ADEME

Agence de l'Environnement
et de la Maîtrise de l'Energie

Quantitative evaluation of explanatory factors of the lower energy efficiency performance of France for space heating compared to European benchmarks

Study carried out by Enerdata for ADEME

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Enerdata

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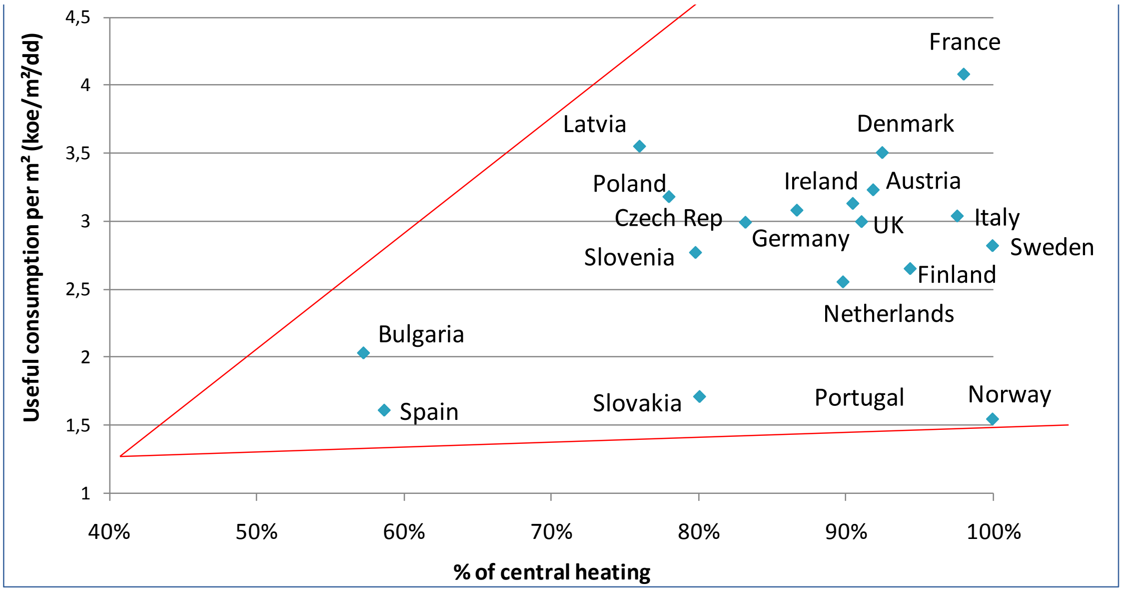
1. Context and objectives

The aim of this report is to understand why France has lower space heating energy performances than most other EU countries. This diagnosis resulted from a graph produced in the framework of the European Odyssee project[1] that compares specific energy consumption of space heating (**Figure 1**). This chart includes several adjustments to take into account quantifiable differences between countries, in the energy mix, in the size of dwellings and in the outdoor climate. The comparison focuses on useful energy consumption of space heating (in order to correct differences in the energy mix and thus in efficiency), per m2 (to correct for differences in dwelling size) and degree-days (to correct for differences in climate) [2].

Figure 1 : Useful energy consumption per m² and degree days of space heating and share of central heating



Source : Odyssee, 2009

The specific useful consumption per m2 and degree-day of The Netherlands is 40% lower than for France. Finland, Denmark and Sweden are 30% more efficient than France (**Figure 2**). The aim of the study is to analyse the gap between France and other comparable EU countries, i.e. with significant heating needs (Sweden, Finland, United Kingdom, Germany, The Netherlands, Denmark and Austria[3]), and to explain quantitatively and qualitatively these differences.

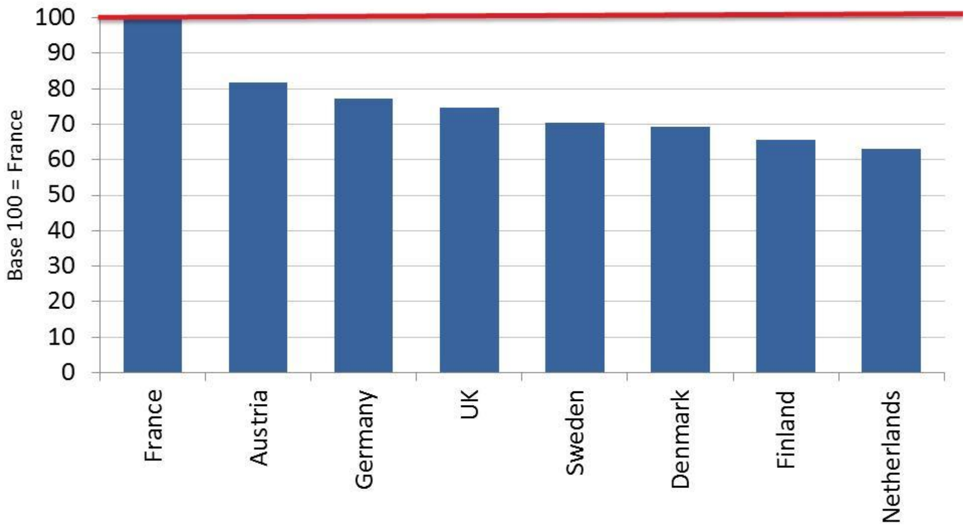
We will first, identify additional factors that might explain differences between France and the best European countries. We will then discuss how to extend and complete this benchmark by providing additional adjusted energy efficiency indicators. Finally, we will propose a method to breakdown the difference in specific space heating consumption between France and the best two countries: the Netherlands and Denmark.

[1] http://www.odyssee-indicators.org/

[2] Figure 1 shows the indicator value (vertical scale) versus the penetration of central heating (horizontal scale) to reflect the fact that countries with a low penetration of central heating, such as Bulgaria and Spain, necessarily have a lower specific heating consumption because the comfort is not the same; so the comparison only makes sense for countries with similar level of central heating penetration.

3 Norway was excluded from the benchmark because space heating consumption data are not reliable, and are being revised.

Figure 2 : Useful energy consumption for space heating per m² and per degree days (2008)



Source : Odyssee

2. Identification of additional explanatory factors

A first explanatory factor is the dwelling structure, between individual and collective dwellings on the one hand, and between different types of individual dwellings on the other hand (e.g. detached, semi-detached), and the average height of building. Indeed the specific consumption depends on wall surfaces in contact with outdoor; dwellings in multifamily buildings or in high building have less wall surfaces in contact with outdoor, and should be more efficient.

The age of buildings may also have a significant impact: a higher proportion of recent dwellings, subject to more stringent and recent thermal regulations, improve the average energy performance of dwelling stock.

The type of materials and the characteristics of building insulation represent additional factors that influence the specific heating consumption.

The dwelling tenure (ownership versus rental) is another factor to take into account, as the owners are more likely to invest in insulation to improve their dwelling energy performance (and as a consequence reduce their energy bill).

We will also study how the structure of space heating equipment can affect the average heating efficiency and thus the useful energy consumption.

Finally, we will examine whether space heating behaviours can explain differences among countries.

2.1. Effect of dwelling stock structure[4]

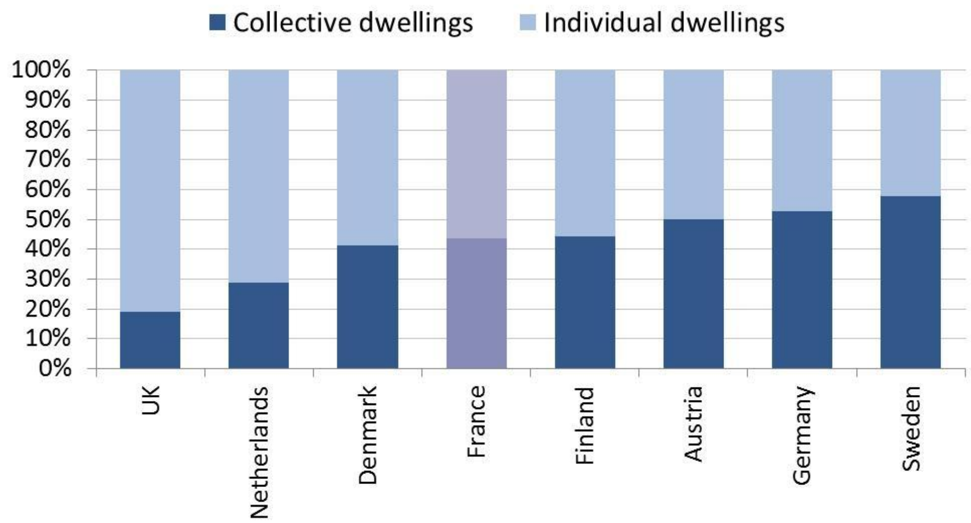
2.1.1. Composition of the stock between individual and collective dwellings

In France, 44% of dwellings are collective, and 56% are individual, it corresponds to the average of the sample of country. In contrast with France, in UK and the Netherlands the

[4] This study has been done in final energy instead of useful energy to avoid bias.

stock of permanently occupied dwelling is composed predominantly of individual dwellings (81% and 70% respectively, (**Figure 3**).

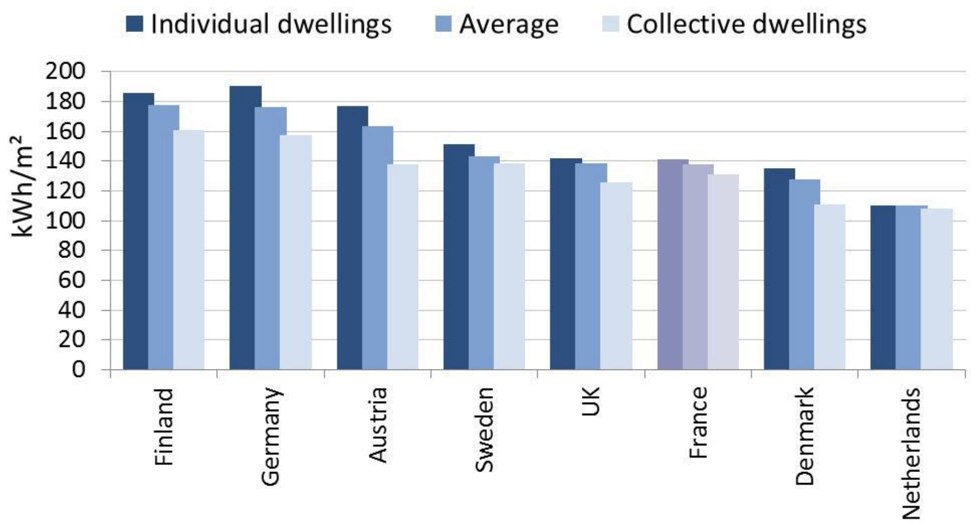
Figure 3 : Dwelling stock structure in 2008



Source : Odyssee

Individual dwellings consume on average twice as much as collective dwellings. These differences are explained by their larger size, and by the fact that they have greater heat losses. Per m², the differences between both types in space heating consumption tighten (**Figure 4**). It is less than 10% in France (8%) and Sweden (9%), but it is higher in Austria (28%) and Denmark (18%). For the Netherlands, the best country of the benchmark, the specific consumption per m² of space heating is quite similar between both individual and collective dwellings.

Figure 4 : Space heating consumption by m² and by type of dwelling (2008, normal climate)



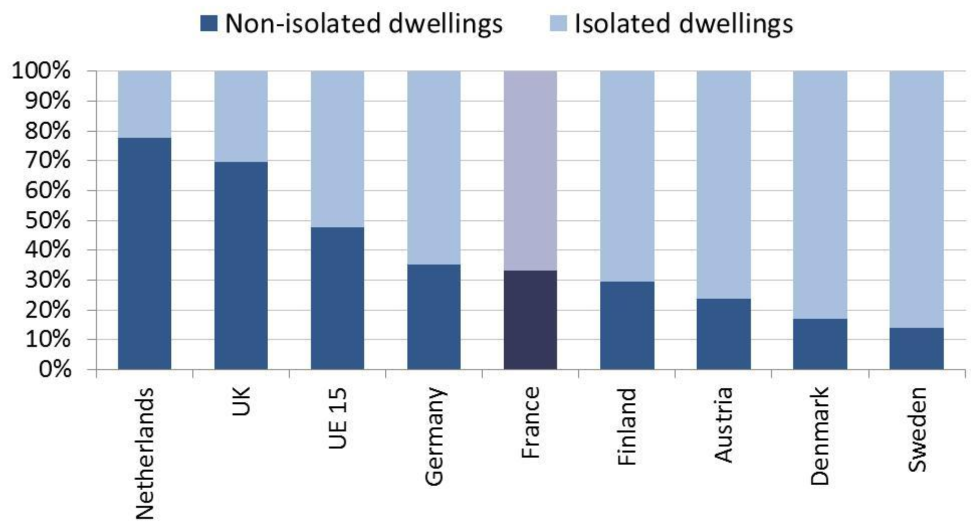
Source : Odyssee

2.1.2. Dwelling stock structure by type of individual dwelling

The stock of individual dwellings may differ significantly from one country to another, according to the share of row house or detached houses. These types of dwellings have different insulation characteristics, therefore it implies different specific space heating consumption (due to different wall area in contact with the outdoor): a semi-detached house consumes on average 15% less per m² than an isolated dwelling[5].

In The Netherlands and UK, the stock of individual dwellings is composed by at least 70% of semi-detached houses, against only 32% in France (**Figure 5**). Some countries have more isolated houses: for instance in Denmark, Finland, Austria and Sweden, more than 70% of dwellings are isolated. The fact that non-isolated houses are dominant in Netherlands may explain its higher energy performance[6].

