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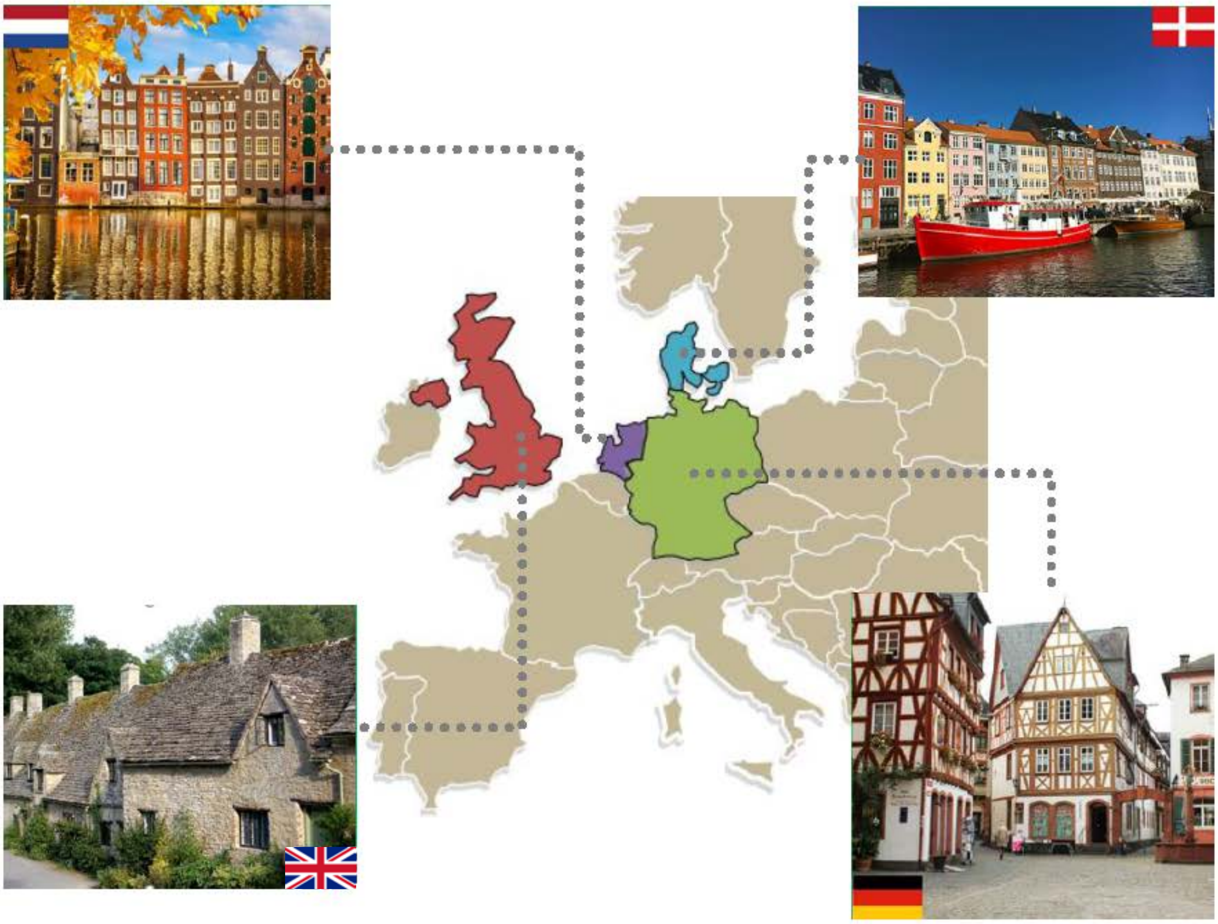

A review of Dutch, German, Danish and British energy savings policies to reduce the energy consumption and CO_2 emissions in the residential sector.

