renewable sources.

The need for higher energy efficiency of the building stock leads to the awareness that, considering energy-efficient residential renovation, demand and supply will significantly change, both in volume and necessity for execution of more thorough renovations. It is necessary to **increase the number of renovated buildings** each year across Europe, but also these interventions need to be **with significant improvement of the energy performance, so-called 'deep' renovation[2].**

In its recently published paper (2010) the Architects' Council of Europe[3], stated that: *"it will be necessary to increase the rate of deep energy renovation (of buildings) by a factor of two to three times the current rate of between 1.2% and 1.4% in the decades up to 2050 in order to reach the short and long term EU targets of reducing CO2 emissions by 80-95% by 2050 as compared to 1990 levels*".

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[1] For example, the European Union has agreed a strategy with 20-20-20 targets:

- Reducing greenhouse gas emissions by 20% compared to 1990 levels
- Increasing the share of renewable energy in final energy consumption to 20%
- And moving towards a 20% increase in energy efficiency.

[2] **What is 'deep' renovation of a building?** A definition was proposed by the Architects' Council of Europe, Taskforce of actors and stakeholders from the European construction sector:
"A deep renovation of a building means extensive works to a building in accordance with the definition in the recast Energy Performance of Buildings Directive (2010/31/EU) set out at 3.6 above that, while preserving any noteworthy architectural character, significantly improves the energy performance of the building such that it achieves a level of performance equivalent to factor 2 (50%), factor 4 (75%), factor 6 (84%) or factor 10 (90%) improvement in its energy performance as compared to its pre-renovation performance. The choice of factor will depend on the age and nature of the building and will have a direct effect on the extent to which it will be permissible to grant financial or fiscal incentives for the execution of works to the building. These works may include the integration of appropriate renewable energy supply technologies in the building or from its immediate vicinity, but only after all cost optimal energy demand reduction and passive energy efficiency measures have been incorporated."

[3] [E²APT] The fundamental Importance of Buildings in Future EU Energy Saving Policies. A paper prepared by a taskforce of Actors and Stakeholders from the European Construction Sector, 12 July 2010.

This evolution calls for future EU energy saving strategies and policies to place the deep energy renovation of existing buildings as a centerpiece of action and to bring into force the necessary accompanying measures in associated fields such as increased research, education and training, manufacturing and renovation capacity, high quality building certification schemes, balanced, progressive fiscal and financial incentives and effective compliance schemes.

When we compare this need to the current situation, a lot of work is to be done. The total of all existing buildings in Europe is 210 billion with current annual estimated renovation rate of about 1.2%, meaning that about 2.5 billion buildings are renovated each year. However, there is limited knowledge on national level in each country about the nature and extent of these renovations.
It is supposed that many of them are superficial with typically 15-20% energy efficiency improvement per renovation.

At present throughout all European countries **advanced renovations of residential buildings exist,** though in limited number as demonstration projects only (typically financially supported by subsidies). Demonstration projects across Europe have shown cost-effective retrofit with 60-90% reduced energy demand compared to the situation before retrofit and depending on the condition of the building.[4]

So in order to go one step beyond the current situation, it is important that a certain multiplication effect takes place. Therefore it is important to investigate how the building typology in different European countries relates to the setting of minimum energy performance standards and the achievability of deep renovations. To go from best practice examples towards a volume market, it is important that an overview of that market is made.

[4] An overview of recent European demonstration projects of advanced renovation was presented by the IEA SHC Task 37 subtask B.

2. Purpose of this project report

In many cases typical buildings are used as showcase examples to demonstrate the energy savings which can be achieved by implementation of refurbishment measures. In this document an **overview of typology of residential building stock in the countries of the project** (Belgium/Flanders, Finland, Norway, Denmark) is made**.**

Sets of typical buildings in combination with statistical data are needed in order to distinguish most appropriate deep renovation targets for building typologies.

Therefore different approaches for building classification according to size and age are examined.

This is a starting point aiming at fostering transfer of innovative building technologies and methods for the uptake of sustainable renovation for most frequent building typologies in specific renovation markets.

Note: This report reflects the 'definition phase' for the One Stop Shop project (www.one-stop-shop.org). Based on the collected information about residential building typologies with highest potential for advanced renovation and key actors involved in these renovations[5], the following elements will be developed in the further course of the project:

- A guide on innovative technical solutions to execute the deep renovation
- Demonstration of cost effectiveness and environmental impact (LCC & LCA) of typical cases and renovation solutions
- Business cases and guiding documents to organize a better cooperation and realization of deep renovations
- Information and communication strategies towards the general audience (translated into the 'One Stop Shop' web platform)

[5] SMEs that are involved in deep renovation activities are considered to be the front-runners on the market/ trend setters.

3. Building Typologies in Belgium

3.1 General characteristics and evolution of the Belgian building stock

Note: The following information is based on reviewed and examined statistical data provided by the federal government (Belgium) and the Belgian regions (Flanders, Wallonia, Brussels Capital Region) and was sourced from the Federal Science Policy funded project 'Low Energy Housing Retrofit – LEHR' , www.lehr.be. (Mlecnik et al., 2010; Hilderson et al., 2010)

In 2008, there were 4.268.090 dwellings in Belgium.[6] The LEHR study showed two clear trends. Over 10 years (1991-2001), the number of dwellings is still growing, for the whole of Belgium 9,0%, for Flanders 9,6%. The number of buildings, as well as the growth, is not homogeneously spread out. Urban areas have the biggest density in numbers, while the increase occurs in the suburbs (14,5%).[7]
The vast majority of the Flemish dwellings (about 80%) are single family houses (SFH). This percentage has not changed significantly over time. Of these single family houses (100%), about 42% are detached houses, the most common building type in Flanders, followed by terraced houses (32%) and semi-detached houses (26%). The remaining 20% of residences are part of a multifamily housing (MFH) stock. The vast majority (95%) of the MFH are apartments, and only a marginal fraction is studios, lofts, etc. (5%).[8]

	2005	2001	1995/1998[9]
SFH	**79,9%**	**79,5%**	**84,4%**
- Detached	33,6%	36,3%	38,3%
- Semi-detached	20,7%	20,5%	22,5%
- Terraced housing	25,6%	22,7%	23,6%
MFH	**19,9%**	**20,0%**	**15,1%**
other	**0,2%**	**0,5%**	**5,0%**

Table 1: Overview of data regarding building type distribution in Flanders[10]

These average values hide some significant geographical variations, as illustrated in Table 2. This table shows the dense building in the agglomerations of big and regional cities. As could be expected, apartment buildings are concentrated in these urban areas, while SFH (semi-detached and detached housing) is less common than average in Flanders. In Ghent for example 64% of the inhabitants live in a SFH, compared to an average over Flanders of 80%. In Antwerp this drops even further to 39%.[11]

[6] Van Ypersele J.-P. & Marbaix Ph., 2008.
[7] Hilderson, W., et al., 2010.
[8] Heylen, K. et al., 2007.
[9] Studied term: 1 June 1995 to 31 May 1998 (average of the three studies 1995/1996, 1996/1997 and 1997/1998).
[10] http://www4.vlaanderen.be/dar/svr/Cijfers/Exceltabellen/woonbeleid/woningkwaliteit/woonbest003.xls, Spreiding van het woningbestand naar aard van de woning, Studiedienst van de Vlaamse Regering, 2008.
[11] VRIND 2003, p. 378; Pickery, J., 2004.

		Detached	Semi-detached	Terraced	Apartments	Total
Agglomeration of big and regional cities	1991	15,5%	11,9%	28,4%	44,2%	100,0%
	2001	13,7%	12,7%	28,1%	45,5%	100,0%
	evolution	**-1,9%**	**+0,8%**	**-0,3%**	**+1,3%**	
Suburbs	1991	51,9%	20,1%	16,0%	12,0%	100,0%
	2001	50,8%	20,1%	14,9%	14,2%	100,0%
	evolution	**-1,1%**	**0,0%**	**-1,1%**	**+2,2%**	
Commuter zones[12]	1991	41,2%	21,6%	25,1%	12,0%	100,0%
	2001	41,2%	22,0%	21,8%	15,0%	100,0%
	evolution	**-0,1%**	**+0,4%**	**-3,3%**	**+2,9%**	
Small cities in rural areas	1991	39,1%	18,2%	27,1%	15,5%	100,0%
	2001	39,4%	18,5%	23,2%	18,9%	100,0%
	evolution	**+0,2%**	**+0,3%**	**-4,0%**	**+3,4%**	
Rural areas	1991	55,8%	19,1%	15,8%	9,2%	100,0%
	2001	55,1%	19,7%	13,9%	11,3%	100,0%
	evolution	**-0,7%**	**+0,6%**	**-1,9%**	**+2,0%**	

Table 2: Building type, according to level of urbanisation for Belgium.[13]

For small cities we notice a large percentage of detached housing. This is explained by the administrative definition of these cities, including not only their urban core, but expanding into the surrounding rural areas, where detached housing is most common.

Table 2 shows no dramatic changes between 1991 and 2001. There is an increase in MFH that is more explicit in small towns and rural areas than in the larger cities. Another trend is the small increase of semi-detached housing. This is explored further by linking building type, building surface, number of residences per building, number of rooms and diversity of functions in a single building.[14]

When it comes to age of the buildings, Table 3 shows a general decrease in the percentage of old buildings (built before 1945): 33% in 1994/1995 compared to 24% in 2005. A large part of this evolution can be explained by the increase of the total number of residences, due to new construction.

Further, we see in Table 3 that the total building stock is relatively young in Flanders, compared to the building stock of Wallonia and the Brussels Capital Region. Between 1991 and 2001, almost 400 000 buildings were constructed in Belgium, of which 290.000 in Flanders.[15] Roughly speaking, this means that for Belgium, between 1991 and 2000 almost three quarters of all newly built houses were constructed in Flanders.[16]

[12] The commuter zone is the outermost ring of the concentric zone model. It represents the upper-class residential area. It is called the commuter zone because of the people who go to the city to work.
[13] Vanneste, D., et al., 2007. p.66
[14] Ibid. p.69-70
[15] Ibid. p. 45
[16] Ibid. p. 191: Brussels: 13.944 new buildings; Walloon region: 96.587 new buildings, over the period 1991-2000. The total for Belgium is than 398.019 new constructions.

During the period 1991-2000 Flanders 9,8% of houses were renovated, compared to 6,4% in 1991.[17]

	Flanders		Wallonia		Brussels region		Belgium	
Building period	%	number	**%**	number	**%**	number	**%**	number
Before 1919	6,4%	175.385	**15,7%**	**260.457**	7,6%	41.247	9,6%	477.089
1919 - 1945	10,3%	283.411	10,5%	173.663	**12,6%**	**68.208**	**10,6%**	**525.282**
1946 - 1970	**21,8%**	**598.882**	**13,7%**	**227.422**	**18,0%**	**97.957**	**18,7%**	**924.261**
1971 - 1980	**11,7%**	**322.553**	8,1%	134.163	5,3%	29.019	9,8%	485.735
1981 - 1990	7,7%	210.579	4,1%	67.085	1,7%	9.114	5,8%	286.778
1991 - 2000	10,5%	287.488	5,8%	96.587	2,6%	13.944	8,0%	398.019
Age unknown	17,1%	469.727	22,2%	367.707	27,5%	149.393	19,9%	986.827
Unknown, but >20 years	13,1%	360.824	18,4%	304.691	22,6%	122.695	15,9%	788.210
Unknown, but <20 years	1,5%	40.266	1,4%	23.019	2,1%	11.201	1,5%	74.486
Total	2.749.115		1.654.794		542.778		4.946.687	

Table 3: Building age in percentages and absolute numbers, according to the data of (Vanneste et al., 2001).[18]

3.2 Energy use

The ODYSSEE database[19] provides some data about the evolution of energy use in the residential sector in Belgium. The following figures shows increasing trends for energy consumption compared to 1990 levels.

Note that the federal energy consumption statistics by individual industrial branch appear to be inconsistent. The ODYSSEE database aggregated the energy consumption statistics of the three Regions, even though these regional statistics may not be completely harmonised.

[17] The data from the 1991 and 2001 research are not perfectly comparable. In 1991 people were asked for a renovation in general terms, in 2001 renovation was defined as an alteration of the surface and/or the number of rooms of the house. No attention was paid to increasing the comfort or quality of the house. Compare: in Wallonia and the Brussels Capital Region, around 10% of the building stock has already been renovated in the period 1981-1990.

[18] Ibid. p. 191

[19] Econotec, 2007.

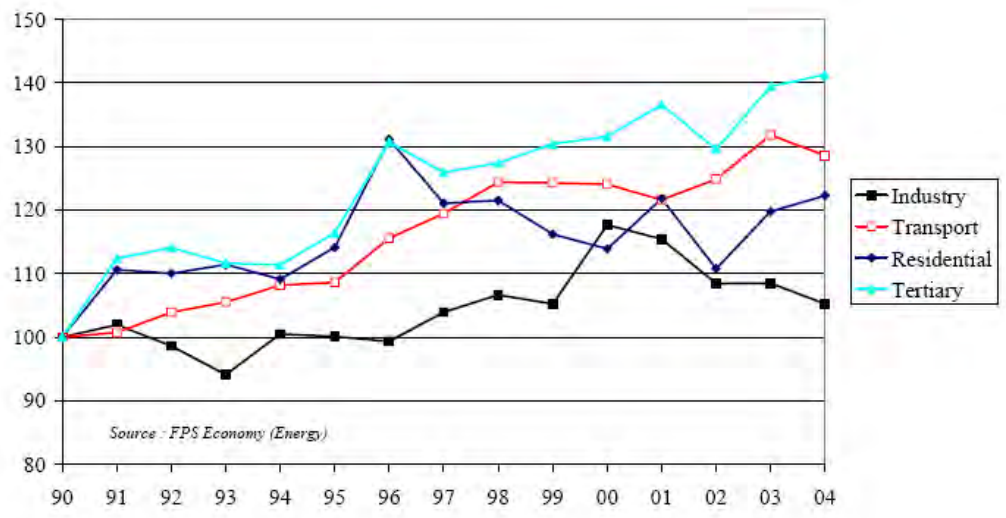

Figure 1: Evolution of final consumption by sector in Belgium (1990=100), before climate correction, according to Econotec (2007).