Figure 5 : Composition of individual dwellings in Europe



Source : Eurostat 2008

2.1.3. Height of collective dwellings

The height of buildings can influence the specific consumption of space heating. Indeed, the higher the buildings are, the lower is their specific consumption per m2, due to more limited wall surfaces in outdoor contact.

In France, in 2010, 37% of collective buildings are higher than four floors (**Figure 6**)[7]. Denmark and the Netherlands have a smaller proportion of high buildings: 27% and 22%, more than 10 points lower than France. In Germany, only 11% of collective dwelling have more than four floors.

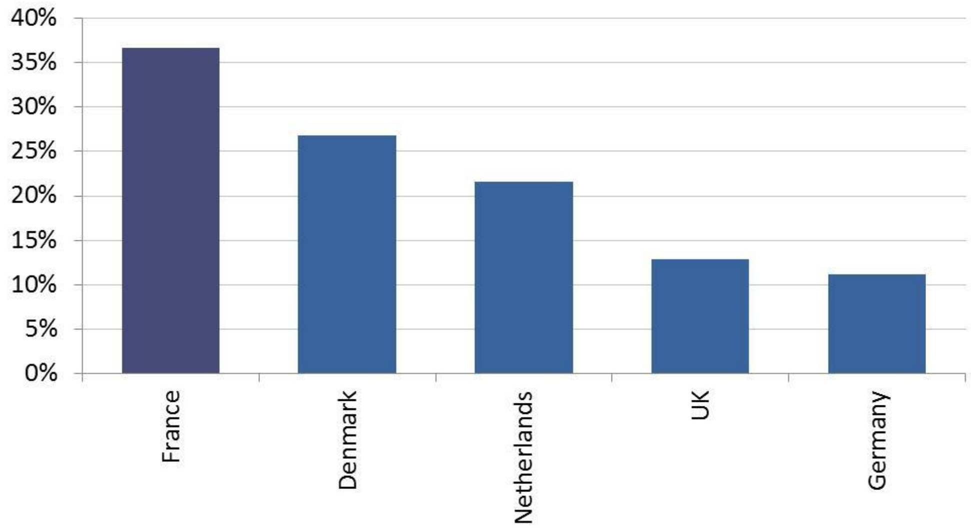
Therefore, the height of buildings does not explain the lower performance of France, as it is the country with the largest share of buildings above four floors.

Figure 6 : Share of collective dwellings higher than four floors (2004)

5 Source ECN for The Netherlands and simulation with EQTOR model for France (http://www.anah.fr/fileadmin/anahmedias/eqtor).

6 We will see later on an estimate of this impact, but the lack of data on both, the distribution between different types of non-detached houses (with two sides or one side) and the specific consumption by type of individual dwellings, makes the assessment uncertain.

7 Given the availability of data, the height threshold is fixed at 4 floors.



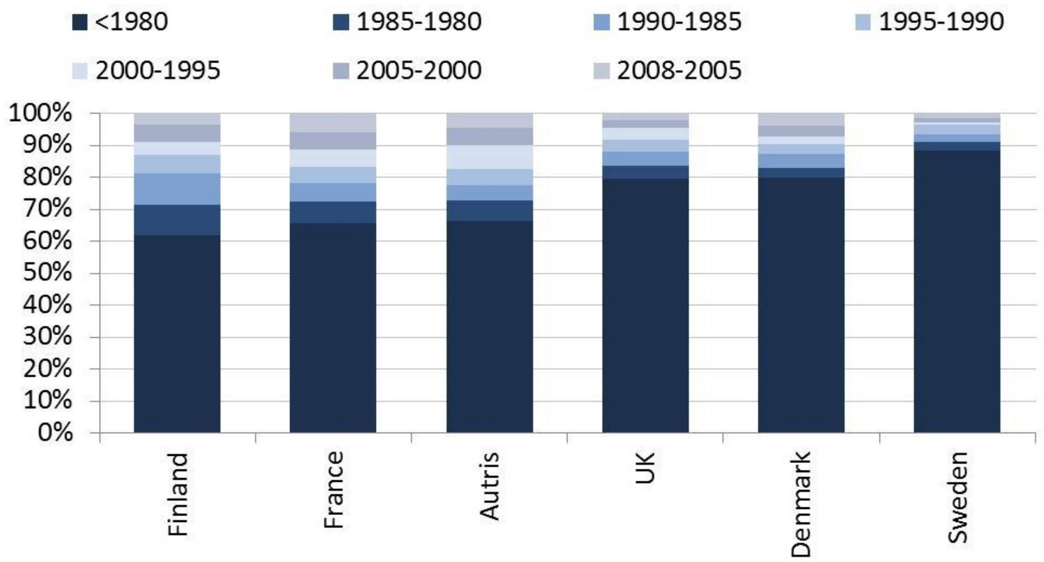
Source: Housing statistics in the EU in 2010

2.2. Average age of dwelling and thermal regulations

2.2.1. Average age of dwellings

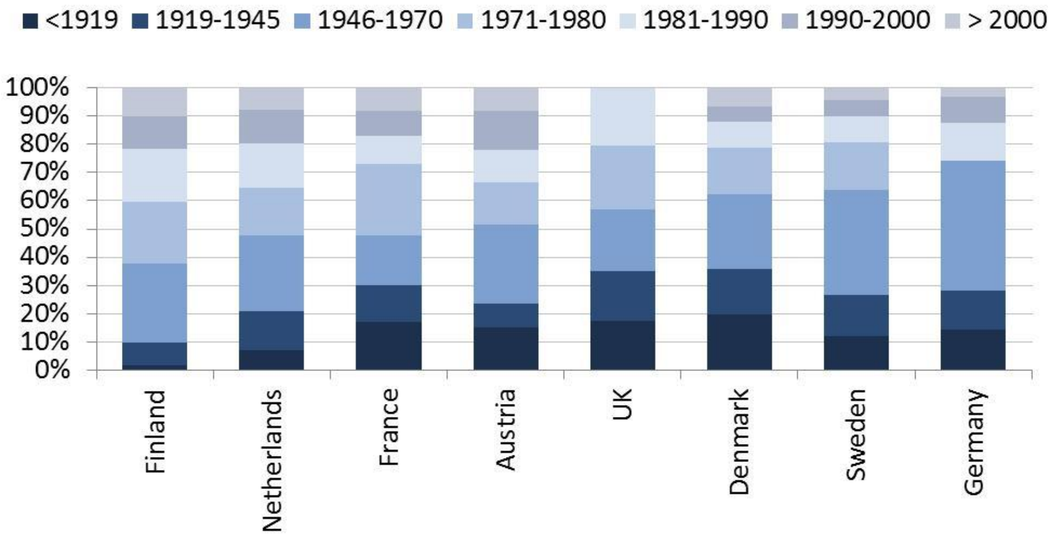
The average age of buildings and the development of new buildings in total stock represent a good indicator of quality and standards of construction. The higher the share of recent dwelling is, i.e. built with more efficient standards, the higher should be the energy performance of the stock.
Denmark and Sweden have the lowest proportion of recent dwellings, and therefore should be less insulated on average: only 10% of the stock was built after 1980 in Sweden, and 20% in Denmark. In contrast, France has renewed its dwelling stock faster, 35% of the dwelling stock was built after 1980 (**Figure 7**). The Netherlands has even a more recent dwelling stock than France (**Figure 8**).

Figure 7 : Age distribution of dwellings since 1980 (2008)



Source : Odyssee, calculation Enerdata

Figure 8 : Age distribution of dwellings since 1900 [8]



Source: Housing statistics in the EU in 2010

The better energy performance of the Netherlands may be partly explained by this rapid turnover of dwelling stock. The fact that the age of the buildings does not explain the differences in consumption between France and Denmark assumes that thermal regulations might have been stronger and/or that dwellings were better retrofitted in Denmark.

2.2.2. Thermal regulations

Energy efficiency standards enforced on new dwellings also have an impact on the space heating energy performance. However, the magnitude of this impact depends on the frequency of thermal regulations updates and on their severity. These standards require theoretical maximum heating unit consumption for new buildings, as shown in **Figure 9**[9].

The Netherlands have the highest number of thermal regulations over the past thirty years, with eight updates. Thus, the theoretical specific consumption of new buildings has decreased significantly over time: by 70% between 1983 and 2008 regulations. The Netherlands and Germany have presently the highest standards (0.3 toe/dwelling, or 3,500 kWh/dwelling).

Denmark implemented four thermal regulations between 1985 and 2010. They enforced on average a 20% reduction on the specific consumption at each thermal regulation. Consequently, the theoretical specific consumption has decreased significantly, by 55%; between 1985 and 2010: thus a dwelling built in 2010 should consume 55% less than a dwelling built in 1985.

In France, six thermal regulations were implemented since the 70's. The comparison of France with other countries highlights the following conclusions:

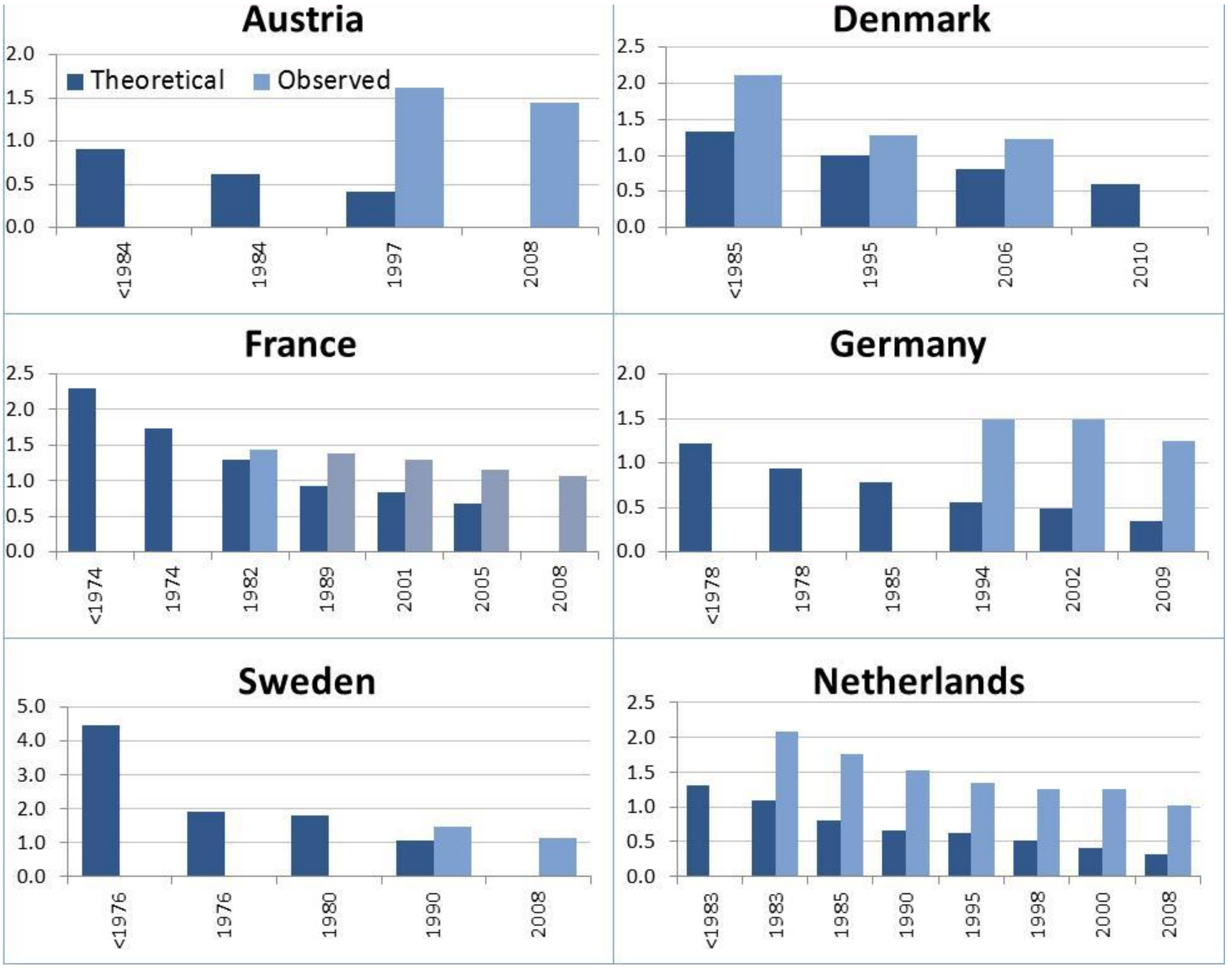
- The difference between the average specific consumption of the dwelling stock and the requirement of new dwellings are lower in France than in all the other counties;
- In 2010, the theoretical consumption of new dwellings was equal to around 0.7 toe/dwelling (or 8,100 kWh/dwelling), a level 55% higher than the last regulations of

[9]The average space heating consumption observed in the total dwelling stock are inserted on the right hand side of each thermal regulation as a reference.

the Netherlands (2005), and twice higher than the last regulations implemented in Germany (2009).

- The specific consumption of new dwellings decreases slower than in the Netherlands, with a decrease of 47% between 1982 and 2008, compared to 70% in the Netherlands during the same period.

Figure 9 : Specific consumption of new dwelling (theoretical) vs average stock at each thermal regulation (toe/dwelling)



Source Odyssee

2.3. Insulation characteristics of dwelling

2.3.1. Wall and roof insulation

An Eurima's survey[10] brings some insights to our analysis on new dwellings (**Figure 10 :** Average thickness of different insulation in mm per degree day. It is completed for The Netherlands with an analysis carried out by ECN for the project that gives penetration rates of insulation (**Figure 29** in Annex).