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Radarweg 60
1043 NT Amsterdam
The Netherlands

www.tno.nl

T +31 88 866 50 10

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Greening the built environment; a comparison of Dutch, German, Danish and British energy savings policies to reduce the energy consumption and CO_2 emissions of space heating in the residential sector

Date	10 mei 2019
Author(s)	Sipma, J.M., Holdsworth-Morris, R.F., Paliouras, S., Niessink, R.J.M.
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Executive Summary

The research topic

In this research we try to understand the effect that certain policy measures have had across countries in order to reduce the energy consumption and CO_2 emissions for space heating in the residential sector. More specifically, we have focused on energy intensity, which is described as the energy consumption each square meter (MJ/m^2) of useful floor area in a dwelling. When taking into account the CO_2 emissions of the types of fuels used to generate domestic heat, the energy intensity can be transformed into a CO_2 emission intensity (kg CO_2/m^2),

Often, it is easier to persuade home owners to take energy saving actions compared to tenants. This relates to the split-incentive. The share of home owners among the population of all 28 European countries has remained relatively stable over the past few years, amounting to approximately 69% (Statista, 2017). The Netherlands has the highest share with 69,4%, Germany the lowest with 51,4%[1], as shown in Figure 1. For the Netherlands, this in theory should lead to more energy savings opportunities compared to the other countries.

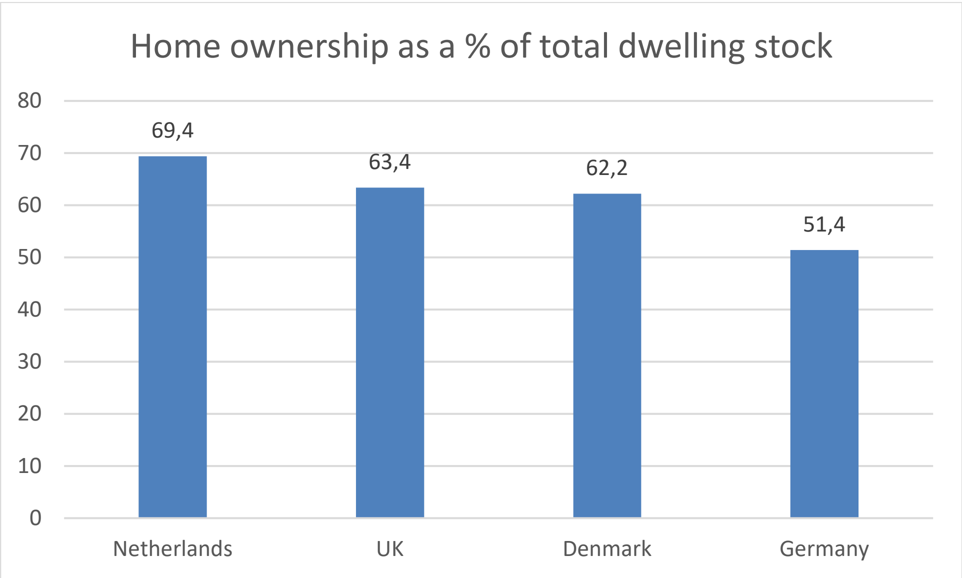


Figure 1 Home ownership as a % of total dwelling stock. (Statista, 2017; Trading_Economics, 2016)

From this perspective, it seems logical to focus on policy measures that target this specific subgroup within the residential sector. However, policy measures do not always make such a clear distinction. Some policy measures, such as the Energy Efficiency Obligation (EEO) could influence several sectors, and are therefore described as ‘cross-cutting’. Furthermore, the supply side can influence the CO_2 emissions within the residential sector drastically, especially when district heating is involved that uses a relatively large share of renewables. The scope of this study is therefore quite broad. We will look at policy measures that directly or indirectly influence the energy consumption for space heating within the residential sector

[1] In Germany relatively a large share of household rent from other families, living in the same building.

and/or the related CO_2 emissions. Four countries dominate our research: the Netherlands, Germany, Denmark and the United Kingdom.