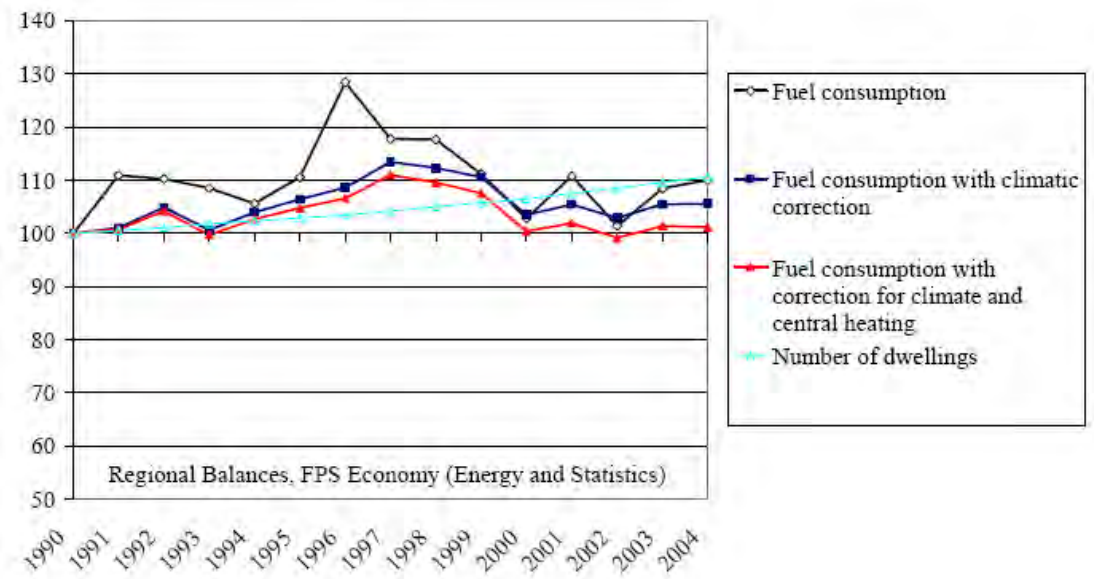

Figure 2: Evolution of final consumption in residential sector in Belgium (1990=100), before and after climate correction, according to Econotec (2007).

In densely populated areas most of the primary energy use goes to dwellings. This is for example illustrated in the following figure for the Brussels Capital Region.

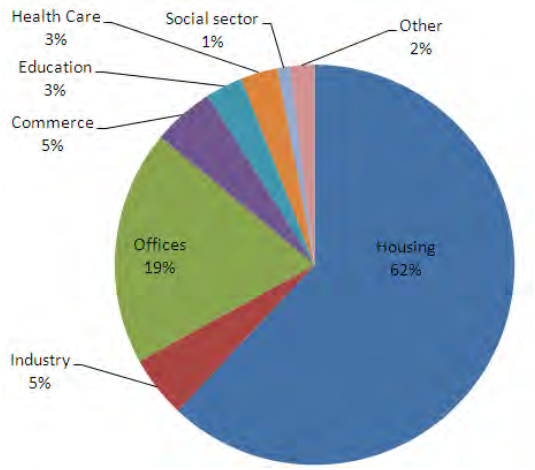

Figure 3: Total primary energy consumption per sector in the Brussels Capital Region (Bilan énergétique 2004)[20].

Total energy use of the Belgian residences was 347990 TJ (or almost 100 billion kWh) in 2005.[21] Table 4 shows that energy consumption in older houses is still double of recently built houses. 61% of all houses is built before 1980 and never seriously retrofitted.[22] These houses represent almost three quarters of total energy consumption. They mostly lack thermal insulation, double glazing and a modern heating installation. Therefore, not only their energy efficiency but also their comfort is insufficient.

	Energy demand per dwelling		Number of dwellings	Total energy demand	
Construction Year	GJ	kWh		TJ	%
<1945	118	32800	1011714	119400	30,4%
1946-1970	107	29700	1022032	109400	27,8%
1971-1980	96	26700	580922	55800	14,2%
1981-1990	79	21900	537400	42500	10,8%
1991-1995	60	16700	422953	25400	6,5%
1996-2000	60	16700	417723	25100	6,4%
2001-2005	56	15600	275346	15400	3,9%

Table 4: Distribution of the total energy demand by construction year in 2005 (total energy demand is energy consumption of heating, cooling, hot water, electricity)[23].

[20] Coûteaux M. Et al.,2008, p.10
[21] Van Ypersele J.-P. & Marbaix Ph., 2008, p. 8
[22] Ibid, p. 7
[23] Ibid.

The Belgian energy consumption is still growing over the last decades, while other countries, like Denmark, stabilised thanks to extensive energy saving policy.[24]

3.3 Ownership

Within the LEHR[25] research project, a study[26] of the ownership of dwellings and their evolution was made. A summary of the results of these study are listed below.

For the LEHR research a segmentation of the building market according to defined types of ownership was done:

— owner (74,4% of all Belgian dwellings)
— tenant in private market (18,5%)
— tenant in social housing (5,6%)

The vast majority of inhabitants in Belgium are owners: 74,4% in 2005. Furthermore, half of all tenants wish to become owner. Ownership is thus very popular in Belgium, mainly because of the financial advantages. For older people, ownership has a large impact on their welfare. In addition, there are fiscal advantages for proprietors.
It is important to notice that the evolution towards more owners and more popularity of ownership is not entirely positive. Only the highest incomes are able to purchase one or more houses, since the payment of a loan to purchase a house is higher than the average rental price. The socio-economic gap between tenants and owners becomes larger. There is also an increasing difference in quality between rental houses and dwellings inhabited by their owners.[27]

Do most proprietors buy a newly built house or an existing house? Over a period of ten years (1995 – 2005), the average house costs 165 263 euro. The amount differs depending on the type of investment. Acquisitions under 100000 euro are mainly purchases of existing houses with or without renovation (32%) and almost never newly built houses (5,6%). Summary (period 1995-2005):

— Purchase of a house: 122 736 euro on average
— Purchase and retrofit: 148 612 euro on average
— Newly built houses: 212 163 euro on average

The price is related to quality and comfort. The average cost difference between a dwelling of good quality and average quality is 24000 euro. Strangely, there is no price difference between houses of average and good comfort. But there is a large gap of 46000 euro between good and very good comfort.

[24] Bartiaux, F. et al., 2006, p. 66
[25] Mlecnik, et al., 2010
[26] Hilderson, W., et al., 2010, 52 p.
[27] Heylen, K. et al., 2007.

Comparing the building type to the type of ownership (see Figure 4), a relationship emerges between both: if almost 80% of all Flemish families live in a SFH, this percentage is even 10% higher amongst owners. On the private market or in the social housing sector, this percentage is much lower. Tenants more frequently live in apartments: more than 55% of tenants within the private market, and 43% of tenants within the social market live in MFH.

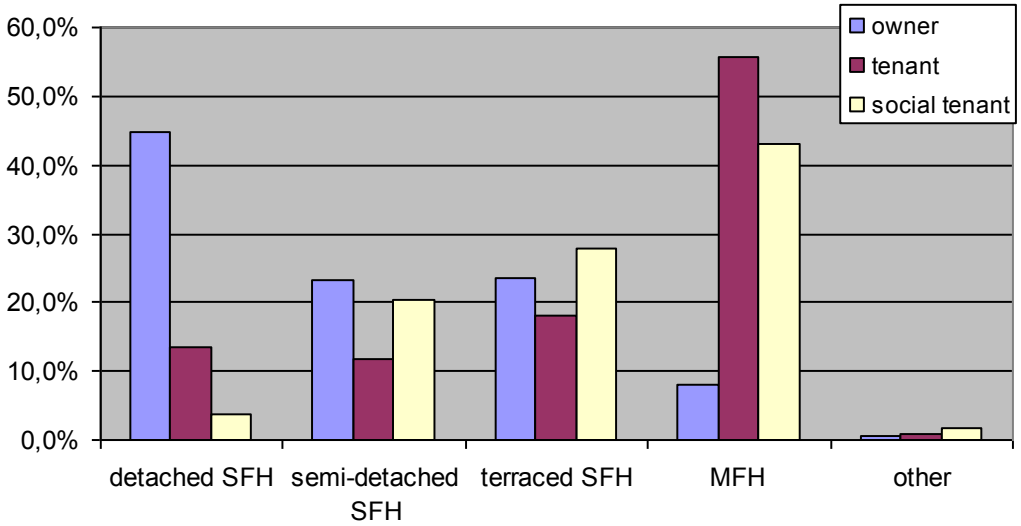

Figure 4: Type of residence, according to type of ownership.[28]

Figure 5 shows a steady general trend towards more ownership. In comparison to 1981, the percentage of residents owning their house increased with 10%. A small group (1,5%) lives in their house for free.

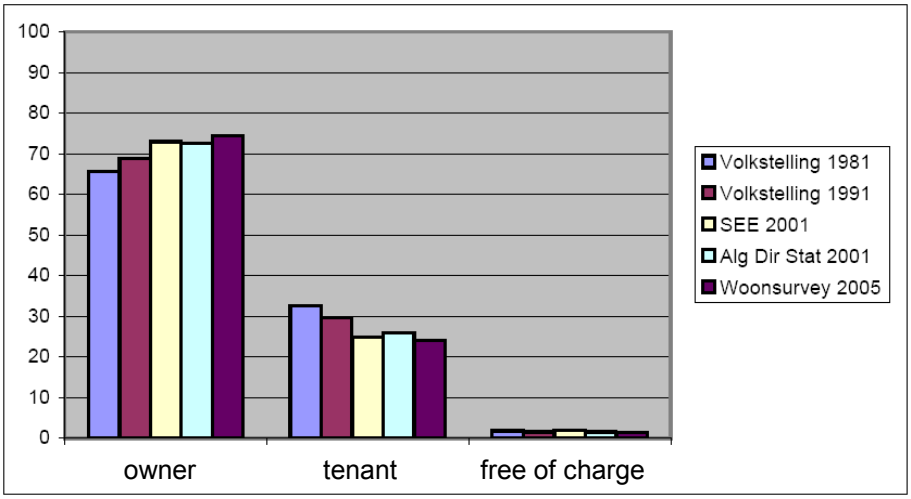

Figure 5: Evolution of ownership between 1981 and 2005.

[28] Pickery, J., 2004, p. 22

Ownership is geographically heterogeneously dispersed. In rural areas, 81,8% of dwellings are owned by the inhabitants. In city agglomerations, this percentage drops to 66,7%. There is also a large dispersion by age. Figure 6 shows that older people are more likely to be owners, while younger people still rent, waiting for an opportunity to buy the right house. However, the percentage of younger owners rapidly increased the last decades. There seems to be an increasing pressure for people to buy a house sooner.

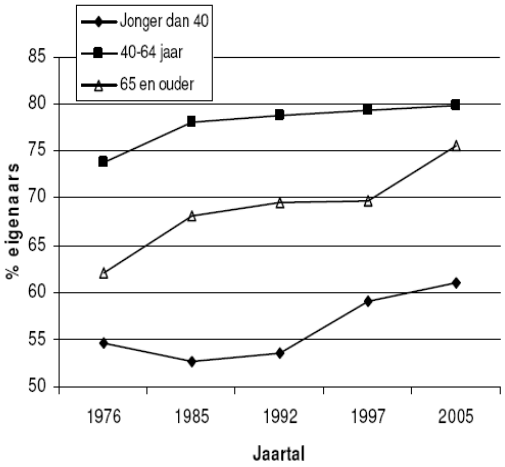

Figure 6: Evolution of the percentage of owners, by age.

The overall percentage for rental houses in Belgium is very low in comparison to other European countries. The construction of dwellings is mainly financed by private families (generally the eventual inhabitants) in Belgium. There are almost no real estate investment funds that construct in a large scale and benefit from standardization, like in Germany or the Netherlands. Pension funds or insurance companies seldom invest in real estate.

In Belgium, there is historically a large amount of different dwelling types, and this makes large scale investments and standardization impractical. Moreover, the private rental market is small in Belgium (18,5%). In comparison: Germany, for example, has a population of 80 million people and 50% rental houses.

There are considerable differences between tenants of social housing, tenants in the private market and proprietors[29]. It is clear that tenants have lower incomes on average. This lower income is mostly the reason why they are no proprietor. Figure 7 shows the difference between owners and tenants in income and expenses on payment or rental prices. 30 years ago, there was no difference in income between owners and tenants, while in 2005, it is obvious that the stronger socio economic population with higher income is able to afford a property and is able to pay off the loan.

[29] Pannecoucke, et al., 2003.