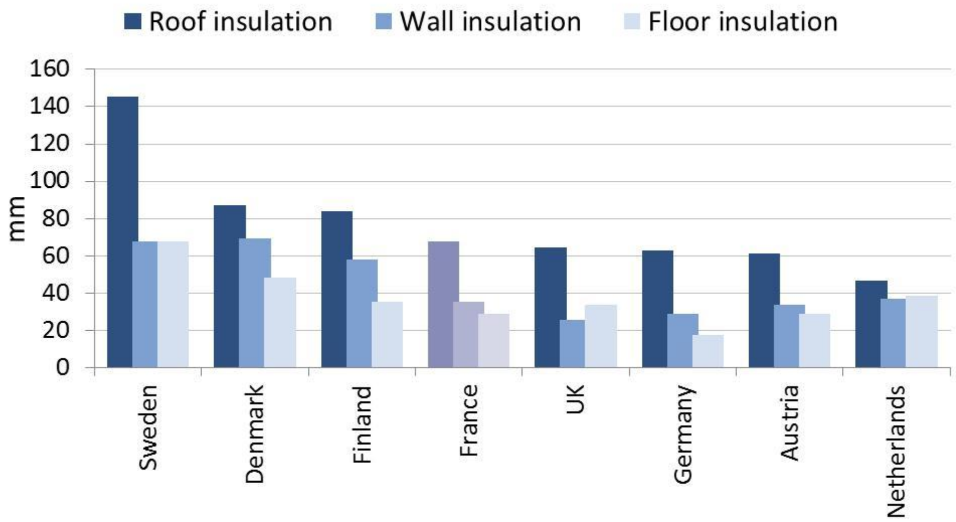
Concerning roof insulation of new dwellings, France was fourth in 2004, with an average thickness of 210 mm for roofing. The thickness of the wall insulation was on average 110

[10] http://www.eurima.org/insulation-thickness/#01. These data were not updated since 2004. But the insulation level evolves sloxly, thus the figure represent well the actual situation in each country.

mm, which is the fifth best performance of the benchmark. Finally, the floor insulation is one of the finest of the benchmark, with 90 mm in the sixth position closed to Austria.

The Nordic countries, with colder winters, have greater insulation thickness than France. If these thicknesses are corrected by the number of degree-days, France keeps exactly the same position (**Figure 10**).

Figure 10 : Average thickness of different insulation in mm per degree day



Source Eurima, 2004, estimation Enerdata

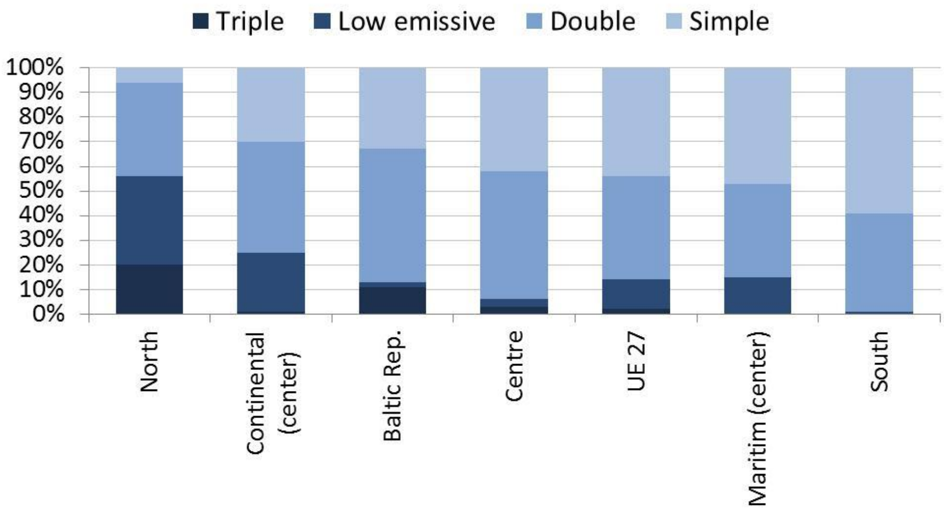
2.3.2. Insulation of glazing

There is few accurate data on the housing distribution by glazing type (double, triple, or low emission, etc.)[11]. This study will be available in October 2011. It will specify the distribution of houses according to the type of glazing. The European Association for the glass industry, "Glass for Europe", has only data by European region (**Figure 11**). The Nordic countries have obviously a higher share of efficient glazing than European average, or than countries in the South of Europe.

In Finland, there exists a label on glazing quality. In 2010, 15% of total sales were Class A, and the majority of sales were in class A. In the Netherlands, 85% of homes have double glazing and 15% have low-emissive glazing[12]. In France, in 2006, 69% of the dwelling stock had over 50% of double glazing. The glazing insulation seems significantly better in the Netherlands and in Finland because of low emissivity glazing penetration that is higher than in France.

[11] BPIE, Building Performance Institute[11] has launched a major investigation on housing stock characteristics in Europe. This study will be available in October 2011. It will specify the distribution of houses according to the type of glazing (http://www.bpie.eu/).
[12] The ECN report inserted in Appendix indicates that glass insulation is much more popular than roof or wall insulation, because of comfort.

Figure 11 : Distribution of dwelling by type of glazing



Source : Glass for Europe

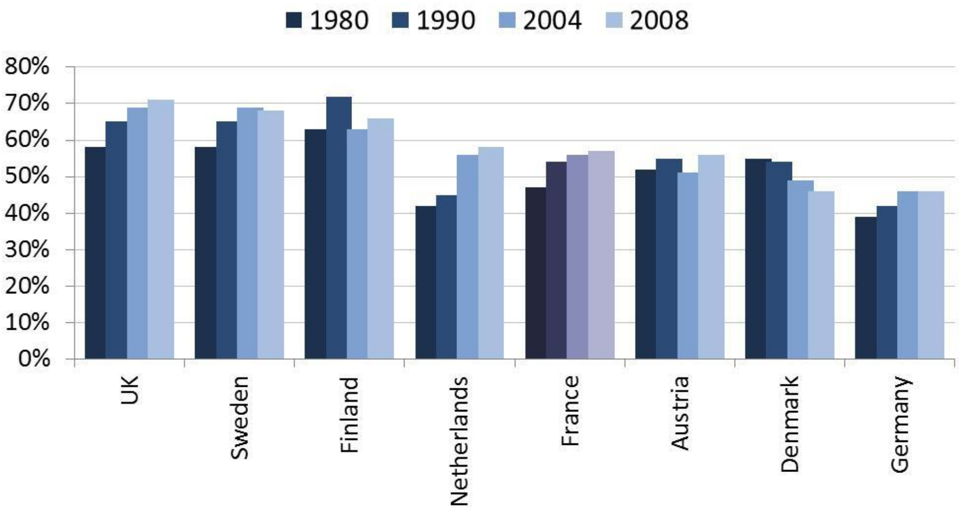
2.4. Ownership structure

The ownership structure certainly has an impact on the average unit consumption of dwelling. The installation of an efficient heating and improvements in the insulation of dwelling have a significant cost that a homeowner bears more easily than a tenant. Whereas it is in the owner's interest to invest in order to reduce energy costs over the long term, tenants have little incentive to improve dwellings that they do not own.

The share of owners is about the same in France and the Netherlands (57%): the ownership structure does not seem to explain the performance gap between France and the Netherlands. On the other hand, the share of owners is much lower in Denmark (46%), which is to the detriment of France when comparing the performance gap between these two countries (**Figure 12**).

The share of owners has increased in every country with the exception of Denmark. In France the proportion has increased from 47% in 1980 to 57% in 2008. This increase should be reflected in the improvement of energy performance.

Figure 12 : Share of owners between 1980 and 2008



Source: Housing statistics in the EU in 2010

2.5. Space heating equipment structure

In order to assess the energy performance of the dwelling stock in useful energy, we use in Figure 1, in accordance with the approach taken in ODYSSEE, identical average efficiency by energy for all countries and fixed over time. This approach has the advantage, when measuring the energy efficiency trends between countries, to separate the effect of energy substitutions from effect of energy efficiency gains that are related to the dissemination of more efficient equipment, such as condensing boilers and heat pumps.

In order to get a more meaningful comparison of useful energy performance, it is preferable to calculate for each country the real average efficiency, taking into account the actual market shares of different types of heating equipment. This approach will mainly affect the two countries that are characterised by a high penetration of efficient equipment: the Netherlands and Sweden.

The Netherlands is the country with the highest penetration of condensing boilers (68% of the housing stock (
Table 1 and **Figure 30**). Sweden is characterized by a wide diffusion of heat pumps which can be estimated at about 18% of the dwelling stock (
Table 1). The stock of heat pumps in Sweden represents about half of the total European stock. In France, the diffusion is low (2% of homes equipped in 2008), nevertheless, sales have sharply increased since 2006.

Table 1 : Share of heat pumps and condensing boilers in the dwelling stock (2008)

Countries	% of HP	% of CB
Austria	2.5%	2%
Denmark	1%	8%
Finland	7%	0%
France	2 %	1.5%
UK	0%	22%
Netherlands	0%	68[13]%
Germany	1%	10%
Sweden	18%	0%

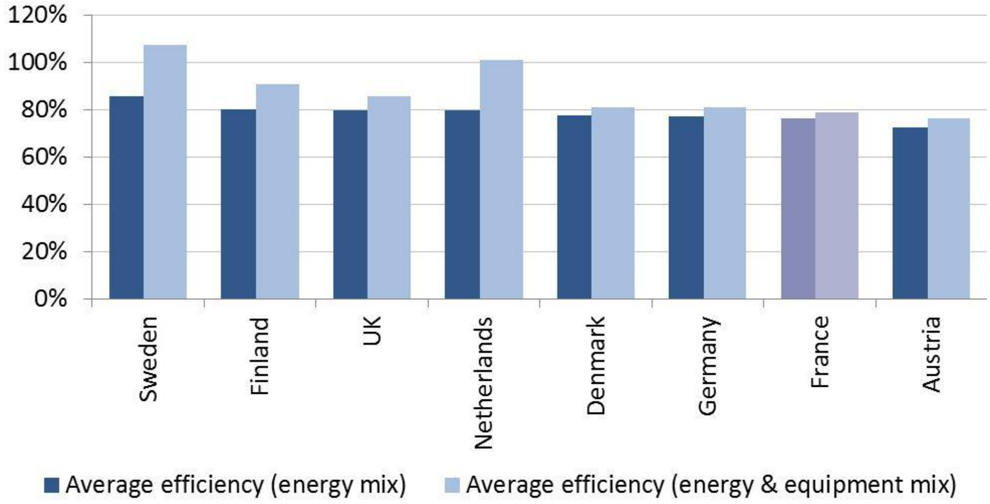
Source : Enerdata[14]

When taking into account the diffusion of condensing boiler to calculate the real energy efficiency, the indicator in useful energy of Figure 1 increases by approximately 20% for the Netherlands[15] (**Figure 13**). Thus the difference between France and Netherlands decreases.

If we take into account the diffusion of heat pumps to recalculate an average efficiency of electric heating[16], Swedish useful energy consumption becomes 25% higher than observed in Figure 1, and the difference between France and Sweden decreases.

[13] This penetration rate is slightly overestimate compared to ECN data: 63% in 2008 for ECN, **Table 5**.
[14] Data estimated from difference sources and addition data from Odyssee partners.
[15] Again, compared to ECN estimation, our efficiency of heating is slightly higher: 92% for ECN compared to 99% in our study, see **Figure 32**. The magnitude of the correction is accurate but the exact values should be considered with care as they are based on data on efficiency that have an uncertainty of + or -5% points.
[16] Compared to traditional electric heating (with an average efficiency closes to 1000%), heat pumps have an efficiency equal to 300%.

Figure 13 : Average heating efficiency rates[17]



Source : Odyssee, Enerdata

2.6. Behaviour

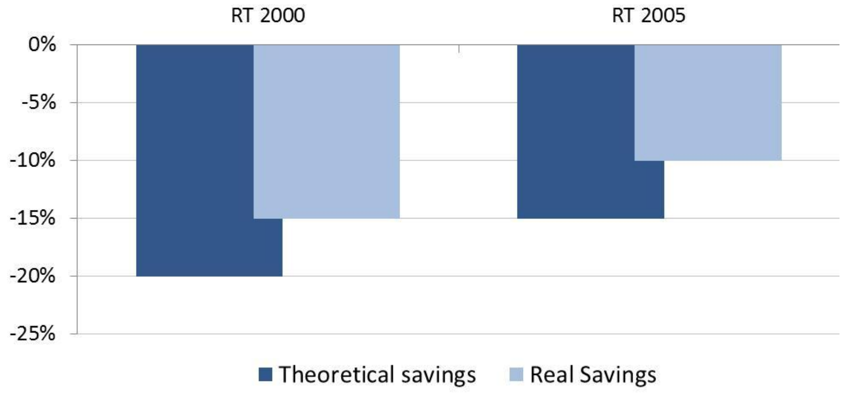
2.6.1. Compliance with thermal regulations: real vs theorical perfomances

The specific consumptions of new dwellings, as shown in Figure 9, correspond to the thermal regulation and are theoretical. What are the real performances of new dwellings? Does the real saving coincide with the theoretical one? There are only few studies on this issue but it seems that the actual performance might be below what was required, mainly for two reasons: on et one hand, a rebound effect, linked to the fact that households can increase their indoor temperature at constant budget in more insulated dwellings; on the other hand, to the quality of construction that may not be conform to the standards.

Available data demonstrate that, for France, the 2005 thermal regulation involved an average savings of 7 to 12% depending on the type of dwelling and space heating, while the regulation stipulates a decrease of 15 %[18] : thus, only 65% of the objective of the 2005 thermal regulation was reached; for the 2000 thermal regulation, it was 75% (**Figure 14**). Thus, dwellings built after 2005 consume 23.5% less than dwelling built between 1989 and 2000, instead of 32% in theory.