Understanding policy measures and non-policy factors that influence the energy and CO_2 emission intensity of space heating (chapter 2)
Besides policy measures, non-policy factors also have had a significant effect on bringing down the energy and CO_2 emissions intensity in the four countries that we examine. For this reason, this topic should not be ignored while evaluating the possible (historical) effect of policy measures. Non-policy factors relate e.g. to population growth, increasing dwelling sizes and decreasing household sizes. Building codes, a typical policy instrument, have made new buildings over time more energy efficient. Although not quantified in this report, we know that the combination of new dwellings and building codes have reduced the average energy intensity of the stock drastically, without any additional policy measures.

Of course, new dwellings will become existing dwellings over time. To reduce the energy intensity further, the older stock needs to be demolished or retrofitted. Both go slowly, although the retrofitting rate is still 10 times higher compared to the demolition rate.

The CO_2 emission intensity can be lowered even further when higher levels of renewable energy become involved. This could be achieved at both the demand- and supply side. The demand side refers to the dwelling itself; e.g. using wood pellets in stoves, or applying electrical heat pumps. The supply side refers to district heating that could use a large share of renewables such as biomass, geothermal heat, solar energy and again heat pumps

Non-policy factors and policy measures have had a combined lowering effect on the energy and CO_2 emission intensity in all four countries. On average over the four countries, the energy intensity lowered by 30% between 2000 and 2016, and the CO_2 emission intensity lowered by 41%. The interesting question now is what part of this reduction has been realized through (national) policy measures only. This is very difficult to calculate, but some studies have tried to do so.

Best performing countries that have reduced the energy demand and CO_2 emissions for space heating, according to international literature (chapter 3)
According to the literature reviewed the Netherlands, Germany and the UK are performing *relatively* well in reducing the energy intensity in the residential sector (see Figure 2). Amongst these three countries, Germany might have performed best. The case of Denmark is different. Denmark did not increase the energy efficiency of the dwelling stock to the same extent as the other EU countries did. But at the same time, Denmark has reduced the CO_2 emission intensity by making sure a significant share of the heat demand is filled-in with renewable energy coming from heat districts and local sources (see Figure 3). A significant proportion of the locally used wood is imported from Sweden. The impressive flexible district heating system is used as well as a buffering system for both heat and (more and more) for sustainable (wind-generated) electricity. This could be considered as a ‘supply and demand side management system’.

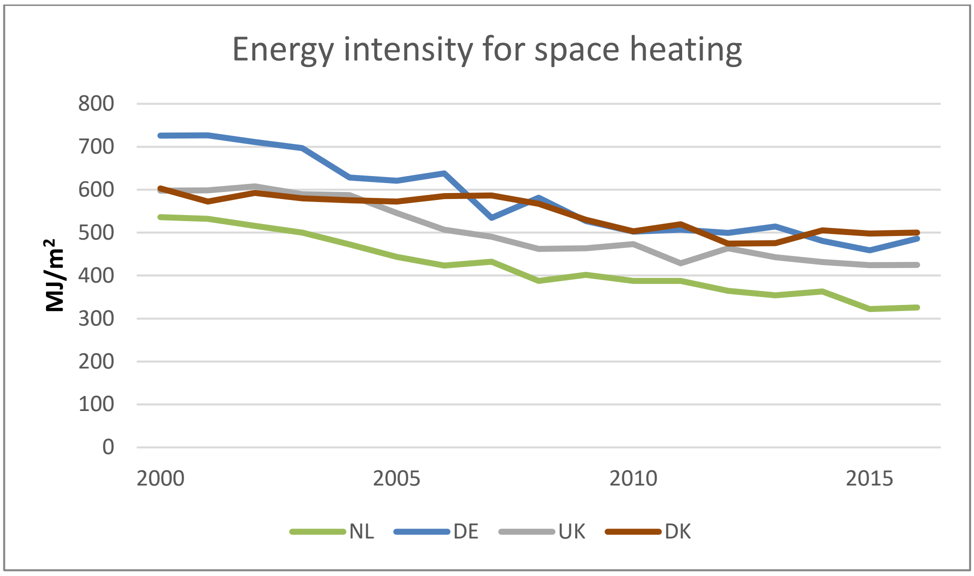


Figure 2 Energy intensity for space heating in dwellings between 2000 and 2016, corrected with national heating degree days (copy of Figure 9).