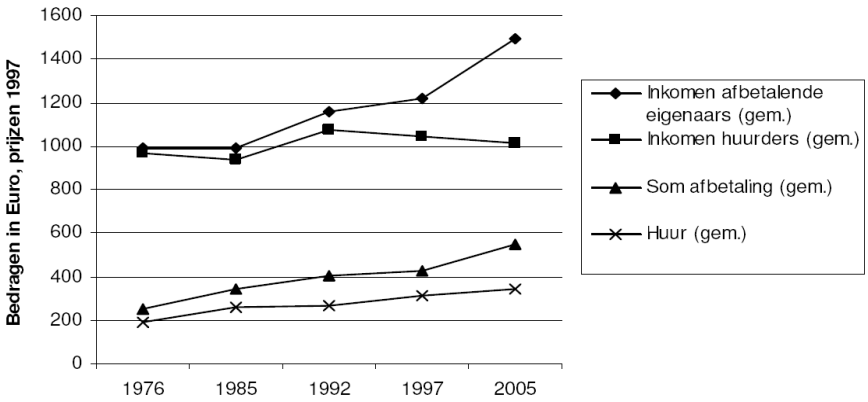

Figure 7: Evolution of income and expenses on the residence of owners and tenants, in euro's per month[30]

The rental market is strongly regulated to keep rental prices low and to protect the tenants who are socio-economically weaker. This appears to have the opposite effect: when there is a maximum rental price, more proprietors of rental houses decide to sell their property because the income of renting out is not high enough. This makes the rental market smaller and makes the weaker socio-economic class, who need a rental house, more vulnerable. Vulnerable tenants and owners are protected by means like special retrofit subsidies.[31]

The largest part of owners of a rental house has only one property for rent. This means that most proprietors are private persons who invest in one house to let. In comparison, in other countries like the Netherlands and the United Kingdom, professionals are encouraged to invest on a large scale in the rental market through fiscal measures, and retrofit on a larger scale is thus more probable.

Summarized, the socio-economic status of owners versus tenants is very different as shown in Table 5. Retrofit on a large scale can be cumbersome due to the differences in building typologies and owner status, but is still an explored opportunity.

[30] Ibid.

[31] In Comparison: In Germany and the Netherlands, social housing sector and the private rental market are equalized. Tenants, who can make a claim to social housing, can also rent in the private market. Subsidies take care of possible price differences between social housing and the private market. As a result, tenants with a weaker socio-economic profile can find an affordable house in both social housing and the private market.

		Owner	Tenant	
			Private	Social
Number		74,4%	24,1%	
			18,5%	5,6%
Location		Suburbs and rural areas	City agglomerations	
Socio-economic profile		Stronger	Weaker	
			Strong	Weaker
Age	< 40	60%	40%	
	40 – 65	80%	20%	
	> 65	75%	25%	
Income	low (q1)	55%	45%	
	average (q2-q3)	65 – 70%	30 – 35%	
	high (q4-q5)	80 – 85%	15 – 20%	
Employment	working	76,7%	22,3%	
	(1 p. working)	67,5%	3,5%	
	(2 p. working)	85,2%	14,8%	
	unemployed	45,7%	54,3%	
Education		Rather high	Rather low	
Household type		Couple with children	Single, Single parent family	

Table 5: Summary of the social profile of owners versus tenants.[32]

[32] Heylen, K. et al., 2007, 7-10

3.4 Typical buildings and selection of case studies

Based on the building stock statistics, showing the differences in age and location, focus is put on the types of 'buildings to renovate' that are the most important in Belgium. Within the LEHR-project (http://www.lehr.be)[33], the building stock analysis led to the definition of building typologies of the Belgian residential building stock in order to define demonstration projects for deep renovation[34]. 11 building typologies were defined for studying deep renovation.

1. The vernacular house: built before 1915 by the owner, in stone, detached, in rural areas or small city centres.

Figure 8: farmhouse, Bousval, Wallonia, built at the start of the 20th century

Figure 9: farmhouse, Herselt, Flanders, built at the start of the 20th century

2. Rural house: built during the interbellum, in towns all over Belgium. These houses can be detached, semi-detached or terraced.

Figure 10: rural house, Chaumont-Gistoux, 1916.

[33] Mlecnik, E. et al., 2010
[34] Hilderson, W., et al., 2010

3. Suburban villa: these houses form the bulk of the ever growing suburbs around the cities, certainly since the seventies, and incorporate the dream of the villa: detached single family houses in a rural context, escaping the density and stress from the cities.


Figure 11: Freestanding house in Sint-Lambrechts-Woluwe

4. Working class house: very small houses in former flourishing industrial zones (coal mines in Wallonia and Kempen) and in the far west of Flanders, quickly built in series in the interbellum.


Figure 12: working class house, Bousval, end of 19th century

5. <u>The urban terraced house</u>: Medium sized urban terraced house, built before WWI or during the interbellum, with architectural value, certainly on the level of the façade, often owned.

Figure 13: Terraced house, Schaerbeek, 1888. Front side before renovation (left) and back side after renovation (right).

Figure 14: Terraced house, Deurne, 1938. Front side and back side during air-tight layer construction.

Figure 15: Eupen, city house, built mid 19th century (after renovation).

6. The large urban terraced building: located in the older urban zones, originally designed as single family houses for the rich and upper middle class, and later on converted into apartments, or directly designed as an apartment building. Built before WWI, often rented and in bad state but with good intrinsic qualities, and architectural value.


Figure 16: old upper class terraced house, Liège, 1905. Renovation transforms the house into 4 apartments and an office space.

7. The suburban semi-detached house: built after the Second World War, they are part of the suburbanisation, mainly built alongside main roads, creating long ribbons of habitation between cities. While the front looks out on a busy street, the back typically looks out on the countryside.


Figure 17: Semi-detached house, built in the fifties, De Pinte. (after renovation).

8. The post-war low rise apartment: built in large numbers after the Second World War in the emerging suburbs, often with low build and architectural quality, often rented. Their relative closeness to the city centre makes them popular, so renovation can be an added value here.

Figure 18: Low rise apartment building, in preparation for renovation.

9. The high-rise apartment building: usually post-1960, concrete slab construction and often prefabricated façades. Low build and material quality, and small and outdated apartment units.

Figure 19: Sterrenveld, social apartment block, 1960, before and after renovation.

10. The social housing neighbourhood: built mainly after the Second World War, as medium sized developments, mostly consisting of terraced houses or medium sized apartment buildings. Note: due to lack of available high performance renovation examples in social housing at time of writing this report, no values are given for this building type in Table 5.

Figure 20: Terraced social housing, built in the 1960s, Wachtebeke

Figure 21: Detached social housing, built in the 1970s, Limal

11. <u>The conversion of an industrial building</u>: renovation of old industrial buildings into lofts has become trendy.

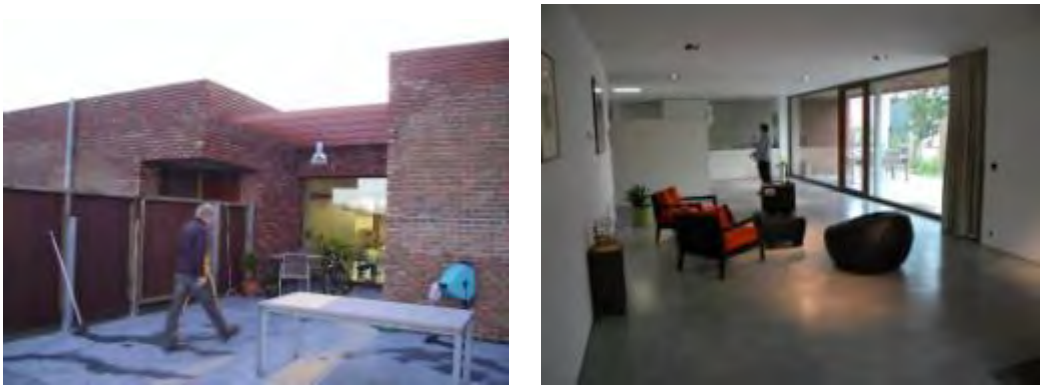

Figure 22: Transformation of a steel workshop in a single family house, Oudenaarde.(after renovation)

For information, the table below gives an overview of U-values after retrofit of these cases.

Building typology for deep renovation	**Thermal transmission parameters U-values (W/m²K) obtained after renovation**			
	Floor above cellar	wall	roof	window
Vernacular house	0.35	0.26	0.18	
Rural house	0.29	0.17 (back) 0.53 (front)	0.17	1.55
Suburban villa	0.49	0.31	0.22	1
Working class house	0.46	0.23	0.18	Uf=1.6 Ug=1.1
Urban terraced house		0.84 0.55	0.38	HR double glazing
Large urban terraced building	0.32	0.29 (front) 0.31 (back)	0.17	1.4
Suburban semi-detached house	0.086	0.126	0.12	Ug=0.6 Uf=0.74
Post-war low-rise apartment	0.191	0.109	0.067	0.9
High-rise apartment building	0.26	0.23	0.28	No info
Social housing neighbourhood	No info	No info	No info	No info
Conversion industrial building	0.112	0.059 0.103	0.08	0.76

Table 6: Overview of building typologies for deep renovation with corresponding U-values after renovation.

Building typologies were also researched during the SuFiQuaD project[35], which allows adding extra information to the typologies above.

Figures 23 and 24 illustrate the classification of dwellings in apartments and detached, semi-detached and terrace houses according to the building age.

[35] http://www.belspo.be/belspo/ssd/science/Reports/SuFiQuaD_Summary_Phase1_DEF.pdf. The Sufiquad project determined for each of the dwelling types (e.g. freestanding house) always four representative dwellings for each of the construction periods (e.g. <1945, 1946-1970, 1971-1990 and 1991-2007).

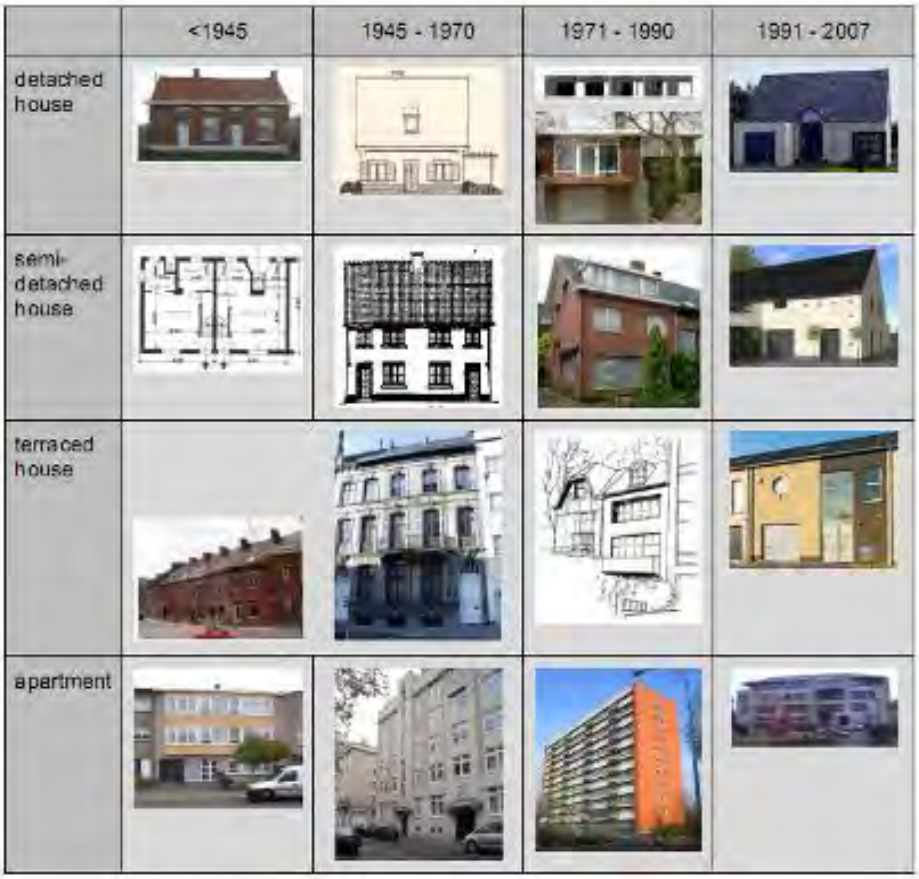

Figure 23: Typology of Belgian dwellings in function of building age.

Figure 24 illustrates that a very large share of the old building stock in Belgium (about 24%) consists of **terraced** and semi-detached **single-family houses built before 1945**, and about 10% consists of **detached single-family houses built between 1971 and 1990**.

Within the Sufiquad project a selection of representative buildings for Belgium was made, with a subdivision for the different regions. This provided similar data for Flanders, as shown in Figure 25.