[17] Efficiency on the mix equipment is calculated by taking into account the market share of the different energies and the penetration of condensing boilers and heat pumps. It is slightly overestimated for Netherlands compared to ECN evaluation because with took a higher CB penetration, see **Figure 32**
[18] Source CEREN : Logement neufs et impact de la réglementation thermique 2005, Février 2010.

Figure 14 : Savings according to thermal regulation



Source: CEREN

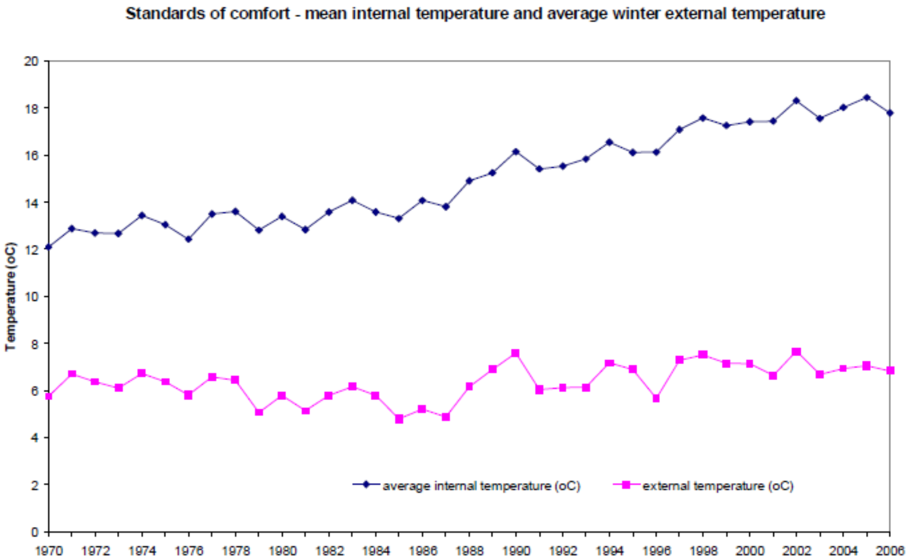
According to this study, there are marginal differences in the indoor temperature between the 2000 and 2005 thermal regulation. The rebound effect seams marginal in that case. However, this result might be linked to the fact that the difference is small between these two last regulations, and thus implies a low rebound effect.

2.6.2. Space heating behaviours

The best parameter to assess space heating behaviours is the average indoor temperature; however it is the least known.
UK is publishing data on indoor temperature over a long time period. BRE's survey indicates that household comfort is increasing over time, mainly due to the penetration of central heating in the 70's and 80's, and since now an increase in the indoor temperature reaching on average 19 ° C, compared to 16 ° C in the early 90's (**Figure 15**).

Without data on dwelling comfort in Europe, it is possible to assess its potential role through monetary factors that, depending on the economic pressures on household budget, may lead consumers to have different behaviours as to their indoor temperature.

Figure 15 : Space heating indoor temperature observed in UK

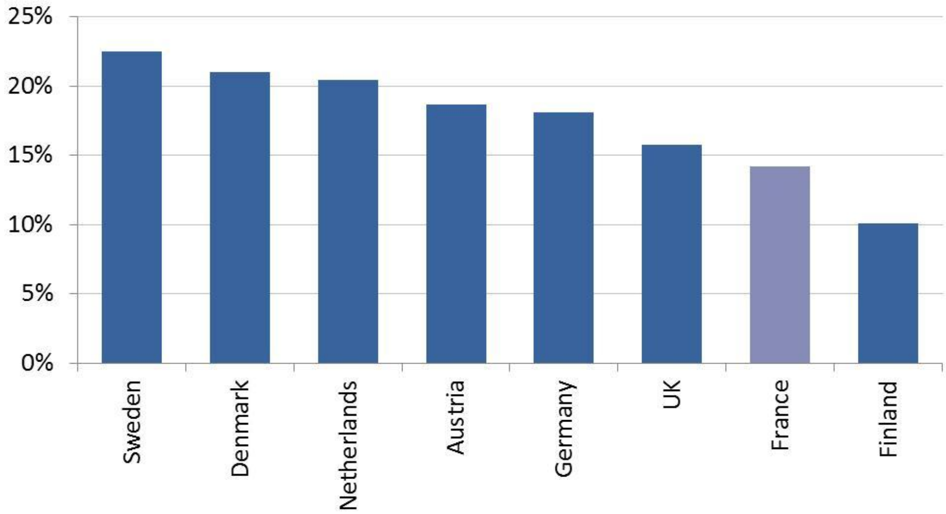


Source: Domestic Energy Fact File, BRE, 2010

2.6.3. Energy budget of households

France is with Finland, among the countries where households spend the lowest share of their budget[19] for energy expenditure (all uses): around 15% of the total budget (**Figure 16**). Sweden, Denmark and the Netherlands spend more than 20% of their dwelling expenditures.

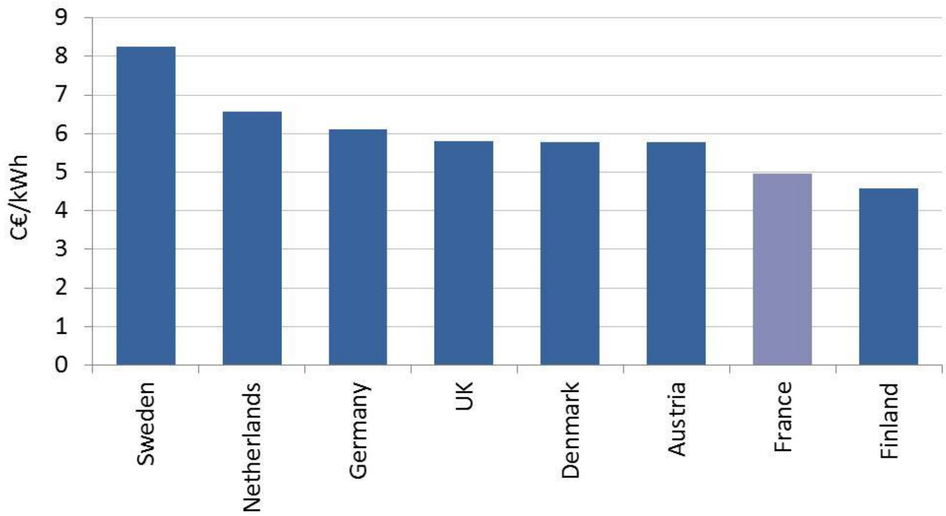
Figure 16 : Share of energy expenditures in dwelling household budget in 2007[20]



Source: Housing statistics in the EU in 2010

France has low energy prices for heating fuels (measured in purchasing power parity) compared to the other countries. The weighted average energy price for space heating was around 5 c€/kWh in 2009 in France, around 6 c€/ kWh Denmark (+20% compared to France), 6.5 c€/kWh in the Netherlands (+30%) and 8 c€/kWh in Sweden (**Figure 17**).

Figure 17 : Average energy price for space heating at power purchasing parity (2009)[21]



Source : Enerdata[22]

[19] The total expenditures of a dwelling include actual renting housing, maintenance and repair of the dwelling and water and energy consumption.
[20] 2003 for Sweden and 2002 for Denmark.
[21] Weighted average by the market share of each energy.

There might exist, for Denmark and the Netherlands, a price effect on specific consumption levels, that may imply different space heating behaviours and higher incentives to make energy savings.

2.7. Mains results

Table 2 summarizes for each factor if it has positive or negative impact on France space heating performance compared to Denmark and the Netherlands.

Table 2 : Explanatory factors of differences in specific consumption [23]

	Netherlands	Denmark	Impact
Share of collective dwellings	-	-	Advantages France
Share of semi-detached individual dwellings	++	-	Advantages strongly The Netherlands and disadvantages Denmark
Height of buildings	=	=	Advantages France
Average age of dwelling stock	=	+	Disadvantages Denmark
Insultaion thickness of new dwellings	+	-	Advantages The Netherlands and disadvantages Denmark
Glazing	++	+	Disadvantages strongly France
Owership structure	=	-	Disadvantages Denmark
Share of efficient equipment	++	+	Disadvantages France
Thermal regulation	++	+	Disadvantages France
Prices	++	++	Disadvantages France

+ : higher than France; - : lower than France ; = : no significant difference,

- Denmark and the Netherlands have a lower share of collective dwellings than France, thus this factor do not explain the least performance of France; for The Netherlands this is offset by a high share of row houses.
- France is the country with the highest proportion of tall buildings.
- Although the thermal regulations were regularly reinforced in France, they remain significantly below compared to the other countries.
- The proportion of owners is equivalent between France and The Netherlands, this factor cannot explain the difference.
- Energy prices for space heating are much lower in France , which could explain part of its lower performance.

3. Additional energy efficiency indicators

So far we examined qualitative impacts of several factors. For some of them, it is possible to take into account their quantitative impact with new adjusted indicators that will complete the indictor used so far, the useful energy consumption per m2 and degree day. We considered three additional indicators:

1. indicator adjusted to the same dwelling stock structure;
2. indicator adjusted to the same mix of equipment and dwelling stock structure;
3. indicator adjusted to the climate with a nonlinear methodology ;

[22] Gas, electricity and fuel: ENERDATA according to IEA and Eurostat; district heating: data collected from various heating suppliers in Germany, Sweden, Finland, France and Denmark; average price by weighted by energy consumption (wood included).

[23] Specific heating consumption by m² and degree day in useful energy.

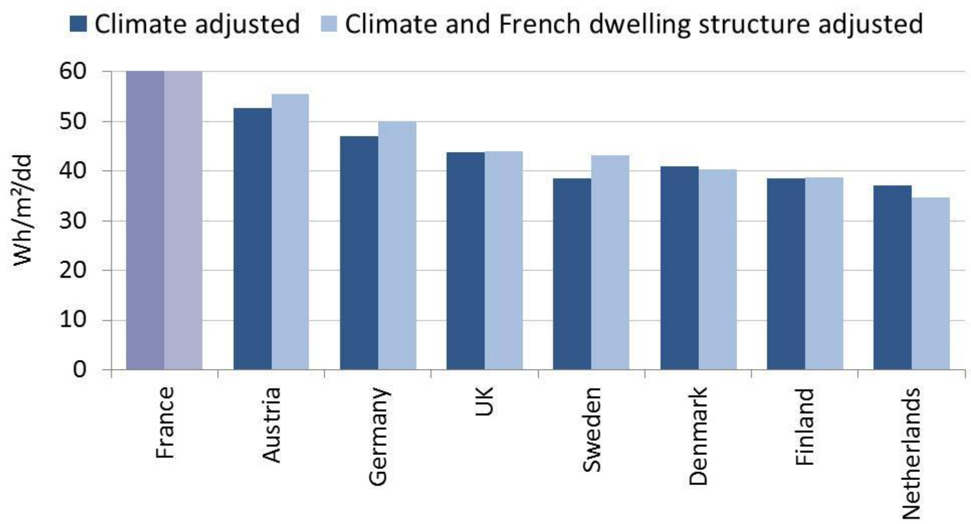
3.1. Average indicator adjusted to dwelling stock structure

To assess the impact of different dwelling stock structures between collective and individual dwellings, we will adjust the specific consumption of space heating to the same structure, i.e. the structure of France. These average adjusted specific consumptions are calculated by weighting the specific consumption of individual and collective dwellings in each country by the structure of the French dwelling stock, i.e. 56% of individual dwellings and 44% of collective dwellings.

The adjustment to the French dwelling stock structure of the specific consumption per m² and per degree day in final energy does not reduce the gap with the Netherlands: on the contrary, the Netherlands improve their performance (**Figure 18**). The difference is as well increasing with Denmark, by 5 points.

This adjustment, however, reduces the difference by 8 points between France and Sweden; but the specific consumption in Sweden stays 30% lower. This is the same for Germany where the gap is reduced by 5 points, and where the specific consumption is still significantly lower than in France (by18%). The difference between France and Austria tightens. Although this structure adjustment decreases the gap between France and other countries, France still remains the least efficient.

Figure 18 : Specific energy consumption for space heating (final energy, 2008)



Source : Odyssee, calculation Enerdata

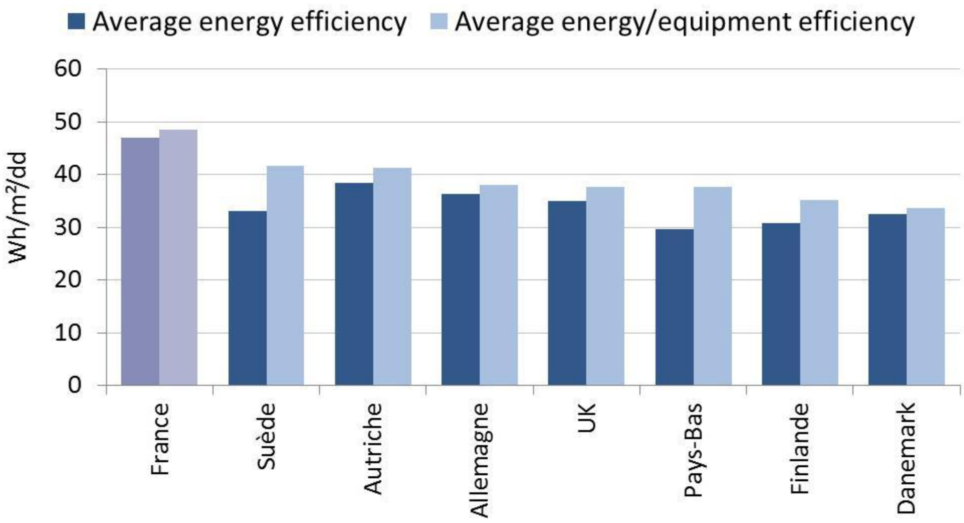
The Netherlands have a higher proportion of semi-detached individual dwellings than France. This structural effect could give advantage to The Netherlands in the comparison. In the absence of detailed data on specific consumption by individual dwellings, it is not possible to create for all countries an indicator adjusted on the share of detached houses and semi-detached dwellings. However, we can make this adjustment to the Netherlands thanks to additional data[24]. This new adjustment shows that actually it compensates for the lower share of collective dwellings in The Netherlands. When combining the two adjustments, on the structure between individual and collective dwellings, on the one hand, and on the structure between detached and non-detached houses, these adjustments have a very small impact.