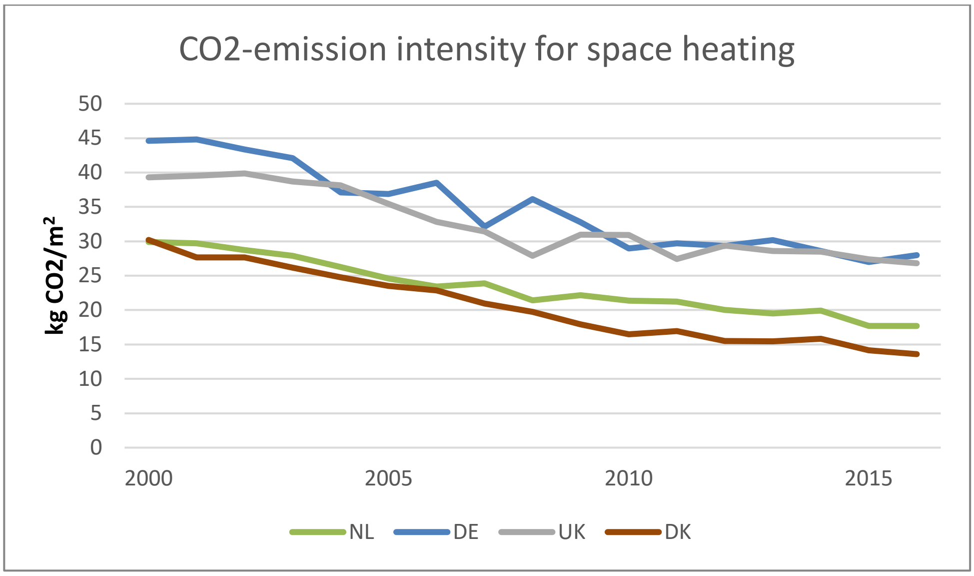


Figure 3 CO_2 emission intensity for space heating in dwellings between 2000 and 2016, corrected with national heating degree days (copy of Figure 10). Calculated with several data sources.

Evaluated policy measures of the selected countries, that have reduced the energy demand and CO_2 emissions for space heating (chapter 4).
The portfolio of policy measures in each country is compared. Policy measures are categorised by certain 'types of policy measures', as legislative, financial, fiscal and cross-cutting.

Besides EU related policies such as the EPBD and Eco-design that apply to every country, countries have chosen to implement Energy Efficiency Obligations (EEO). The EEO is another EU-related policy that has been adopted by both the UK and Denmark. Germany and the Netherlands have chosen to follow an alternative route.

When an EEO is in place, the responsibility is shifted towards the utility sector. We have observed therefore that the UK and Denmark have in general less national policy measures implemented in comparison to Germany and the Netherlands.

In their searches for an alternative route, Germany and the Netherlands have made different choices. The Netherlands is searching for collaboration with all the kinds of stakeholders that are involved (e.g. the government, housing corporations, construction- installation and energy companies), which must be a cultural imbedded approach. There are also some additional supporting national-legislative measures. This is in contrast to Germany, where national-legislative measures are much more dominantly present. These main types of measures have been reported to yield a high impact, supported by measures that have the characteristics of financial/fiscal and/or information/education type policies.

The highest electricity prices and share of related taxes and levies are in place in Germany and Denmark. While in Germany the high electricity tariff is one of the main pillars of the designed alternative route, Denmark uses tax-income to finance their EEO programme.