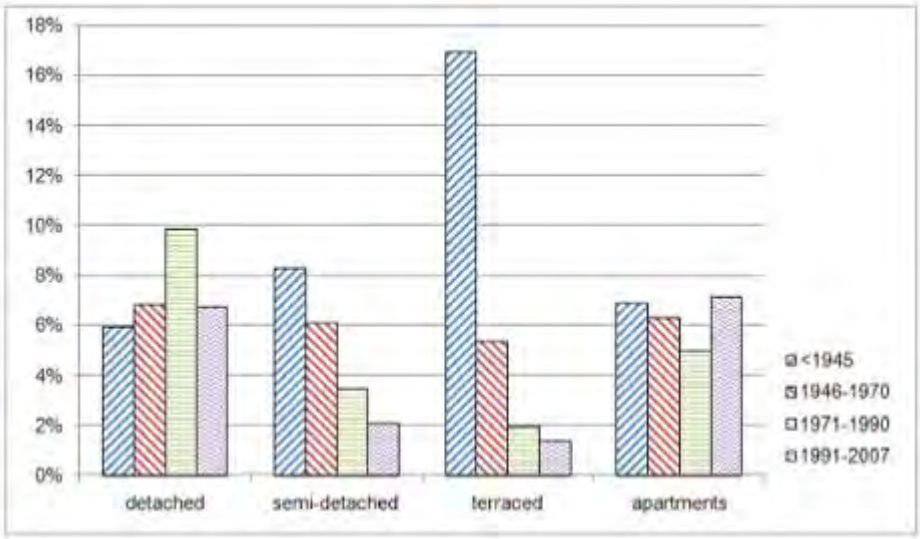

Figure 24: Distribution of the Belgian dwelling types.

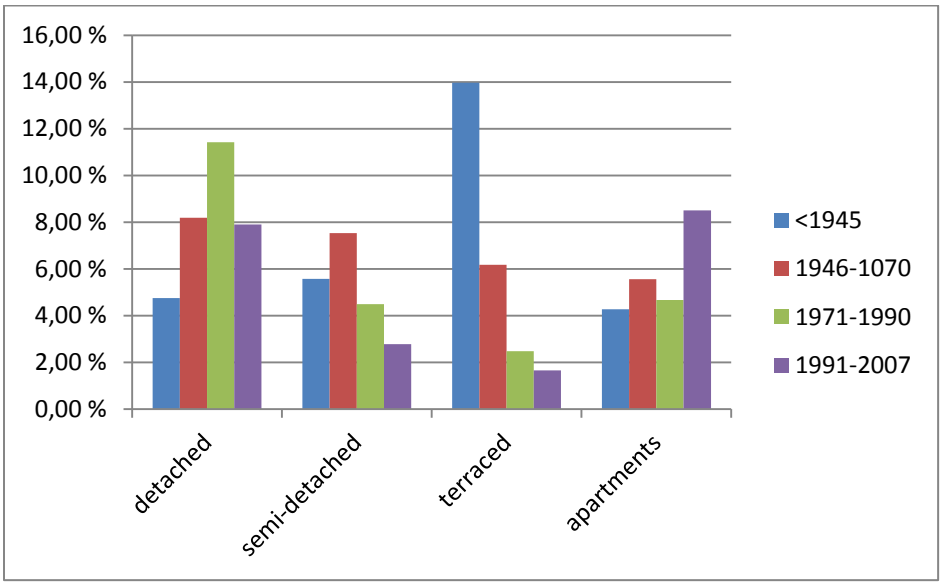

Figure 25: Distribution of the Flemish dwelling types.

Taking into account the previous considerations regarding the building stock and the focus on the Flemish Region, the most promising cases for multiplication are the terraced (and semi-detached) houses from before 1945. Another very interesting group of buildings consists of the 'one-generation'-villas, constructed in the 1970-1990s. [36] However, one must note that these groups together account for only 35% of the housing stock.

[36] In the selection of cases to study into detail in the one-stop-shop project WP2 (LCC & LCA) this information will be taken into account, and interesting 'old row houses' and '1970s villas' will be selected if possible. The other 8 or 9 identified typologies from the LEHR-project might be as interesting to study, especially taking into account factors like 'availability of information', 'demonstrated innovative technology' and 'special attention to an integrated execution process or quality assurance'.

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4 Building Typologies in Finland

This report describes a dwelling stock analysis concerning the Finnish (national) dwelling stock. The report is partly based on a report carried out as a part of the IEA SHC Task 37 Advanced Housing Renovation by Solar & Conservation, Subtask A.

4.1 General characteristics and evolution of the Finnish building stock

Major part (86 %) of the Finnish building stock of 1,4 million buildings consists of residential buildings. Of the total floor area, the residential buildings covered for 64 % in 2007. Nearly half (45 %) of the dwelling stock consists of one or two-room dwellings. The share of single-family houses was 56 % of the dwellings.

Almost 60 % of the Finnish dwelling stock is built before 1980. The number of dwellings in blocks of flats has doubled since 1970. Annual new building construction stands at 1.5–2 % of the total building stock. The volume of the buildings stock increases 0.5–1.0 % (10–20 mil. m3) per year.

It is estimated that the renovation value will grow 2,5 to 3,5 % per year, but the renovation value of dwellings will grow even 3,5 to 5 % per year. In 2007, the average spending for renovation per dwelling was about 1600 € (Pajakkala, 2009).

The total number of household-dwelling units in Finland at the end of 2007 was 2,5 million, and 40 %, of them consisted of one person. The average floor area of dwelling per household-dwelling unit was 79.4 m^2, or 38.9 m^2 per person in 2009 (Table 7).

	Buildings total	Detached houses	Attached houses	Blocks of flats	Other buildings	Floorarea per person
1970	60,0	66,0	73,0	51,0	54,0	18,9
1980	69,3	83,6	71,7	54,8	55,5	26,3
1985	73,9	92,8	72,0	56,3	59,1	28,9
1988	73,8	93,8	70,8	55,8	60,3	30,5
1989	74,2	94,9	70,5	55,8	60,2	31,0
1990	74,4	95,3	70,2	55,8	59,7	31,4
1991	74,8	96,6	70,1	55,8	59,6	31,9
1992	74,8	97,1	70,1	55,8	56,9	32,3
1993	75,1	98,0	70,1	55,9	56,5	32,7
1994	75,3	98,7	70,1	55,9	56,5	33,0
1995	75,5	99,2	70,1	55,9	56,7	33,4
1996	75,7	99,7	70,2	56,0	59,0	33,7
1997	75,8	100,1	70,2	56,0	58,6	34,1
1998	76,0	100,6	70,3	56,0	59,0	34,5
1999	76,5	101,1	70,7	56,1	60,4	34,9
2000	76,5	101,9	70,0	56,1	59,8	35,3
2001	76,8	102,6	70,1	56,1	61,2	35,8
2002	77,0	103,5	70,2	56,2	59,9	36,3
2003	77,3	104,1	70,3	56,2	59,7	36,7
2004	77,6	104,9	70,4	56,2	59,6	37,2
2005	78,1	105,3	70,6	56,2	59,2	37,5
2006	78,4	106,5	70,7	56,3	60,4	38,0
2007	78,8	107,1	70,9	56,4	60,6	38,3
2008	79,1	107,8	71,0	56,4	60,8	38,6
2009	79,4	108,0	71,1	56,5	60,9	38,9

Table 7: Floor area per dwelling by type of building 1970–2009 (Source: Dwellings and Housing Conditions, Statistics Finland 2010).

Table 8 shows the amenities in the Finnish dwellings. For example, 93.4 % of the dwellings do have central heating and 53,1 % have a sauna.

		1960	1970	1980	1990	2000	2009
Amenities	Dwellings total	1 211 200	1 463 221	1 838 058	2 209 556	2 512 442	2 784 469
	Sewer	623 927	1 088 789	1 659 765	2 132 671	2 475 737	2 731 372
	Piped water	569 946	1 054 301	1 642 188	2 105 701	2 463 916	2 737 026
	Flush toilet	428 323	897 768	1 542 514	2 052 829	2 393 949	2 688 671
	Warm water	281 182	760 178	1 465 347	1 984 878	2 400 982	2 703 584
	Bathing facilities	190 057	571 453	1 256 644	1 938 628	2 487 992	2 758 879
	Central heating	377 158	819 665	1 474 325	1 963 819	2 301 903	2 599 510
	Sauna in dwelling	..	..	548 264	931 908	1 212 227	1 479 172
%	Dwellings total	100,0	100,0	100,0	100,0	100,0	100,0
	Sewer	51,5	74,4	90,3	96,5	98,5	98,1
	Piped water	47,1	72,1	89,3	95,3	98,1	98,3
	Flush toilet	35,4	61,4	83,9	92,9	95,3	96,6
	Warm water	23,2	52,0	79,7	89,8	95,6	97,1
	Bathing facilities	15,7	39,1	68,4	87,7	99,0	99,1
	Central heating	31,1	56,0	80,2	88,9	91,6	93,4
	Sauna in dwelling	..	..	29,8	42,2	48,3	53,1

Table 8: Dwellings by amenities in 1960–2009 (Source: Dwellings and Housing Conditions, Statistics Finland 2010).

In 2005, 63% of the Finnish residential buildings were owner-occupied, whereas the percentage of social and private rented dwellings was respectively 17,2% and 16,8%.

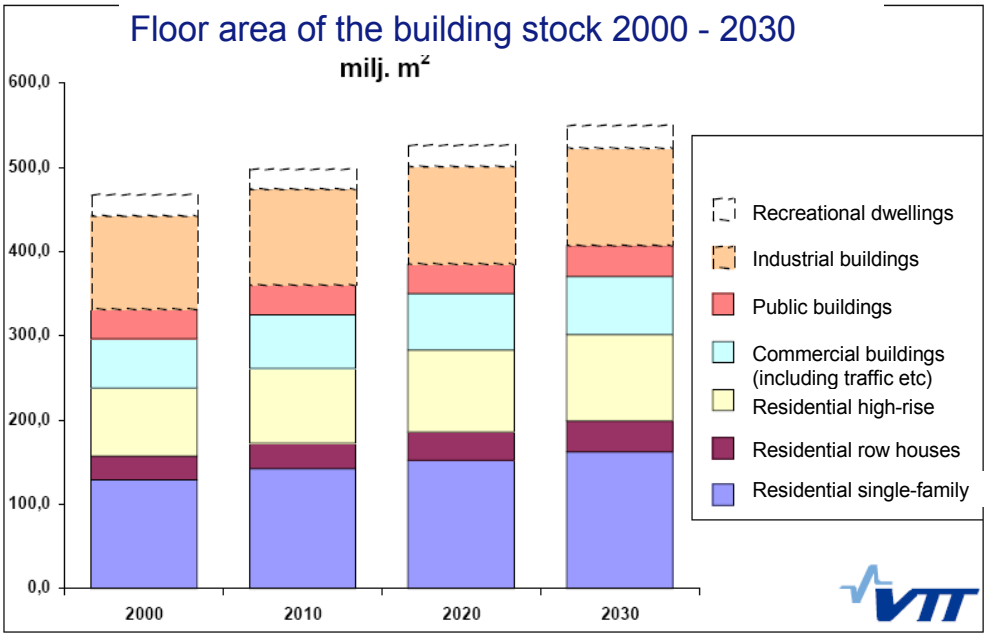


Figure 16: An estimation for the development of Finnish building stock up to 2030. (Heljo et al. 2005).[37]

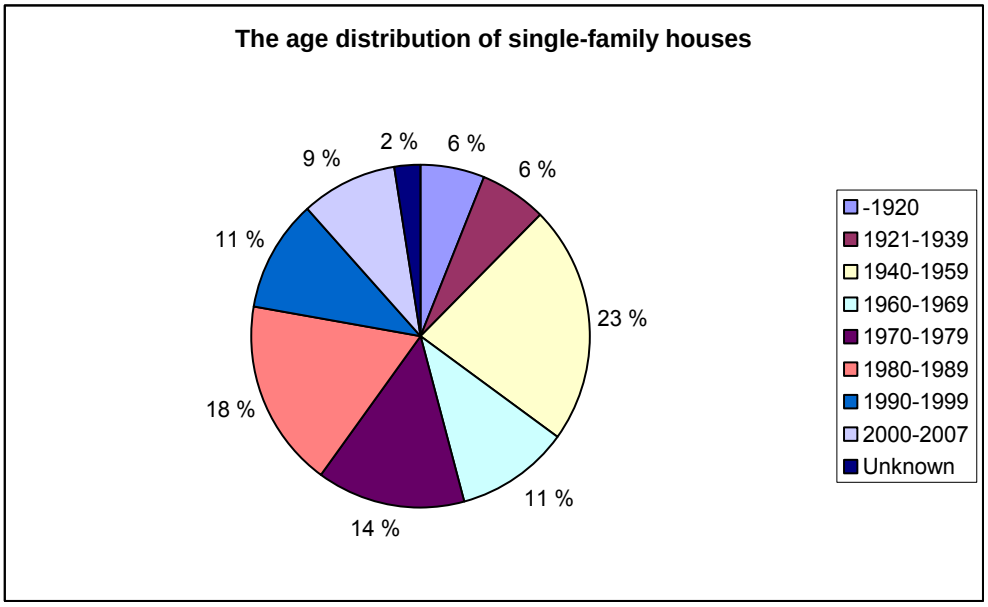


Figure 27: The age distribution of Finnish single-family houses (Statistics Finland 2011).

[37] Residential single-family houses are also known as detached single-family houses.