[24] Data on structure and specific consumption of individual dwelling by m² were provided by ECN.

3.2. Indicator adjusted to the same space heating structure

The first indicator in useful energy was based on an average efficiency by energy that was identical for all countries. (**Figure 19** gives a more realistic measurement of the useful energy consumption, based on a new average efficiency per energy that takes into account the market shares of condensing boilers for gas, and heats pumps for electricity[25]). This revised heating efficiency was called average energy/equipment efficiency.

Figure 19 : Specific consumption with average energy/equipment efficiency[26] (2008)



Source : Odyssee, calculation Enerdata

In order to calculate an indicator in final energy adjusted to both, dwelling stock structure and space heating structure of France, the useful specific energy consumption adjusted by the French dwelling stock has been divided by the average efficiency observed in France (that is calculated from the mix of energy and equipment of space heating of France, i.e. 79%)[27].

The best performing countries remains the Netherlands and Denmark, although the difference is narrowing with France and is now 30% (**Figure 20**). France remains the least efficient country despite both adjustments. The difference with Sweden is considerably reduced; it is only 4% instead of 37%. The gap with Austria and Germany is not affected.

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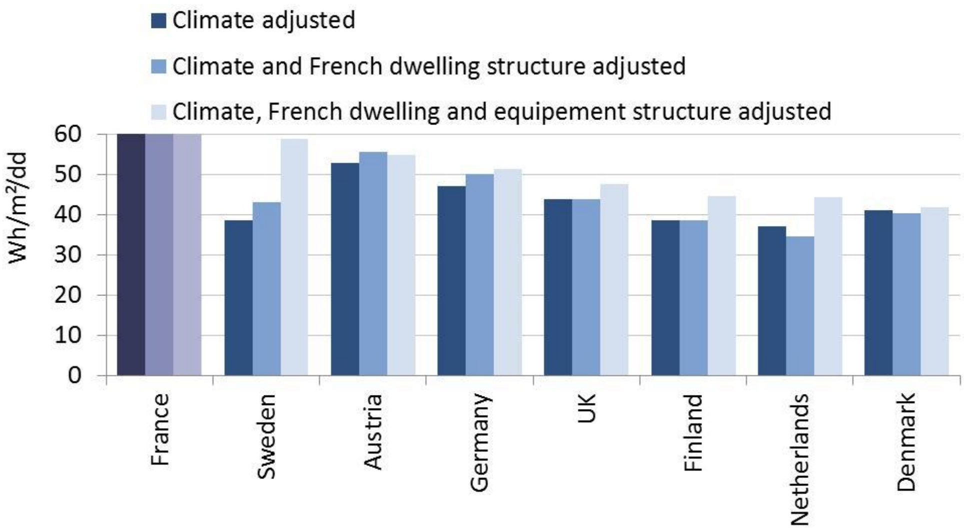
[25] We assume an average efficiency of 300% for heat pumps, and equals to 107% for condensing boilers.
[26] Useful energy
[27] It is calculated by assuming 2.5% of heat pumps and 2% of condensing boilers.

Figure 20 : Consumption adjusted to French dwelling stock and energy/equipment structure (final energy, 2008)



Source : Odyssee, calculation Enerdata

3.3. Indicators with a non linear climate adjustment

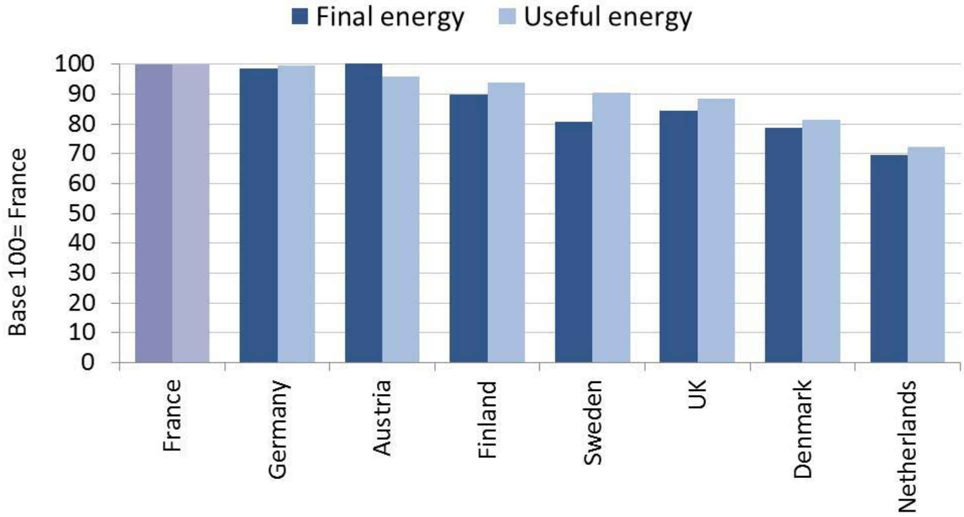
So far, the indicators were adjusted to the same climate by dividing the specific consumption by the number of degree days in each country; this was equivalent to consider that space heating consumption is proportional to the number of degree days.

Swen Werner from Chalmers University of Technology proposed an alternative approach to improve the country comparisons[28], considering that the linear methodology does not take into account the fact that the optimal level of thickness is not linearly dependent on the climate, i.e. with the number of degree days, and depends on the insulation cost, the thermal thickness conductivity and is a reverse function of the heating cost with an elasticity of -0.5.
He proposed to use a new correction method to compare countries which implies that the optimum insulation thickness is proportional to the square root of the number of degree-days, according to a given space heating budget and thermal insulation. This method reduces the difference between specific consumption adjusted to the same climate (**Figure 21**).

In general, the nonlinear climate adjustment improves the position of France as the country has a lower number of degree days than the other countries. The Netherlands have still the lowest specific consumption per m² (in useful or final energy), 30% lower (against 40% with the linear methodology) than France. Thanks to this new method, the specific consumption of space heating in useful energy in France is equivalent to Germany or Austria.

[28] "The New European Heating Index", Swen Werner- Chalmer University of Technology-2006

Figure 21 : Specific consumption of space heating in final and useful energy 2008 (base 100)

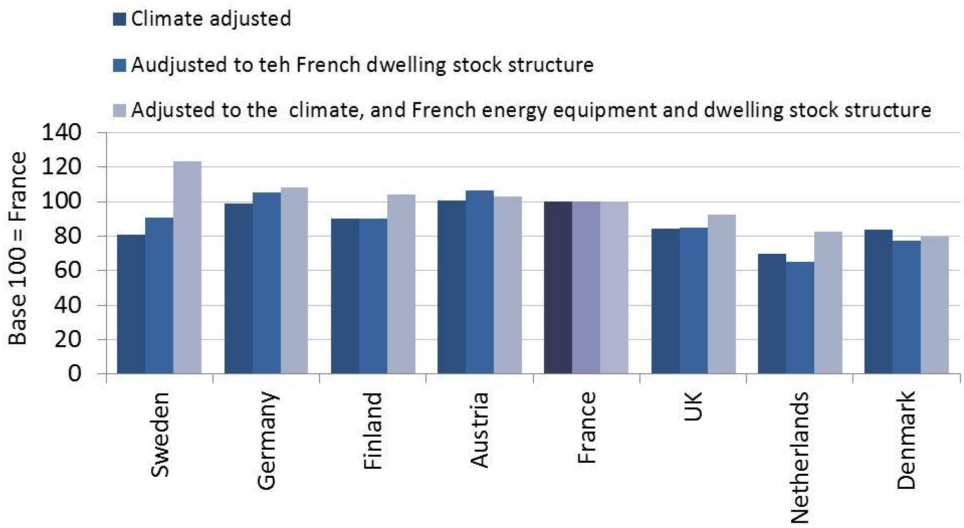


Source : Odyssee, calcul Enerdata avec méthode de Werner

By applying a nonlinear climate adjustment[29] to the specific consumption adjusted to the same dwelling stock, and taking into account the average efficiency of energy /equipment mix, the difference between France and other countries decreases (**Figure 22**). Thus France is not anymore the least performing country, Sweden, Germany and Austria are now worse than France.

The difference with Denmark and Netherlands is however still significant, respectively 19% and 17%. This gap is nevertheless lower than initially observed in **Figure 2** (i.e. 33% of difference with Denmark and 40% with the Netherlands).

Figure 22 : Consumption adjusted to the French dwelling and equipment/energy structure (final energy, 2008) (nonlinear climate adjustment)



Source : Calculation Enerdata

[29] Werner's methology (Chalmer, 2008).

3.4. Main results of additional indicators

The differences between France and the two best performing countries, the Netherlands and Denmark, are summarized in the table below. It shows that:

- The structure of the dwelling stock significantly influences the specific consumption for space heating in some countries (Germany, Austria, Sweden) but not for others, especially for the two benchmark countries (The Netherlands and Denmark).
- Taking into account the efficiency of heating equipment by technology affects the specific consumption, and reduces the gap between France and the Netherlands .
- The nonlinear climate adjustment reduces differences in specific consumption, but France remains still less efficient than the Netherlands and Denmark

Table 3 : Differences in specific consumption with France according to adjustments

	Denmark	Netherlands
Observed	-33%	-39%
Adjusted to the French dwelling stock structure	-34%	-44%
Adjusted to the French individual dwelling structure	n.d.	-38%
Adjusted to the French dwelling and heating equipment/energy structure	-32%	-28%

4. Consumption differences breakdown between France and other countries

This section proposes a breakdown of the specific consumption differences between France and the other countries, with a in particular focus on Denmark and The Netherlands.

The performance difference between France and benchmark countries will be decomposed here for the year 2008 to show the effect of two explanatory factors, for which it is possible to quantify their impact:

- The dwelling stock structure, between individual and collective dwellings;
- The energy and space heating equipment mix, that affects directly the space heating efficiency due to the different energy performances of energy sources and space heating equipment.

4.1. Breakdown of the differences performances with France

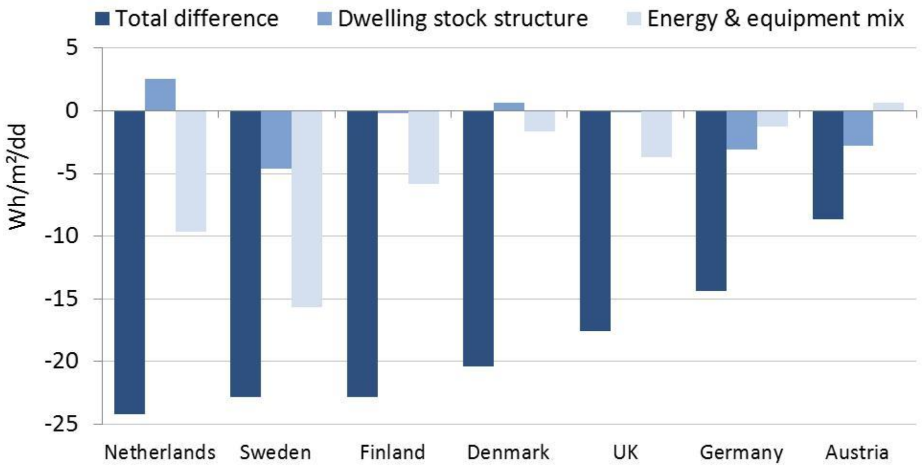
Figure 23 summarizes the relative importance of various explanatory factors on the specific consumption differences between benchmark countries and France (in final energy and climate adjusted).

For Sweden, it is possible to explain most of the difference from the two above mentioned factors: 20% of the difference is explained by the dwelling stock structure and 70% by the energy and space heating equipment mix.

For most of the other countries, the adjustments explain a marginal part of the gap, and the "other effects" are predominant (**Figure 23**). These other effects correspond essentially to differences in insulation level, but maybe to some extent to differences in behaviours. These insulation level differences can be explained by several factors, such as:

- Differences in new dwelling standards;
- Initial difference in the dwelling stock insulation, before the implementation of thermal regulations;
- And differences in the retrofitting of existing dwellings.

Figure 23 : Differences with France (in final energy and climate adjusted)

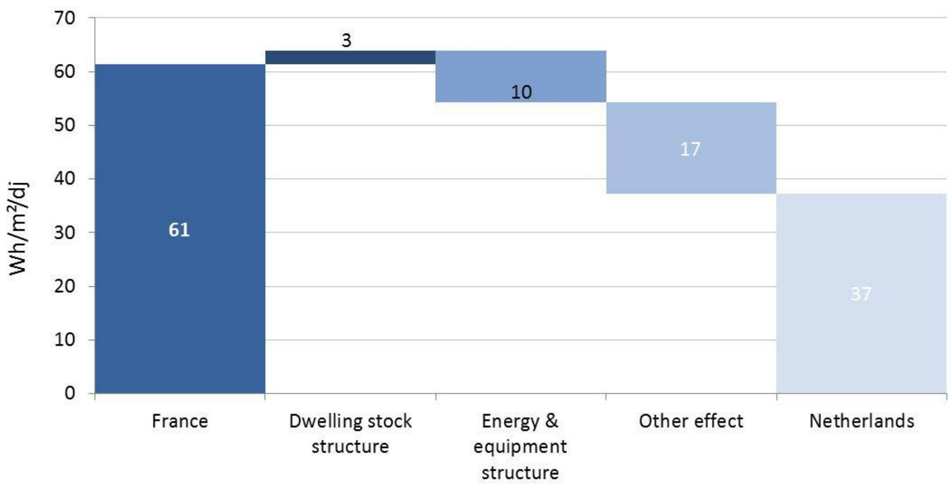


Source : Odyssee, calculation Enerdata

The difference of energy performance between France and the Netherlands corresponds to 24 Wh/m2/degree day, that is to say 39% of difference: 40% of this difference is explained by differences in energy and equipment mix, because of the high penetration of condensing boilers in the Netherlands (**Figure 24**).

Most of the rest of the difference between France and Netherlands comes from differences in new dwelling insulation level, as discussed above. However it is also highly dependent on the existing dwelling stock: because of higher thermal retrofitting in existing buildings. A small part of this difference may probably be explained by behaviours leading to a lower temperature in the Netherlands because of higher prices. Unfortunately there is no data to confirm this hypothesis. The dwelling stock structure plays in the opposite direction: the proportion of individual dwellings is higher in the Netherlands.

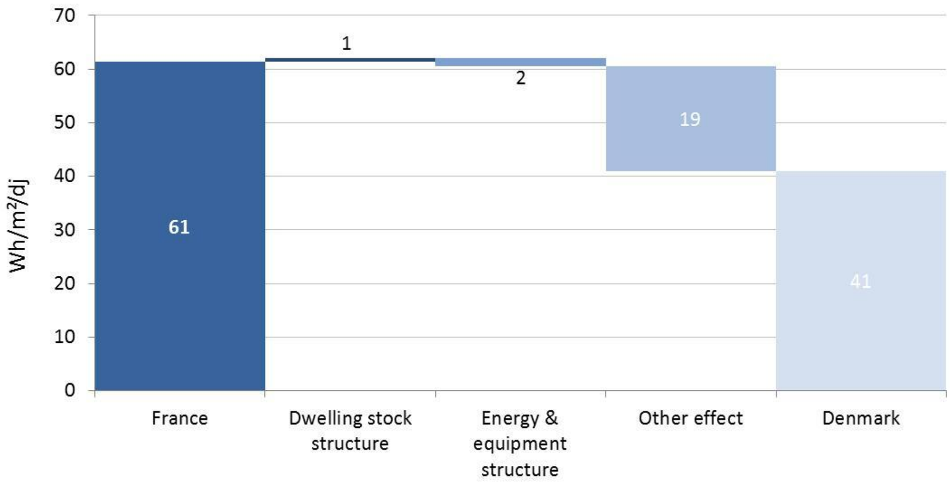
Figure 24 : Specific consumption difference between France and Netherlands



Source : Odyssee, calculation Enerdata

Between Denmark and France, the difference in specific consumption is equal to 17 Wh/m2/degree day, corresponding to 28% of differences: a small part of this difference (7%) is related to the energy and equipment mix, the dwelling stock structure has an opposite effect because there is a higher proportion of individual dwelling than in France. The differences in the dwelling stock structure and energy mix explain only a marginal part the difference between Denmark and France, and, as the Netherlands, most of the difference is explained by different thermal insulations (**Figure 25**).

Figure 25 : Specific consumption difference between France and Denmark



Source : Odyssee, calculation Enerdata

The dwelling stock structure and the energy mix explain only a small part of the differences between the best performing countries (Denmark, Netherlands) and France: differences in dwelling insulation, particularly in existing dwellings, have a decisive impact.

It is very difficult to get comprehensive data on the magnitude of the thermal retrofitting of existing dwellings: number of retrofitted dwellings per year, share of the retrofitted dwelling stock, average saving rates from retrofitting[30]. In order to assess the relative impact of this factor, and because of a lack of information, we have modelled the dwelling stock insulation evolution from 1980 (the oldest data available) and particularly the insulation levels of the stock of existing dwellings.

4.2. Breakdown of efficiency gain over time

4.2.1. Trend in space heating consumption since 1980

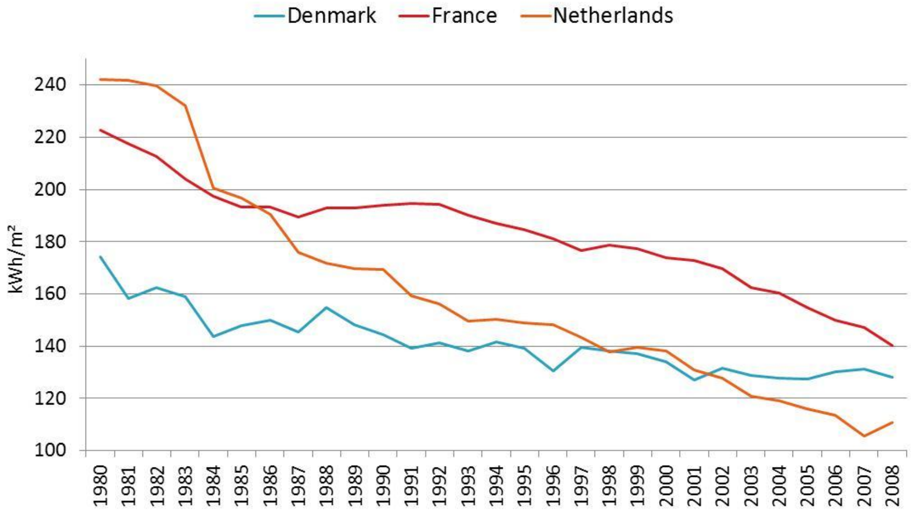
Since 1980, the Netherlands have significantly reduced their specific space heating consumption, 2.7%/year on average between 1980 and 2008. However this specific consumption was higher than France in the early 80's, and is nowadays much lower. Most of the decrease in the specific consumption occurred during the first decade (**Figure 26**).

In France, the specific consumption declined as well, but less rapidly than in the Netherlands, 1.1%/year on average.
In 1980, Denmark had specific space heating unit consumption much lower than France (about 20% less). But this consumption decreased at a slower pace than in France until

[30] Even in France these macro data are not available, an annual survey from ADEME identify the number of energy savings retrofitting since 20 years. However it does not provide quantitative evaluation of the total level of such savings

2008[31]. The dwelling stock structure does not explain this steady consumption, given the fact that the share of individual dwelling is decreasing over time.

Figure 26 : Evolution of space heating consumption at normal climate since 1980



Source : Odyssee

In France the average real price of space heating energy (at constant prices) decreased by 0.5%/year on average between 1980 and 2008, while an opposite trend can be observed in the Netherlands and Denmark, where it increased on average by respectively 1.6%/year and 0.8%/year. At the same time, the heating consumption declined less rapidly in France than in The Netherlands. The gradual increase of energy prices in both Denmark and Netherlands may partly explain their better performance.

4.2.1. Breakdown of efficiency gain in Netherlands

To assess factors that can explain evolution differences observed between France and the Netherlands[32], energy efficiency gains are broken down according to three main explanatory factors:

- Thermal regulations in new dwellings that were built with steady reinforced standards over time,
- The impact of the space heating efficiency improvement related to the evolution of energy market share and space heating equipment.
- Insulation improvement impact on existing dwellings, related to their retrofitting.

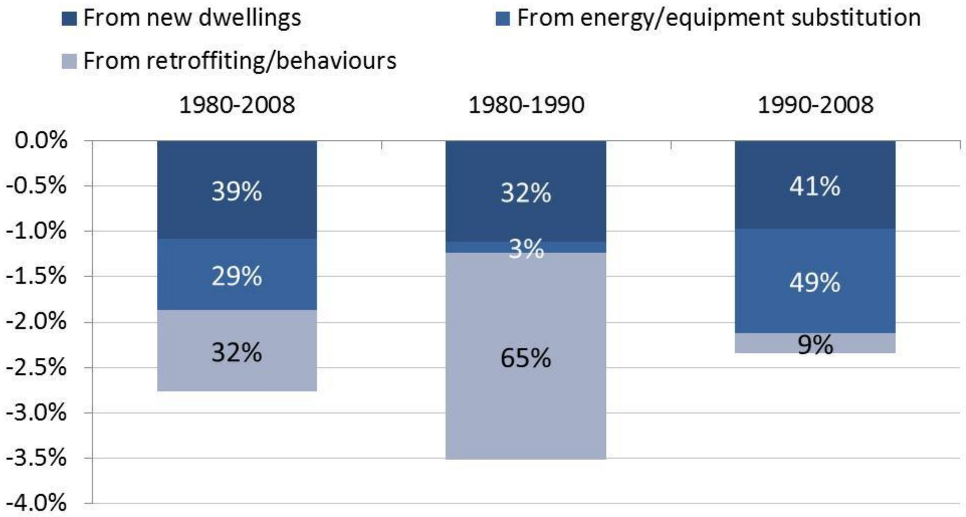
The sharp decrease in the average specific consumption in the Netherlands is due to a better performance of the existing dwelling stock. Indeed, new dwellings helped to reduce the specific consumption by 0.9%/year, while the existing building has reduced it by 1.8%/year. This decrease in specific consumption of existing dwellings is composed of a decrease of 0.8%/year (thanks to the diffusion of condensing boilers), and 1%/year through better dwelling insulation (**Figure 27**).

[31] In the case of Denmark, Odyssee data do not distinguish water and space heating consumptions. Thus we estimated for each year that the share of water heating corresponded to 20% of the total. However, if the dwelling insulation improved across time, the share of space heating consumption could diminish, as the water heating consumption doesn't vary significantly across time. This bias could explain the fact that specific space heating consumption decrease slowing from 1980 to 2008.

[32] Denmark was not included in this section because of a statistical problem above-mentioned (there is no distinction between water and space heating in the total).

The reduction of the specific consumption in the Netherlands occurred mainly during the first decade, from 1980 to 1990, with an average decrease of 3.5%/year, against 2.4%/year during the next period 1990 to 2008. Around 65% of the decrease observed in the 80's is due to extensive renovation of existing dwellings. Since 1990, the high penetration of condensing boilers explains half of the decrease in specific consumption. The new building insulation contributed as well to improve Netherlands performance[33].

Figure 27 : Specific heating consumption variation factors in Netherlands

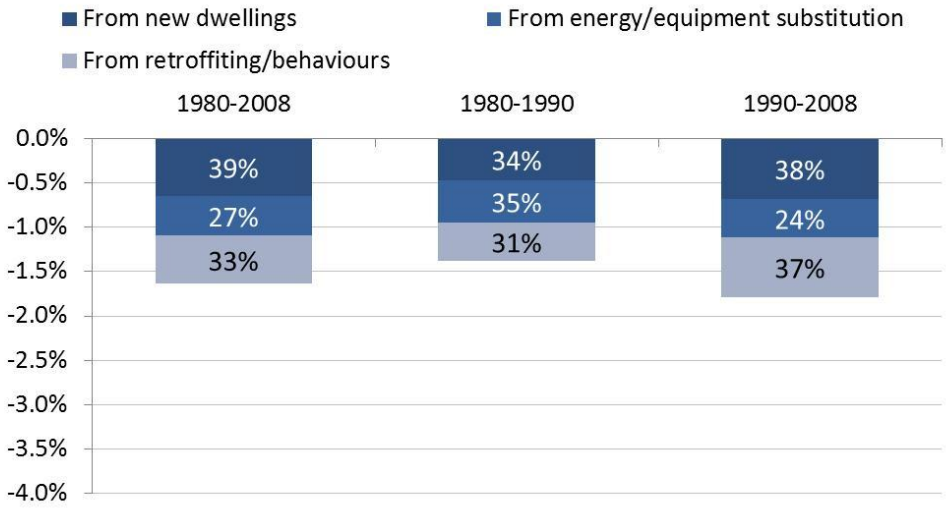


Source : Odyssee, calculation Enerdata

4.2.2. Breakdown of efficiency gain in France

In France, the specific energy consumption for space heating decreased at a slower pace than in The Netherlands: 1.6%/year on average. First, this decrease was due to new dwelling insulation improvement (thermal regulation), followed by retrofitting and thirdly by energy and equipment substitutions (**Figure 28**). As this decrease occurs although prices were steady, we can assume that behaviours had no significant influence on this global decrease.

Figure 28 : Specific heating consumption variation factors in France



Source : Odyssee, calculation Enerdata

33 This result is consistent with the annual savings analysis of ECN study (section 6.4), although we underestimate the impact of renovations (25%), and the impact of new dwelling would be 25%.

5. Conclusion

The structure of occupation (owner versus renter), building height, the average age of building stock are not significantly different from one country to another, and do not explain the performance difference. France is the country with the highest proportion of high rise buildings. Finally, the proportion of owners is pretty closed between France and the best performing countries.

The **dwelling stock** structure between individual and collective dwellings influence countries energy performance, since an individual dwelling consumes on average per m² more than a collective dwelling, and as the share of individual and collective dwellings is substantially different from one country to another. However, this factor has a small influence for the Denmark, and in a manner that disadvantages France. Indeed, if Denmark data are adjusted to the French dwelling stock structure, the performance differences become larger. Concerning the Netherlands, taking into account the structure of individual dwelling, between isolated and non-isolated where specific consumption are significantly different according both types, the least performance of collective dwellings in Netherlands is offset by the fact that the Netherlands is mainly composed of semi-detached houses (60% against 20% in France of the housing total): in the end, dwelling stock adjustments to the French structure does not change the performance of Netherlands.