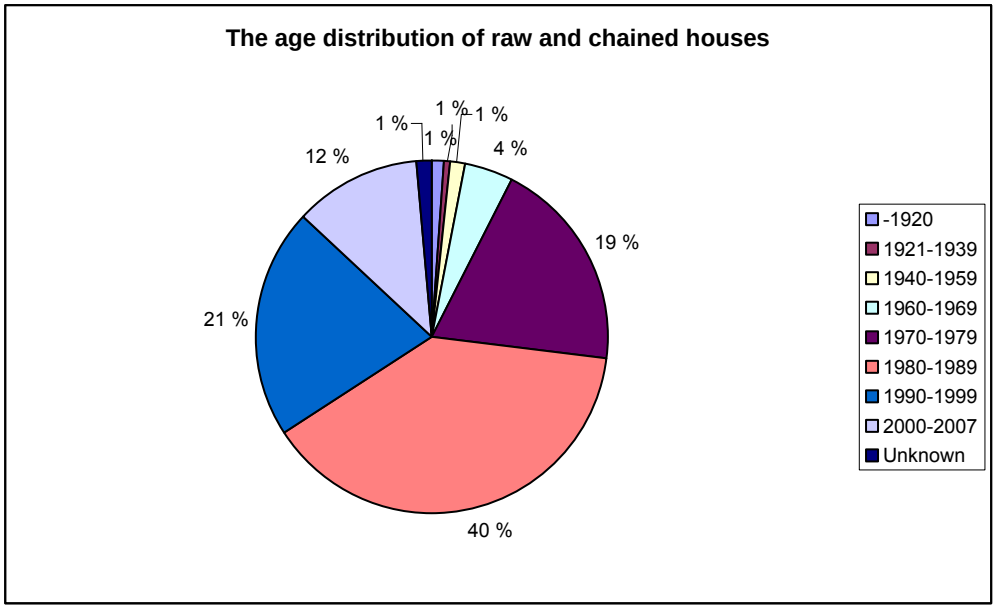


Figure 28: The age distribution of Finnish raw and chained houses (Statistics Finland 2011)

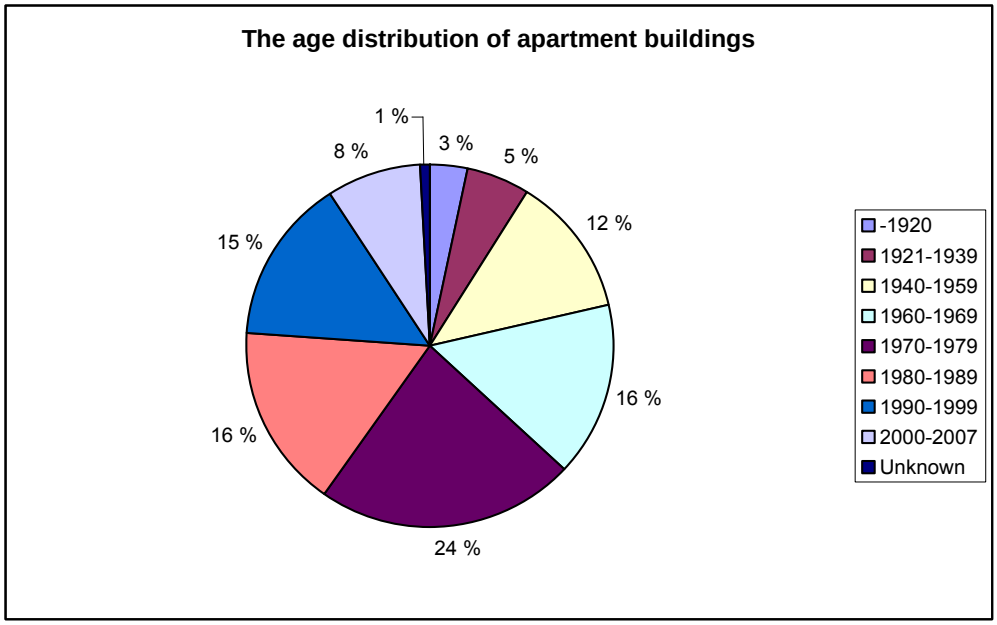


Figure 29: The age distribution of Finnish apartment buildings (Statistics Finland 2011).

4.2 Energy use

In 2009 the final energy consumption in Finland was 287.2 TWh (yearly change -6.7 %). In 2009, 70.8 TWh (24.7 %) was used for space heating (Statistics Finland 2011). Of the total energy use for heating, 10 % comes from wood, 20 % from light fuels, 1 % from heavy fuels, 0.3 % from gas, 0.4 % from coals and peat, 20 % from electricity, 46 % from district heating, 0.4 % from ground heat, and 2 % from other sources. The trend in new construction (2002) is an increase in district heating (50 % of the total new building stock) and electricity (27 %) and a strong decrease in light fuels (9 %) and wood (6 %).

Energy use for heating purposes in the dwelling stocks increased three decades starting from 40's. Oil crisis in the 70's turned the development trend downward trend. The economic growth gave uplift to the development trend before the 90's economic recession when to trend turned downward again. (Figure).

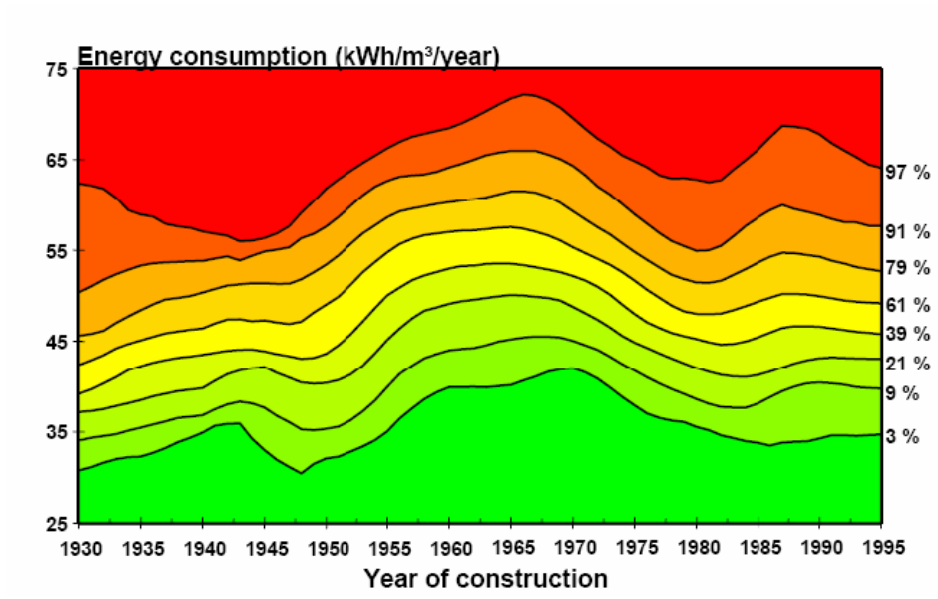


Figure 30: Energy consumption levels of Finnish buildings by construction year. The colours indicate the percentage (on the right axis) of the buildings consuming less than the amount of energy indicated on the left axis. (Aho 2004)

4.3 Ownership

In 2009, 65,7 % of the Finnish household-dwelling units were owner-occupied, whereas the share of rented dwellings was 30.3 % (Dwellings and Housing Conditions, Statistics Finland 2010). Other or unknown type of ownership structure was applied in 4 % of the dwellings. In Finland, municipalities own the largest share of social rented housing (60 %) while a further 20 % is owned by non-profit agencies. Cost rents are charged for all dwellings financed with the aid of state subsidised loans. "Right of occupancy" tenure was introduced in the 1990s, which falls between social renting and owner-occupancy. Residents buy a dwelling by paying 15 % of its value and pay a monthly charge for management and maintenance. About 1 % of the Finnish housing stock is a right-of-occupancy dwelling. (Itard et al. 2008)

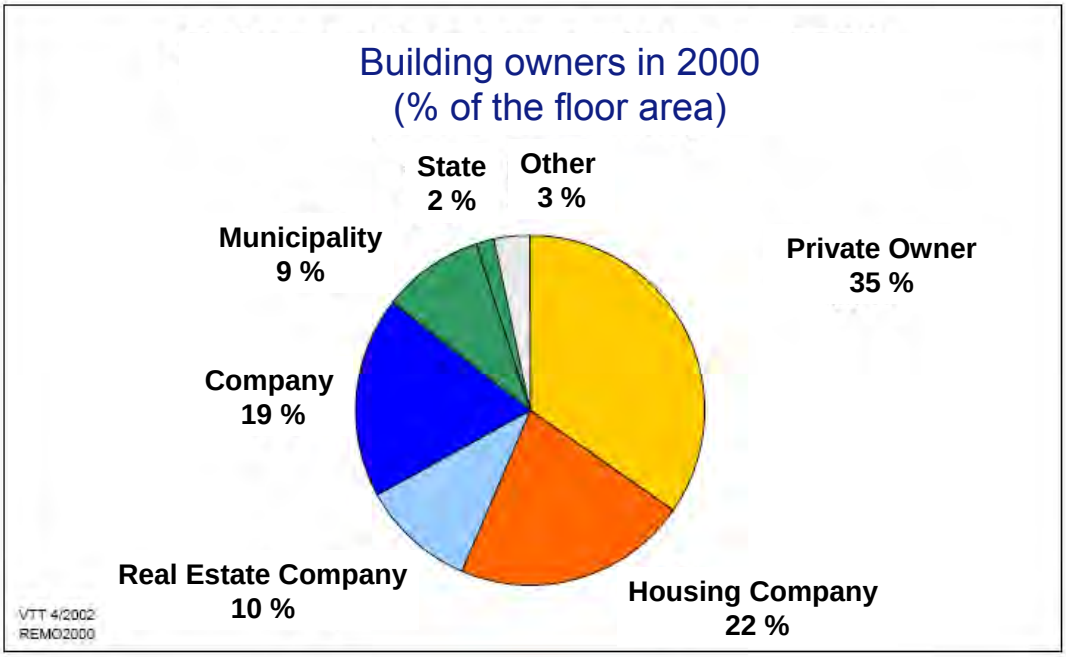


Figure 31. Ownership of Finnish buildings by floor area in 2000. All buildings. (Vainio et al. 2002.)

4.4 Typical buildings and selection of case studies

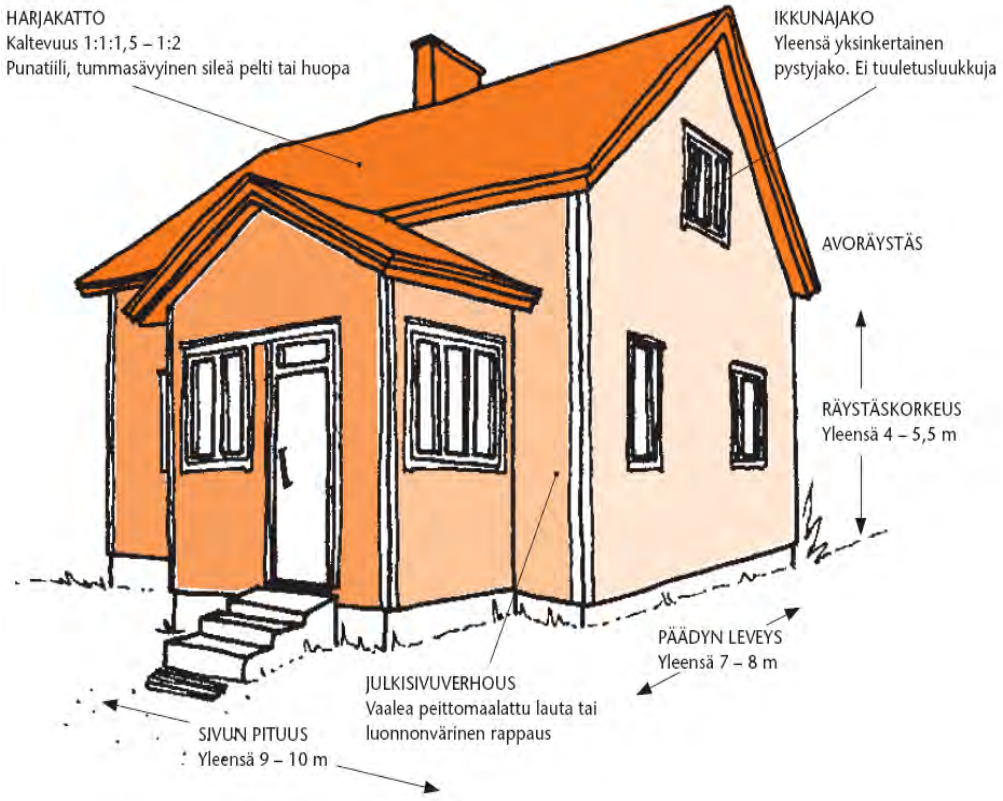
Single-Family buildings are responsible for most of the emissions in the Finnish building stock, so the biggest potential of energy efficiency improvement lies in this segment. Some very typical Finnish single-family houses are presented in Figure 32 and 33.

Veteran House

The Veteran houses from 1940's and 1950's had typically 1,5 stories and a cellar. The floor area is typically below 100 m^2, about 60-80 m^2. Typical U-values are [W/ m^2K] (Hekkanen et al. 1993):

U-values:

- Outer wall: 0,55-0,7 W/m²K
- Roof: 0,3-0,4 W/m²K
- Floor: 0,35-0,45 W/m²K
- Windows: 3,5-4 W/m²K
- Outer doors: 4,5-5 W/m²K



Kuva: SPU Systems Oy

Figure 32: Typical house from 1940's and 1950's, so called Veteran house. (SPU systems Ltd. a)

1970s house

The typical single-family house from 1970's had typically a floor area about 100 m^2. Typical U-values are [W/ m^2K] (Hekkanen et al. 1993):

U-values:

- Outer wall: 0,24-0,28 W/m²K
- Roof: 0,18-0,22 W/m²K
- Floor: 0,2-0,3 W/m²K
- Windows: 1,8-2,1 W/m²K
- Outer doors: 0,7-1,2 W/m²K

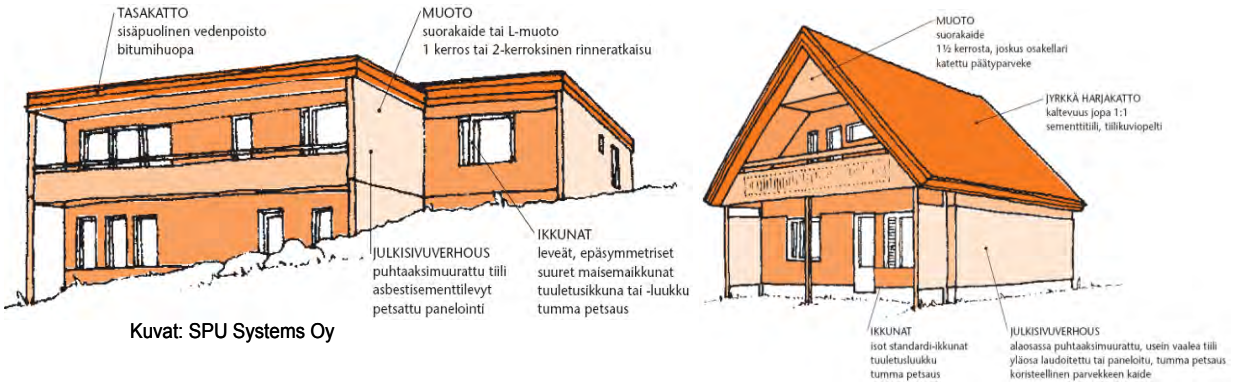


Figure 33: Typical single-family houses from 1970's. (SPU systems Ltd. b)

Apartments

The typical constructions in apartment buildings before 1940 were 2-massive bricks with no insulation. This construction was still widely used until 1965.

During 1940 to 1970's 1,5-2 hollow core bricks (420-560mm) with or without insulation was a typical structure. Between 1950's and 1970's a lot of different structures were used, e.g. aerated and/or reinforced concrete, asbestos cement board with air gap and insulation, building board and different combinations of these were usual. Also Light Expanded Clay Aggregate (LECA) was used in apartment buildings. As insulation material, mineral or wood wool was typically used.

After 1970's concrete sandwich elements with mineral wool in the middle became the most typical construction for outer walls. (Vikström et al. 2000.)

Typically the windows in apartment buildings built before and during 1970s were double glazed windows with wooden frames. In 1970-1980 double and triple glazed windows with wooden frames were typical. After 1980's, 3-glass windows with wooden and aluminium frames were mostly used. (Vikström et al. 2000.)

Typical U-values for different envelope parts are presented in Figure 34.

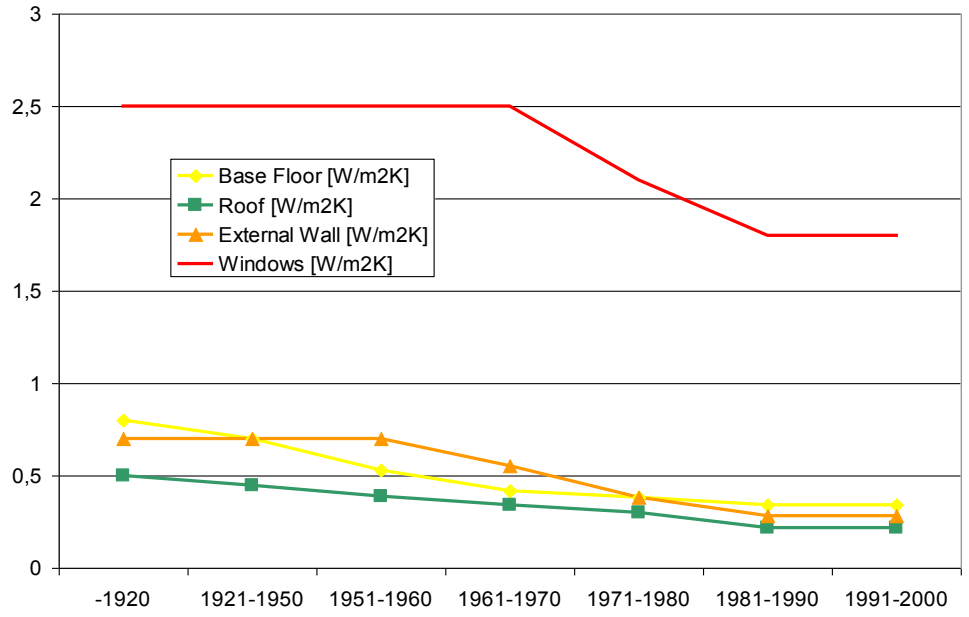


Figure 34: Typical U-values for apartment buildings. (Vikström et al. 2000.)

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5 Building Typologies in Norway

As part of International Energy Agency, Solar Heating & Cooling Programme, Task 37 - Advanced Housing Renovation by Solar and Conservation - the Norwegian building stock was analyzed[38]. Some of the content from this report is replicated below.

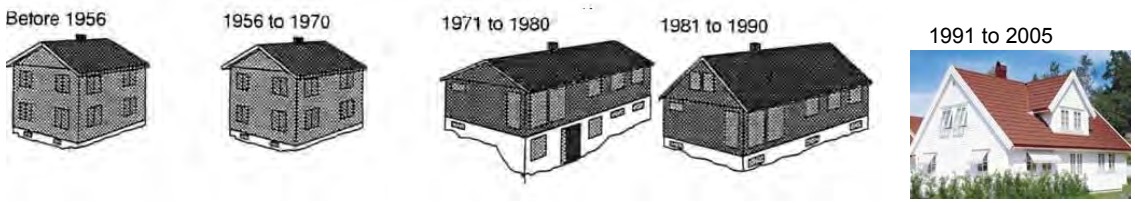
5.1 General characteristics of the Norwegian Building stock

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

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

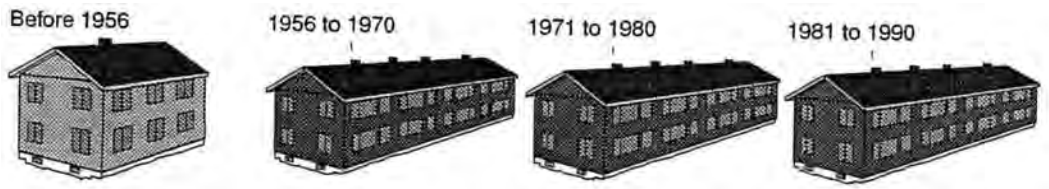
The main groups of dwellings may further be divided into five sub-groups according to the year of construction:

Single-family houses



[38] Thyholt, M, Dyrstad Pettersen, T., Haavik, T. Wachenfeldt, B.J., *Energy Analysis of the Norwegian Dwelling Stock*, Solar & Heating Programme, International Energy Agency, TASK 37 - Advanced Housing Renovation by Solar and Conservation, Trondheim, April 2009. http://www.sintef.no/project/eksbo/Dwelling_stock_analysis_Norway_010409.pdf

Divided small houses



Large apartment buildings (blocks of flats, courts)

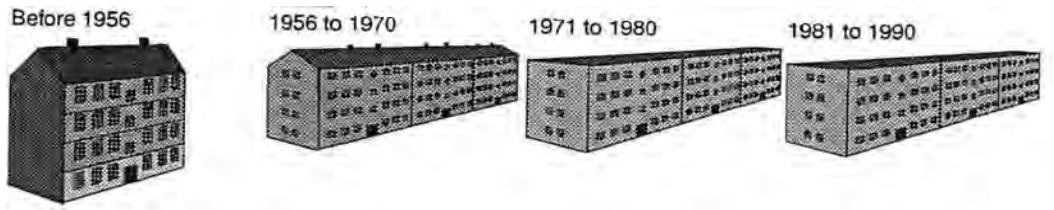


Figure 35: Illustration of some of the stereotypes (no illustration of divided small houses and large buildings for the period 1981 – 2005).

Figure 36 illustrates that the single family houses dominate the Norwegian dwelling stock in all periods except from the ten last years.

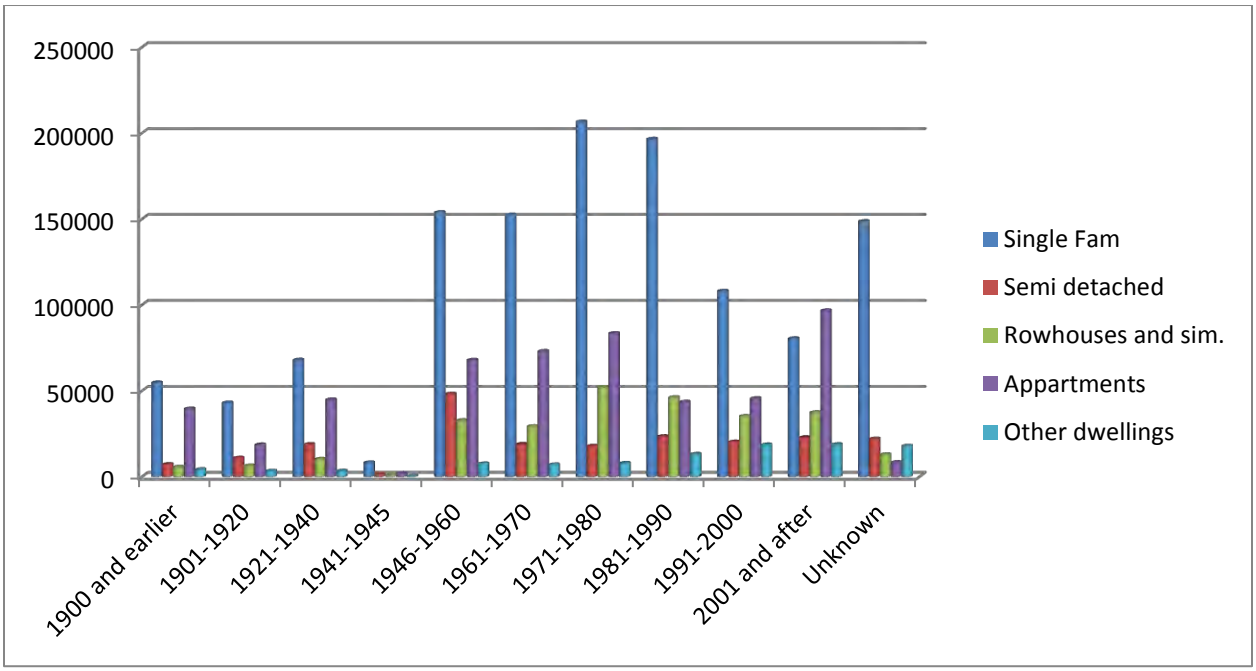


Figure 36: Quantity and distribution of residences for the year 2010[39]

[39] Statistics Norway, www.ssb.no consulted May 15th, 2011

The physical parameters are partly based on typical constructions and the insulation level when the dwellings were built, and the assumed renovation rate and level for the buildings. These assumptions are based on the work presented in a PhD-thesis on energy saving measures[40] and a report from 2000 on future energy use in the Norwegian dwelling stock[41], in addition to qualified assumptions related to the renovation since 1999.

Based on values of these stereotypes and official statistics on number of dwellings, the total dwelling area used for heating can be estimated (see Figure 36). The estimated total heated area is approx. 230 million m², with a distribution as shown in the figure. It should be noted that this is about 30 % lower than the numbers presented in the Figure below. Some of the deviation is probably because heated area is slightly less than the utility floor area, and some deviation also is caused by assumed sizes of the stereotypes.

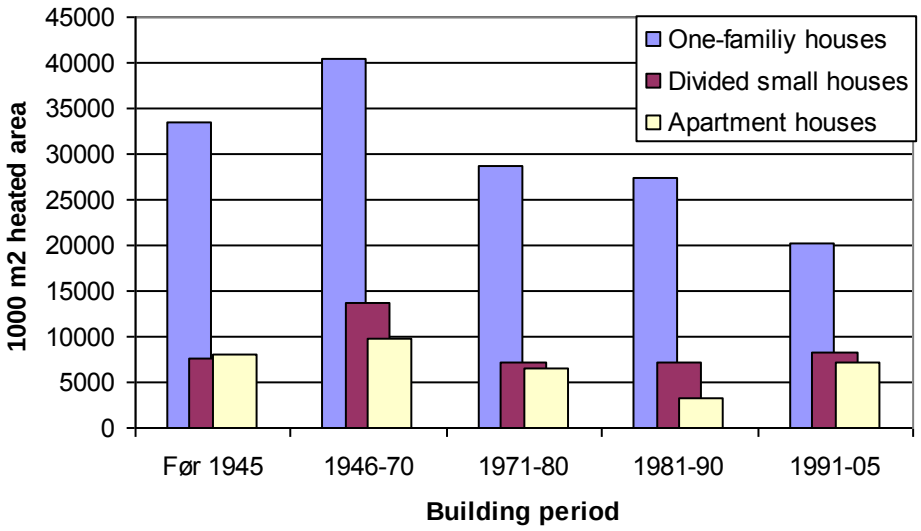


Figure 36: Total heated area split into the three categories of dwelling, according to building age.