Differences in **energy and space heating equipment mix** allow to explain some performance differences between France and the Netherlands. In particular, the diffusion of condensing boilers and heat pumps significantly alter the heating average energy efficiency, and therefore the specific consumption. Condensing boilers are the dominant heating equipment in the Netherlands (68 % of the dwelling stock), and have a significant impact of energy performance. The space heating specific consumption adjustment to the French energy and equipment mix (that is to say 2.5% of heat pumps and 2% of condensing boilers in 2008) reduces the differences: the Netherlands would consume 27% more, the impact of this adjustment is smaller for Denmark (only 5% extra). However, even after this correction, France is still significantly less efficient than these two countries.

Without data on the **thermal retrofitting of existing dwellings**, we assessed by modelling the impact of new dwelling penetration and the impact of substitution of energy and space heating equipment. We evaluated, by difference with the overall trend observed, the impact of the existing dwelling stock retrofitting since 1980. In the Netherlands, efforts to improve energy efficiency on existing dwelling occurred during the 80's thanks to very active policies[34]: the national program for existing dwelling insulation concerned 2.5 million dwellings from 1978 to 1987. While the energy performance of the Netherlands was lower than France (9% of difference), it became rapidly more efficient as early as 1986. In addition, Denmark and the Netherlands implemented more thermal regulations than France, and enforced more rigorous specific consumption norms for new dwelling than in France.

In France, the growing share of new dwellings since 1980 explains most of the specific space heating diminution.

The calculation of this Odyssee indicator, i.e. the specific consumption of space heating, was linear and based on the annual number of degree days. According to Swen Werner, from Chalmers University, this linear methodology does not take into account the optimal insulation level of dwellings: he proposed an alternative methodology that refines countries comparison. It assumes the optimal insulation thickness is proportional to the square root of the degree days, for a given heating budget and thermal insulation. Thanks to this

[34] See section 6.5 for a detailed analysis on policy measures on retrofitting process in Netherlands.

methodology, space heating consumptions are smoothed. And with a French nonlinear climate adjustment, and the same dwelling structure, France is not the least performing countries. However, it remains still 18% on average lower than Denmark and Netherlands specific consumption.

Some important data are not available, for instance, indoor temperature during winter, or the number of retrofitted households per year, the diffusion of efficient glazing, etc. For this reason, this report could not quantify the effect of all explanatory factors. However, following discussions with Odyssee partners, we hope this report will contribute to improve data collection and to better explain such energy efficiency differences.

6. Appendix : Retrofitting of dwellings in The Netherlands[35]

ECN

Energy research Centre
of the Netherlands

6.1. Introduction

The purpose of this Annex is to better understand why The Netherlands is one of the best countries in the benchmark, and in particular how far the retrofitting of existing dwellings can explain this situation. Some background data on the retrofitting process in the Netherlands will be presented. Then using different data sets available at ECN, that contain detailed information on energy efficiency measures being taken by households, additional analyzes were carried out with ECN modelling tools.

Part of this retrofitting can be linked to specific policy measures. The policy measures implemented in The Netherlands will be briefly described and the paper will also discuss how they could have influenced the retrofitting process.

6.2. Penetration rates of energy efficiency measures

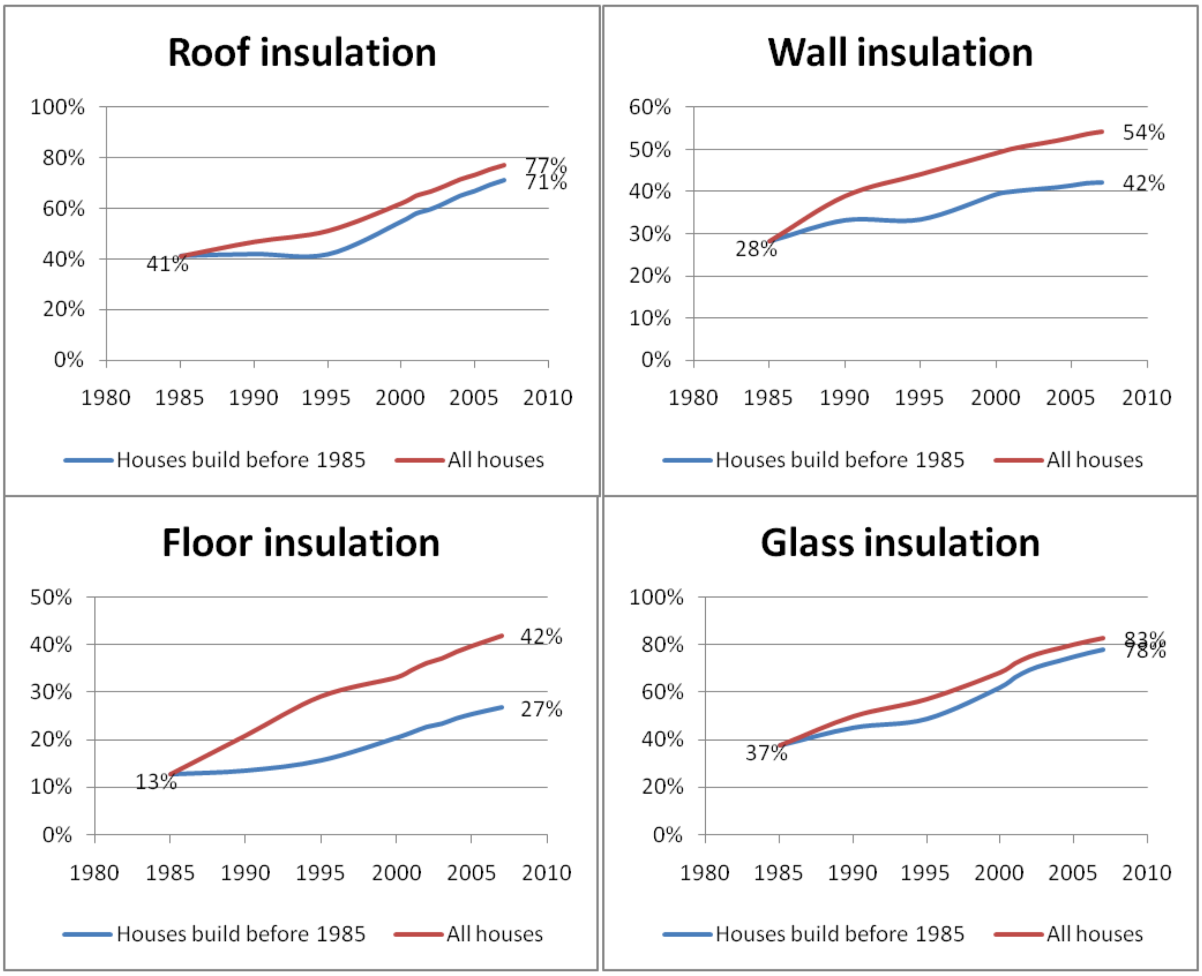
The description of the development of efficiency measures in the buildings stock is based on a combination of three surveys (WoON 2006, KWR and HOME) and data derived from ECN modelling tools:

- **WoON 2006** is a **l**arge scale survey (n> 4700 households) on energy related technical details of dwellings in the Netherlands for the year 2006.
- **KWR** is similar to WoON 2006, but cover the years 1995 and 2000.
- **HOME** is a **y**early survey based on a panel of more than 3000 households on the energy consumption in households, with data for the years 2000-2007.
- **ECN Model** contain information for the years 1985-2040; it is used for projecting energy consumption in residential and non-residential buildings.
  Data derived from our modelling tools Our models.

Figure 29 shows the development of penetration rates for insulation measures. For all measures the penetration increases, but this is partly due to newly build dwellings. To see how insulation of existing dwellings developed, we estimated the penetration rate for dwellings built before 1985 (the blue line). Floor and wall insulation are not increasing as fast as glass or roof insulation in existing dwellings. Glass insulation is much more popular because of comfort. The increase of roof insulation is partly due to the replacement of flat roofs about every 25 years. In this replacement, insulation is often incorporated. **Table 4** shows the detailed data.

[35] Prepared by Casper Tigchelaar, ECN Policy Studies for Enerdata.

Figure 29 : Penetration rates insulation in all dwellings and dwellings build before 1985



Source: HOME survey, KWR survey, WoON survey, ECN.

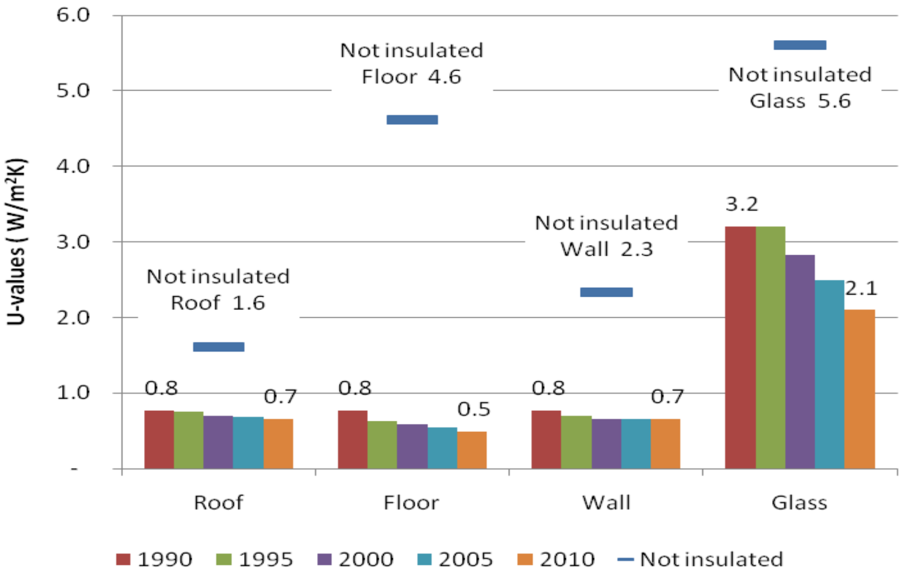
Table 4: Number of dwellings (x1000) with insulation measures

		1985	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007
All dwellings	Roof	2,218	2,763	3,435	4,123	4,362	4,510	4,696	4,901	5,060	5,248	5,416
	Floor	686	1,234	1,834	2,208	2,331	2,451	2,535	2,650	2,753	2,852	2,953
	Wall	1,519	2,295	2,769	3,268	3,364	3,439	3,504	3,573	3,653	3,740	3,812
	Glass	2,013	2,927	3,439	4,537	4,831	5,066	5,232	5,374	5,525	5,669	5,811
Dwellings before 1985	Roof	2,218	2,255	2,423	3,050	3,227	3,320	3,460	3,612	3,715	3,845	3,950
	Floor	686	726	823	1,136	1,196	1,262	1,298	1,361	1,409	1,449	1,487
	Wall	1,519	1,788	1,758	2,195	2,229	2,250	2,268	2,284	2,309	2,338	2,346
	Glass	2,013	2,419	2,428	3,464	3,697	3,876	3,996	4,085	4,181	4,267	4,345

Source: HOME survey, KWR survey, WoON survey, ECN.

It's not only important to look at the penetration of insulation measures. It's also important to look at quality. **Figure 30** shows the U-values that are used for insulating dwellings. As a reference the U-values of non-insulated parts are shown in the graph as well. Especially not-insulated floors and windows are considerable heat leaks.

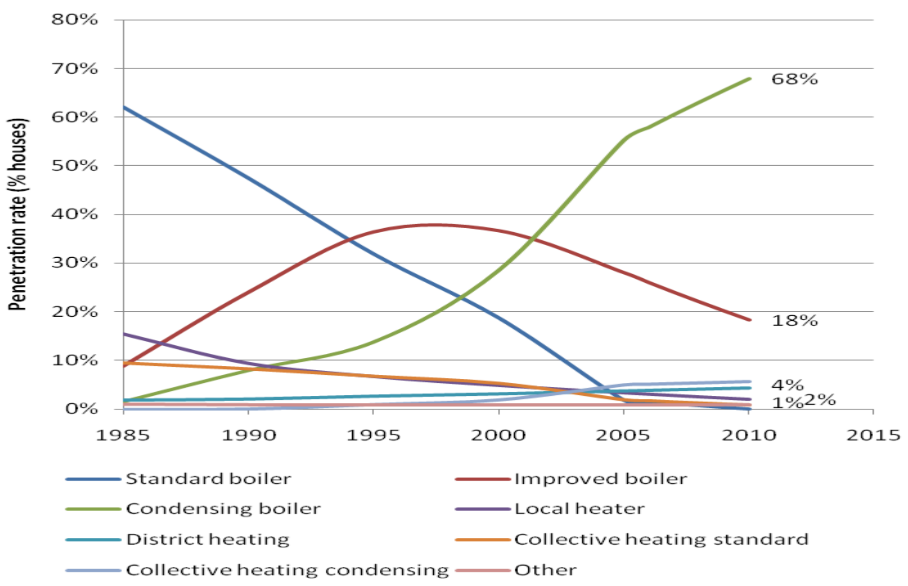
Figure 30 : Estimation of level of insulation used in retrofitting in different years



Source: ECN model.

Figure 31 shows the penetration of heating systems over time. In the Netherlands almost the entire housing stock (86%) is heated by individual central heating systems using natural gas as a fuel. In the eighties these were mostly standard boilers with an efficiency rate of 75%. In the nineties these were replaced by improved boilers with an efficiency rate of 80-90 %. After the introduction of building code standards for new dwellings in 1995 condensing boilers were installed in new dwellings. Soon after that also boilers in existing dwellings were replaced by condensing boilers with an efficiency rate of 95-107%. Only 4% of dwellings are heated by district heating. **Table 5** shows the detailed data for heating systems.

Figure 31: Penetration rates heating systems



Source: KWR survey, WoON survey, ECN.