[40] L. Myhre (1995), Some Environmental and Economic Aspects of Energy Saving Measures in Houses, Doktor ingeniøravhandling 1995:120 (thesis for the doctorate), Norwegian University of Science and Technology

41 L. Myhre (2000), Towards Sustainability in the Residential Sector. A study of Future Energy Use in the Norwegian Dwelling Stock., Norwegian Building Research institute, NBI Note 41, 2000. Building Technology,

5.2 Energy use

The total energy consumption for the entire dwellings stock can be estimated by multiplying the energy consumption for each defined stereotypes of dwellings, with the number of dwellings within each group that the stereotype represents. The energy consumption for each of the stereotypes are calculated based on the physical parameters and the simplified monthly calculation method described in the Norwegian calculation standard "*NS 3031 Calculation of energy performance of buildings - Method and data*" (similar to EN-ISO 13790). This means that average climate data for Norway and standardized internal loads and energy use for tap water heating are used in addition to the information given in Figure 36.

The specific net energy consumption (useful energy) for the 15 stereotypes of residential building as average is shown in Figure 37.

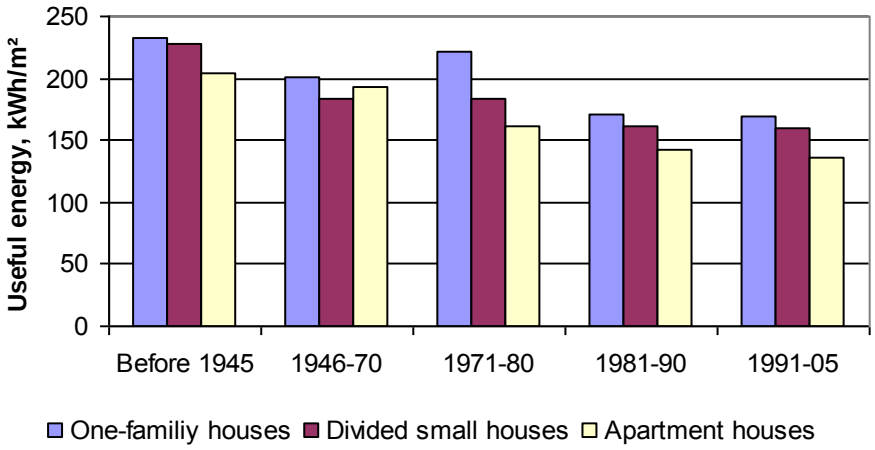


Figure 37: Average specific net energy consumption for the stereotypes of residential buildings.

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

5.3 Ownership

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

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

The distribution between these groups is as follows:

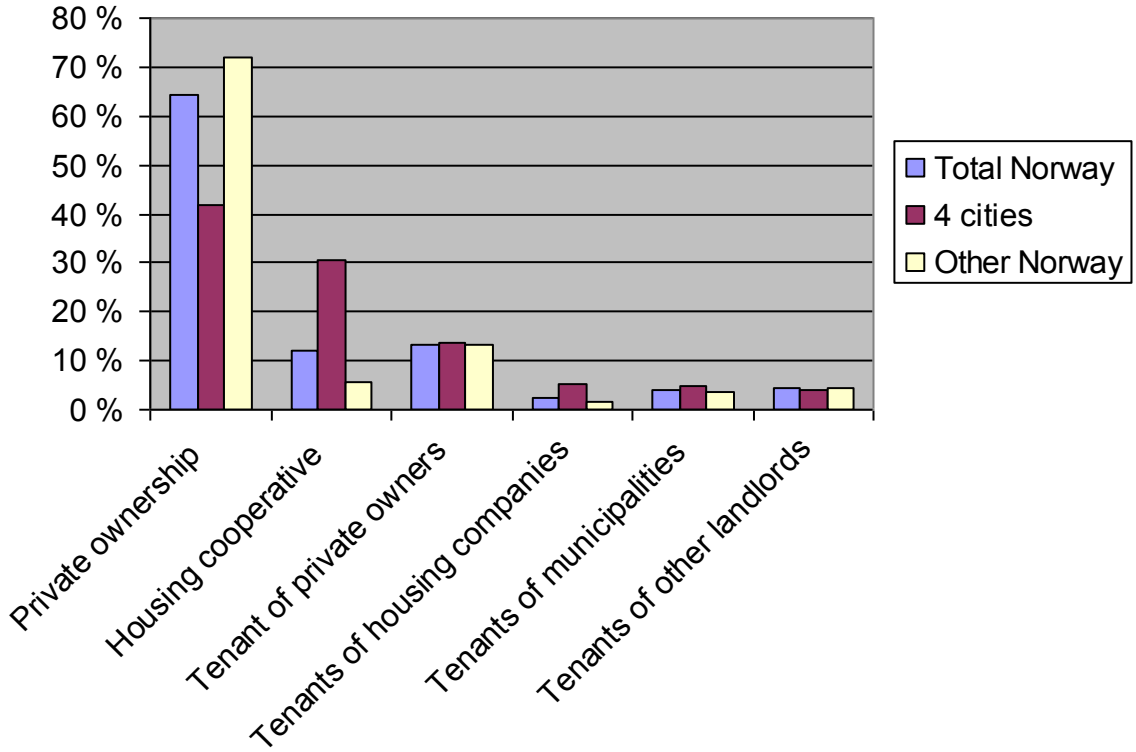


Figure 38: Ownership of Norwegian homes in 2001[42]

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

[42] "4 cities" includes the four biggest cities in Norway (Oslo, Bergen, Trondheim and Stavanger). These cities count alone for 26 % of the total Norwegian building stock (Oslo half of this).

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

5.4 Typical buildings and selection of case studies

Based on the high number of single family houses built from the 60'ies and through the 80'ies, houses built in this period represent the highest potential for sustainable renovation. It is also anticipated that a high amount of these dwellings still have not been through a major renovation. The "opportunity window" for energy efficient renovation has therefore not been closed yet.

As part of the "OneStopShop" project, the partner Bolig Enok will buy a single family house within this period and renovate it towards passive house standard and sell after the renovation is completed. This reference project will be used as a pilot case in WP2.

The Norwegian pilots of business models will target the selected typologies in the marketing of one stop shop for energy efficient renovation.

5.5 References for Norway

Thyholt, M, Dyrstad Pettersen, T., Haavik, T. Wachenfeldt, B.J., *Energy Analysis of the Norwegian Dwelling Stock*, Solar & Heating Programme, International Energy Agency, TASK 37 - Advanced Housing Renovation by Solar and Conservation, Trondheim, April 2009. http://www.sintef.no/project/eksbo/Dwelling_stock_analysis_Norway_010409.pdf

Statistics Norway, www.ssb.no consulted May 15th, 2011

L. Myhre (1995), Some Environmental and Economic Aspects of Energy Saving Measures in Houses, Doktor ingeniøravhandling 1995:120 (thesis for the doctorate), Norwegian University of Science and Technology

L. Myhre (2000), Towards Sustainability in the Residential Sector. A study of Future Energy Use in the Norwegian Dwelling Stock., Norwegian Building Research institute, NBI Note 41, 2000. Building Technology,

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

6 Building Typologies in Denmark

Information about the Danish building stock has been collected from information provided by the Danish Building Research Institute [1], [2], the Technical University of Denmark [3] and Statistics Denmark [4].

6.1 General characteristics of the Danish Building stock

There are about 2.5 millions (2.459) dwellings in Denmark, which account for a total heated floor area of approximately 275 million m^2. Apartment buildings constitute 25% of the total heated floor area, whereas the other 75% of the heated floor area can be categorised as single family houses. Besides summer houses and dorm rooms, single family houses can be divided in three main groups, i.e. detached houses, farmhouses and row houses. With 1.14 million detached houses and farm houses, they account for almost 46% of the dwelling stock (2008 numbers).

Besides different types of dwellings, the Danish building stock can also be subdivided into different groups of dwellings according to their year of construction. The subdivision in such groups is based on commonly used thermal insulation levels according to the requirements at that time. The number of dwellings (excluding summer houses and dorm rooms) and heated floor area stated by year of construction is shown in Table 9 (based on a survey from 2004).

		1850-1930	**1931-1950**	**1951-1960**	**1961-1972**	**1973-1978**	**1979-1998**	**Total**
Farmhouses	Number of houses ($x10^3$)	**93**	13	5	5	3	5	124
	Heated floor area ($x10^3$)	16,484	2,153	742	797	634	951	21,761
	Average heated floor area (m^2)	177	163	158	175	200	195	176
Detached houses	Number of houses ($x10^3$)	216	120	100	**345**	139	117	1,037
	Heated floor area ($x10^3$)	31,104	15,437	12,373	50,424	21,858	17,340	**148,535**
	Average heated floor area (m^2)	144	129	124	146	157	148	143
Row houses	Number of houses ($x10^3$)	29	13	15	28	22	67	174
	Heated floor area ($x10^3$)	3,619	1,827	2,114	4,482	3,679	12,747	28,467
	Average heated floor area (m^2)	126	136	141	161	170	190	164
Apartment buildings	Number of houses ($x10^3$)	**58**	23	6	7	2	7	103
	Heated floor area ($x10^3$)	23,450	14,082	7,568	13,546	4,317	7,632	**70,595**
	Average heated floor area (m^2)	403	623	1,272	1,918	2,155	1,071	658

Table 9: Number of single-family houses and apartment buildings, gross floor areas and average floor areas [3].

Table 9 shows that approximately half of the single family houses (i.e. farmhouses, detached houses and row houses) have been built before 1961 when the first requirements for insulation standards have been laid out. Approximately one quarter has been built during the period 1961 to 1979 and the last quarter has been built after 1979 when the first significant tightening of the thermal insulation requirements was introduced.

An illustration of the evolution of the number of different types of dwellings can also be seen in Figure 39.

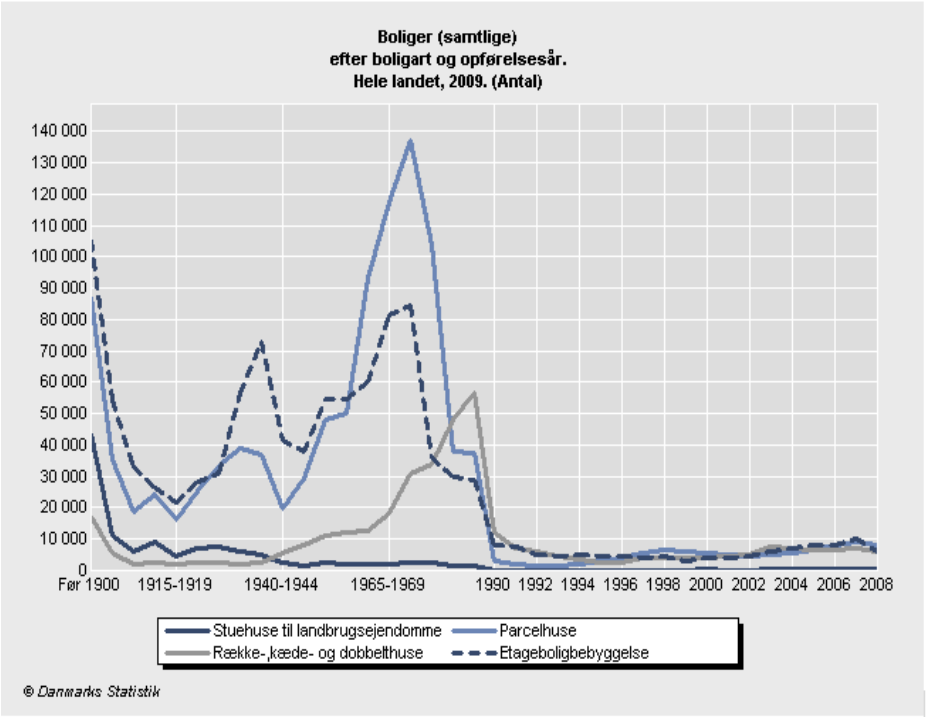


Figure 39: Evolution in number of farmhouses (Stuehuse), detached houses (parcelhuse), row houses (rækkehuse) and apartment buildings (etageboliger). Danmarks Statistik.

In a 20 year period, from 1960-80, approximately 450,000 detached single family houses were built, which corresponds to approximately 45% of the total stock of detached houses, and it is almost as many as were built in the previous 100 years. The vast majority are so-called 'type houses'. Besides the construction of these *type houses*, a small peak in construction of detached houses can also be seen around 1930. Many of these houses are constructed as villas outside the city, and are called *master builder houses*.

Most farmhouses have been built in the period before 1930. A peak in construction of row houses can be seen after 1979, after tightening in requirements regarding thermal insulation.

Most apartment buildings have been constructed before 1973 (ca. 75% of the heated floor area). In the period from 1961-1978, the average heated floor area per apartment building increased due to the use prefabricated concrete elements.

6.2 Energy use

The building stock in Denmark accounts for a heating use of 216 PJ/a, of which 96 PJ/a is related to single family houses. Figure 40 shows the energy use for heating in the different segments of single family houses.

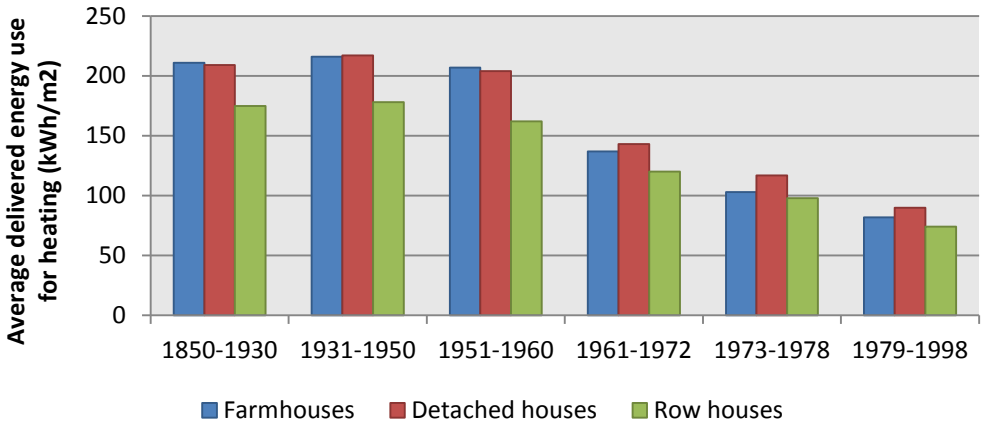


Figure 40: The average delivered energy use for heating (space and hot water), dependent on the type of dwelling and the year of construction [1].

6.3 Ownership

The Danish residential building stock consists of approximately 1.53 million units, of this 79 % are detached single-family houses and farm houses, 15 % are terraced, linked or semi-detached houses, 6 % are multi-dwelling houses and 0.4 % are other types of residential buildings [4].

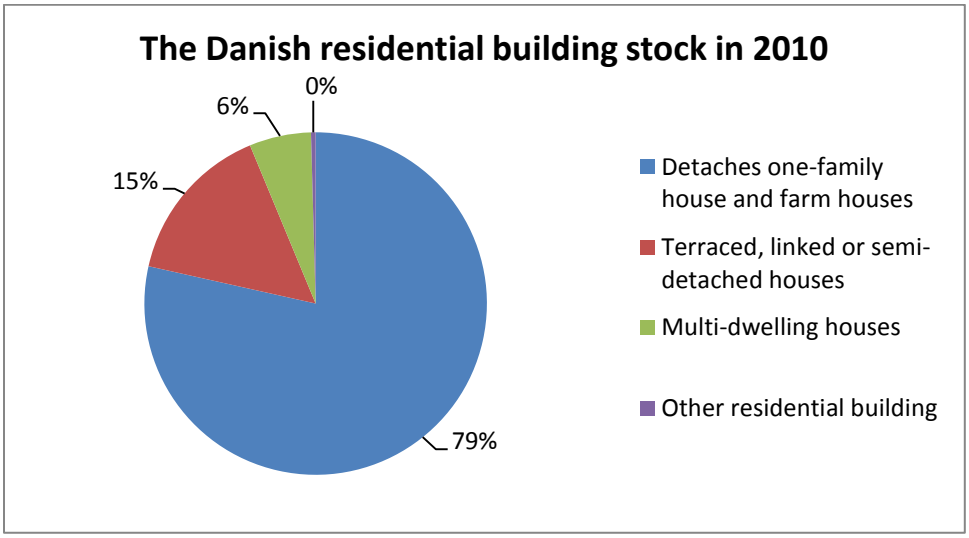


Figure 41: The Danish residential building stock in 2010 [4].

In Denmark around 64 % of the residential buildings are owned by a private owner, 7.3 % are privately owned rental apartments and 6.2 % are privately owned rental houses. About 12.5 % of the residential building is owned by social housing and 5.0 % are owned by housing society. Around 5.2 % are privately owned holiday houses [4].

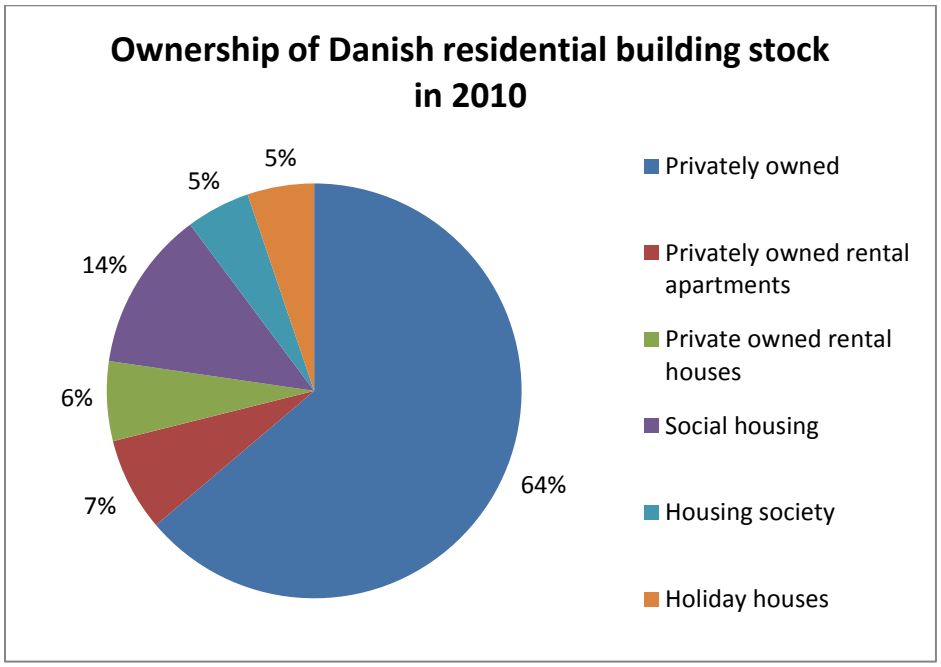


Figure 42: Ownership of Danish building stock in 2010 [4].

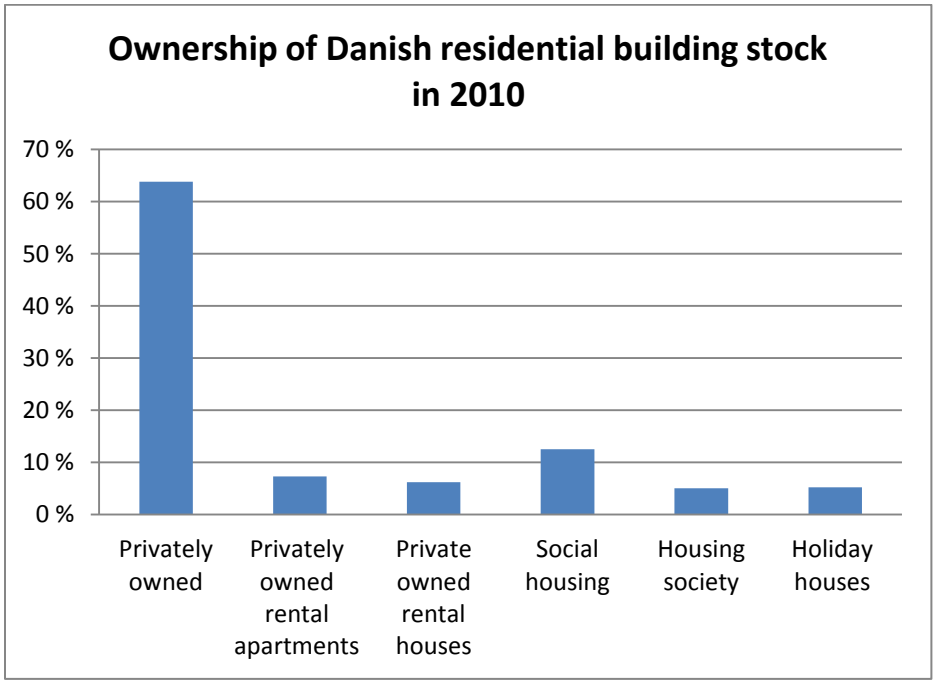


Figure 43: Ownership of Danish residential building stock in 2010 [4].

6.4 Typical buildings and selection of case studies

Looking at the average delivered energy use for space heating for the different types of single family houses for each construction period (Figure 40) and the number of single-family houses and their gross area (Table 9), three types of typical single family houses with great energy savings potential can be distinguished for different construction periods in the Danish building stock: farmhouses built before 1930, master builder houses built before 1930 and standard detached houses built between 1961-1978.

Old farmhouse, built before 1930, typically have a quite large floor area (around 175 m^2 in average). Many of these farmhouses are in a bad condition because they are badly insulated and have many thermal bridges which result in mould problems and damaged structures. As a result, the condition and the living comfort of these buildings need to be improved. Many of the farmhouses typically use an oil-fired central heating system, or they use (cheap) heat from a larger heating system for the stables and production buildings. However, many of the stables and production buildings have been abandoned today and replacement of the existing heating is needed.

Master builder houses built before 1930 originally have a full basement (not heated) and a floor area of around 150m². Exterior walls are constructed as non-insulated cavity walls (110-80-110mm) with an inner and outer leaf of masonry from clay bricks with solid brick ties in the wall at window sill and corners. The effect of adding insulation in the cavity wall is therefore limited. As many people consider facades of master builder houses worth of preserving, adding exterior insulation might influence the image of these buildings. Windows are often old, but high quality wooden windows. Many of these houses have old oil-fired boilers and old iron cast heaters in need of replacement.

Standard detached houses built during 1960/70´s are typically constructed in one storey with a heated floor area of around 150 m². Since they have been erected before real energy requirements were introduced, they are generally poorly insulated although some improvements have been carried out (mainly roof insulation). External walls are constructed as cavity or framed walls with an insulation thickness of 75-100mm, an outer leaf of 110mm masonry and an inner leaf of 100mm of light-weight concrete or 110mm of masonry. Windows are typically wooden (coupled) windows which need a replacement. The roofs are mostly constructed with elevated roofing; however, some roofs are constructed as flat built-up-roofs. Extensions to these houses are common and are typically carried out in the late 1970´s.

Typical U-values for all dwellings for different Construction periods can be found in Table 10. U-values for the typcial houses are highlighted (grey).

		1850-1930	**1931-1950**	**1951-1960**	**1961-1972**	**1973-1978**	**1979-1998**
Farmhouses	U-value wall (W/ m^{2}K)	0.85	0.88	0.86	0.74	0.51	0.37
	U-value roof (W/ m^{2}K)	0.34	0.42	0.32	0.36	0.26	0.26
	U-value floor (W/ m^{2}K)	0.41	0.34	0.37	0.35	0.27	0.33
	U-value windows (W/ m^{2}K)	2.59	2.61	2.52	2.70	2.47	2.43
Detached houses	U-value wall (W/ m^{2}K)	0.86	0.85	0.84	0.65	0.50	0.37
	U-value roof (W/ m^{2}K)	0.39	0.39	0.32	0.26	0.26	0.20
	U-value floor (W/ m^{2}K)	0.37	0.38	0.36	0.30	0.28	0.24
	U-value windows (W/ m^{2}K)	2.56	2.50	2.50	2.52	2.48	2.40
Row houses	U-value wall (W/ m^{2}K)	1.02	1.00	0.99	0.65	0.54	0.34
	U-value roof (W/ m^{2}K)	0.42	0.57	0.25	0.31	0.30	0.20
	U-value floor (W/ m^{2}K)	0.42	0.57	0.25	0.31	0.30	0.20
	U-value windows (W/ m^{2}K)	2.58	2.46	2.49	2.47	2.46	2.50
Apartment buildings	U-value wall (W/ m^{2}K)	1.10	1.16	1.00	0.93	0.52	0.36
	U-value roof (W/ m^{2}K)	0.45	0.54	0.37	0.44	0.30	0.18
	U-value floor (W/ m^{2}K)	0.45	0.48	0.51	0.39	0.27	0.24
	U-value windows (W/ m^{2}K)	2.72	2.68	2.69	2.48	2.58	2.41

Table 10: U-values for wall, roof, floor and windows for typical single family houses and apartment buildings [2].

6.5 References for Denmark

[1] *Varmeplan Danmark* (in Danish), Projekt nr. 2008 – 01, Rambøll Danmark A/S in cooperation with Aalborg University.

[2] Wittchen, K.B. *Potentielle energibesparelser i det eksisterende byggeri* (in Danish). SBi 2009:05, Statens Byggeforskningsinstitut, Hørsholm, Aalborg Universitet 2009.

[3] Tommerup, H. 2004. *Energibesparelser i eksisterende og nye boliger* (in Danish). DTU Byg rapport R-080.

[4] Statistics Denmark. *Construction and Housing – Building stock.* BYGB11. StatBank Denmark 2011.

7 Conclusions

Based on the high number of houses built from the 60'ies and through the 80'ies, houses built in this period represent the highest potential for deep renovation, also since a high amount of these dwellings still have not been through a major renovation.

Differences in typologies between the countries exist. Most residential buildings suitable for retrofit are owner-occupied, but they differ in terms of:

- General characteristics of the housing stock. For example, regarding the age of the building stock, Finland has a relatively younger building park (only 8% of the houses is constructed before 1945), Denmark has had a couple of 'construction peaks', whereas the age of buildings in Norway is more spread and the stock in Flanders is relatively young. Also, architectural styles, insulation levels, and the evolution of construction solutions differ.
- Energy use, in particular supply for heating and warm water. For example, Finland has a lot of electricity heated buildings, whereas this share is very limited in Flanders, where oil and gas are predominant. District heating is also more popular in the Nordic countries as compared to Flanders.
- Ownership: In most countries large opportunities are detected in dealing with owner-occupied houses, but the support and legal structures for owners/occupants can differ in different countries.

Selection of case study typologies is thus a matter of national choice. The research detected that some types of buildings (small row houses, larger alone standing 'villas') seem to be interesting housing types for deep renovation, present in more countries. For each participating country, typical dwellings suitable for deep renovation could be identified[43].

These cases are selected for further research work in the project, since they match the most relevant national typologies - as analysed in this report, based on statistical data. However, attention should be paid to the fact that case selection for further analysis is also influenced by availability of cases and detailed information and data, the demonstration of innovative technology or solutions, and the focus that is put on the integrated, whole-building solution and quality assurance, in accordance with application of eventual new business concepts.

[43] For application within the One-Stop-Shop project and its work packages.