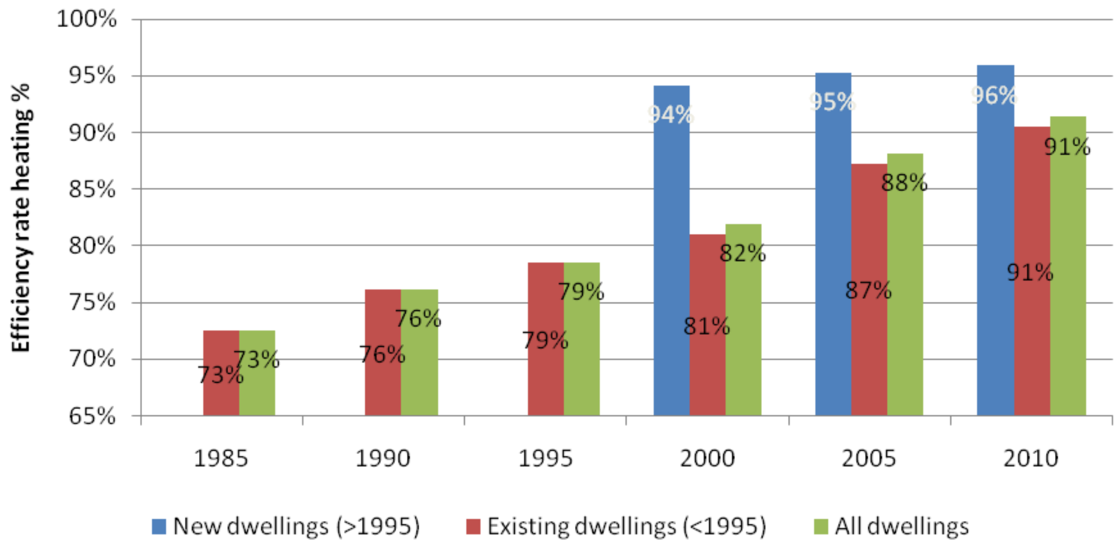
Table 5 : Penetration rates heating systems

[%]	1985	1990	1995	2000	2005	2006	2007	2008	2009	2010
Standard boiler	62	47	32	19	2	1	1	1	0	0
Improved boiler	9	24	36	37	28	26	24	22	20	18
Condensing boiler	1	8	14	29	55	58	61	63	66	68
Local heater	15	9	7	5	3	3	3	3	2	2
District heating	2	2	3	3	4	4	4	4	4	4
Collective heating standard	9	8	7	5	2	2	1	1	1	1
Collective heating condensing	0	0	1	2	5	5	5	5	6	6
Other	1	1	1	1	1	1	1	1	1	1
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: KWR survey, WoON survey, ECN.

Figure 32 shows the average efficiency rate of heating systems. In this graph you can see the effect of building code standards for new dwellings. Condensing boilers were installed in new dwellings built after 1995. Afterwards the efficiency rate of heating systems in existing dwellings improved rapidly when they got replaced by the same type of boilers.

Figure 32 : Efficiency rate of heating systems

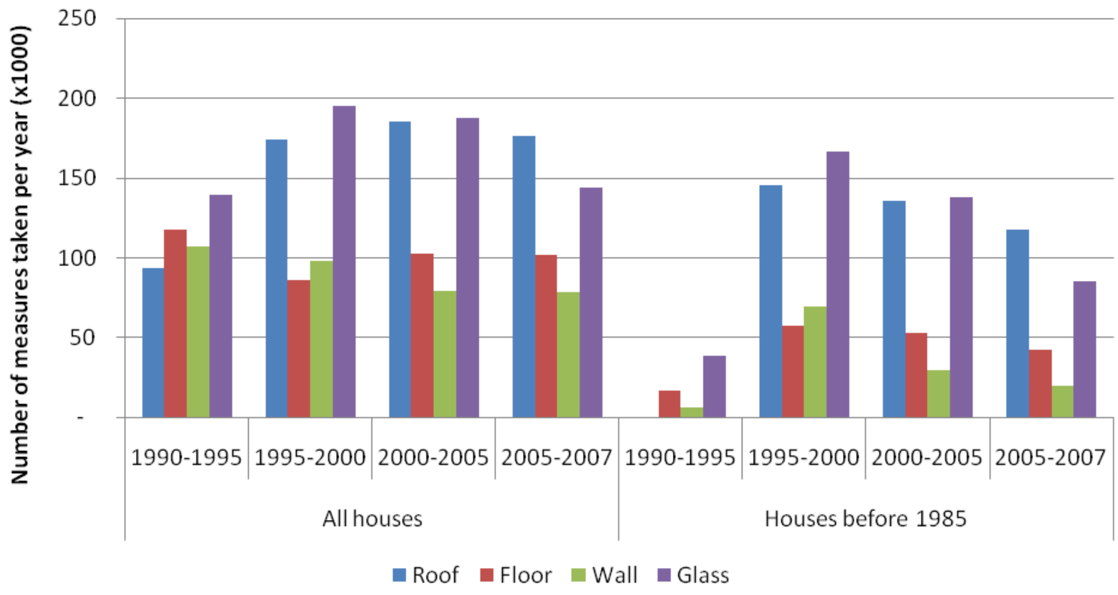


Source: ECN Model.

6.3. Number of measures taken in 1990, 2000, 2005 and 2010

Based on the penetration rates we can estimate the number of measures taken each year. We combined different sources and analyzed the number of dwellings in which measures were taken in different timeframes. **Figure 33**shows the average number per year. **Table 6**gives the detailed data.

Figure 33 : Average number of measures taken each year (x1000)



Source: HOME survey, KWR survey, WoON survey, Methonder (2010), ECN.

Table 6: Average number of measures taken each year (x1000)

	All dwellings				Dwellings before 1985			
	1990-1995	1995-2000	2000-2005	2005-2007	1990-1995	1995-2000	2000-2005	2005-2007
Roof	94	174	185	177	-	146	136	118
Floor	118	86	102	102	17	57	53	43
Wall	107	98	79	79	6	69	30	20
Glass	140	195	187	144	39	166	138	85

Source: HOME survey, KWR survey, WoON survey, Methonder (2010), ECN.

6.4. Annual saving in the household sector

Table 7 shows estimates of savings by different types of measures. These savings are based on ECN model calculations. Our estimations for savings in dwellings build before 1985 is based on the number of measures installed as discussed in Paragraph 6.3. For the effect of improved boiler efficiency we calculated the energy consumption for the residential sector as if the average efficiency of boilers did not improve. The difference between the real energy consumption and this assumed frozen efficiency is presented as savings because of boiler efficiency improvement. We don't have specific data available for boiler replacement to make a division between dwellings build before 1985 and after.

Table 7 :Average annual saving because of measures in ktoe final energy

	All dwellings				Dwellings before 1985			
	1990-1995	1995-2000	2000-2005	2005-2010	1990-1995	1995-2000	2000-2005	2005-2010
Roof	30	64	35	25	-	54	26	16
Floor	11	8	5	6	2	5	3	2
Wall	30	28	16	15	2	20	6	4
Glass	20	48	25	25	6	41	19	15
Boiler efficiency	54	73	114	51				

Table 8 shows the average savings per dwelling because of insulation measures. Despite the fact that the quality of insulation materials improved, the absolute savings weren't increasing as much. This is due to heating systems becoming more efficient. Because it takes less natural gas to produce 1 toe of heat, savings on heat demand leads to less gas savings when boiler efficiency improves.

Table 8 : Average annual saving per dwelling because of measures final energy

	All dwellings				Dwellings before 1985			
toe/dwel	1990-1995	1995-2000	2000-2005	2005-2010	1990-1995	1995-2000	2000-2005	2005-2010
Roof	0.33	0.37	0.19	0.14	-	0.37	0.19	0.14
Floor	0.09	0.09	0.05	0.06	0.09	0.09	0.05	0.06
Wall	0.28	0.28	0.21	0.19	0.28	0.28	0.21	0.19
Glass	0.14	0.24	0.13	0.17	0.14	0.24	0.13	0.17

6.5. Policy measures and influence on retrofitting process

The Netherlands has a long history of policy measures on energy efficiency in the build environment. Among several minor programmes and subsidy schemes there were a few very influential policy measures:

- National insulation program (Nationaal Isolatie Programma).
- Energy premiums (energiepremieregeling).
- Energy tax.
- Building codes.

These will be discussed briefly in this paragraph.

6.5.1. National insulation program (Nationaal Isolatie Programma)

The National Insulation Program was launched in 1978 and ran until 1987. The measures in this program were focused on the existing building. As part of the NIP, the following activities took place:

- Grants for insulating existing homes.
- Loans for the insulation of residential buildings.
- Financial assistance for setting up an insulation plan.
- Promote the installation of boilers.
- Several educational programs.

In 1974, only ten percent of housing had one or more types of insulation installed. Between 1974 and 1978, in the pre-phase of the NIP, 400,000 homes were insulated. At the end of 1987 energy saving devices were installed in approximately 1.8 million homes, due to the NIP. At that moment 1.15 million homes weren't insulated.

The spending of funds for the NIP was evaluated. 1.809 million guilders (€ 820.9 million) were spent on grants. This corresponds with 91 percent of the available resources.

45.2 million guilders (€ 20.5 million) were spent on information activities, 27.1 million guilders (€ 12.3 million) on technical research and 90.5 million guilders (€ 41.04 million) for project support. In total this saved 1.45 million cubic meters of natural gas.[36]

6.5.2. Energy premiums (energiepremieregeling)

[36] Entrop, A.G. and H.J.J. Brouwers (2007).

The energy premiums program (EPR) has been in force from 1 January 2000 to October 2003 and provided subsidies for energy efficient appliances (eg refrigerator and freezer with A-label), energy saving devices (eg HR-glass insulation), equipment for generating renewable energy (PV systems, solar heaters and heat pump water heaters) and the energy performance advice (the predecessor of the Energy performance certificate). The EPR was paid from the income of energy taxes.

According to the decision on 16 September 2003 the premium scheme ended at 16 October 2003. In the last months 60.000 applications for subsidy have been made. This contributed to the over crossing of the budget with € 100 million (€ 175 million instead of € 76 million).**Erreur ! Source du renvoi introuvable.** shows the number of units for which premiums were given.

Table 9 : Number of units with premium requests 2001-2002

Facilities		2000	2001	2002
Insulations (measures numbers 2001 t/m 2005)	[m^2]	1,159,080	3,443,367	4,110,203
Do-it-yourself insulations (measures number 2006)	[m^2]	693,647	1,606,108	2,374,834
High efficiency ++ glass	[m^2]	202,719	615,671	715,995
High efficiency boiler <= 35 kW)	[boilers]	32,796	73,008	103,244
High efficiency boiler >35kW	[kW]	42,180	108,098	138,455
High efficiency heat recovery from room ventilation air, direct current ventilation, high frequency lighting	[item]	414	1,890	101,869
Presence sensors and/or day-light sensors	[sensor]	4	0	282
Photo voltage systems	[Wp]		736,435	2,738,727
Solar boiler	[item]		1,872	5,061
Collective solar boiler	[m^2]		498	2,801
Heat pump boiler	[boilers]		84	1,938
Other[37]	[dwellings]	744	3,734	6,920

Source: EnergieNed.

6.5.3. Energy tax

The Energy Tax (ET) is a levy on energy consumption that improves the yield of measures focussed on energy saving thereby making energy savings more attractive (by changing behaviour or by investing in energy-saving technologies). The level of the tax has been adapted a number of times (for more detail see MURE database http://www.isisrome.com/data/mure_pdf/NLD1.PDF). Until 2003 the energy tax was used to finance subsidies for energy efficiency measures. After that year there is not a link anymore and the tax goes to the general state budget.

6.5.4. Building codes

The Building Decree from 1992 already contained requirements for thermal insulation and air permeability of the outer layer of dwellings and buildings. In line with the policy for sustainable building a better way to achieve energy efficiency was found in the Energy Performance Standard (EPN in Dutch) that was introduced in 1995. This EPN was already announced in the policy bills on Sustainable Building (1990) and on Energy Saving (1990).

[37] Gallery or balcony sealing, dwelling adjustment to heat delivery, individual heat metering, low temperature central-heating, floor heating or wall heating connected to low temperature central-heating, low air heating, and ventilation system with active grilles

For the sector Households the Energy Performance Standard enables calculation of the overall energy performance of a new dwelling and its heating, ventilation, air-conditioning and lighting equipment. (For more detail see MURE database http://www.isisrome.com/data/mure_pdf/NLD3.PDF).

The Building codes in general and more specifically the EPN stimulated innovation. It's plausible to claim that the application of more efficient techniques in new dwellings, such as condensing boilers, due to the EPN, also had its effect on techniques used in existing dwellings.

References

ECN (2004): *Internal note on historical subsidy schemes*.

Entrop, A.G. and H.J.J. Brouwers (2007): *Het Nationaal Isolatie Programma als voorloper van het energiebesparingsplan 'Meer met Minder' voor de bestaande bouw* (*The National Insulation Program as a pioneer of energy-saving plan 'More with Less' for existing buildings.* University Twente, Enschede. http://doc.utwente.nl/60317/

Methonder (2009): *Isolatiegraden: trend 1995 - 2007*. Internal note SenterNovem.
MURE Database on energy efficiency measures, http://www.isisrome.com/mure/

VROM (2002): *Energiebesparende maatregelen in de woningvoorraad*. Ministry of housing, spatial planning and the environment, The Hague, http://www.rijksoverheid.nl/documenten-en-publicaties/brochures/2002/12/02/energiebesparende-maatregelen-in-de-woningvoorraad.html

VROM (2010): *Kernpublicatie WoON energy 2006*. Ministry of housing, spatial planning and the environment, The Hague, http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2010/03/11/kernpublicatie-woon-energie-2006.html