We should be careful interpreting evaluations of policy programmes and reported energy savings. The calculating of energy savings in general is complex, and sometimes exaggerated for several reasons. Since national policy programmes all have their own system boundaries, period of monitoring, evaluation methods and correcting factors, it is even harder to compare the rate of success of countries with each other. Since countries have made historical choices, carry different cultural aspects, have or do not have access to natural energy resources and are doing economically well or less well, we feel we are just able to make observations. These observations could inspire countries while making certain decisions for the future though. Learning 'what went well' and 'what went badly', is the highest feasibility of this study.

The Netherlands (chapter 5)
The most successful Dutch policy for reducing the energy consumption within the residential sector is classified as 'Normative/Regulatory policy', followed by 'Cooperative' (in the chapter these classifications wuill be explained further).

- In addition to EU policy, the former includes, for example, the Building Decree (new buildings and large-scale renovations), but also the 'Adjustment of the housing valuation system' for the rental sector, and the Heat Law with a lesser impact.
- Cooperative refers only to the More With Less program, of which it is doubtful whether this still has impact.

Although the Netherlands, according to international literature, is certainly not doing badly compared to other EU countries, it is not one of the leaders when it comes to retrofitting the existing stock. Whilst the reduction of energy intensity might be quite large compared to the other three countries; the retrofitting rate still only has an 'average' pace. Possibly non-policy factors have contributed more to the reduction of energy intensity than policy measures have done, with the highest impact coming from the need for new dwellings.

The programme called ‘Energy Jump’ (‘Energiesprong’ in Dutch), started off in the Netherlands with positive results and has gone international with projects in the UK, France, Germany and Italy, as shown in the below graph (energiesprong.org):

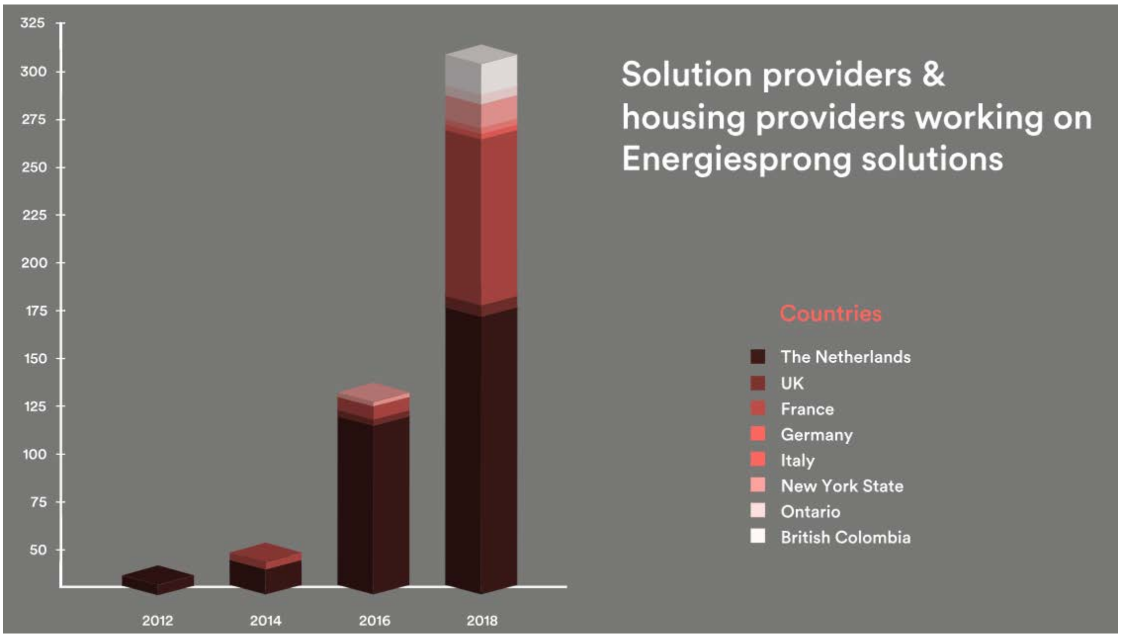


Figure 4 ‘Energiesprong is a revolutionary, whole house refurbishment, new build standard and funding approach. It originated in the Netherlands as a government-funded innovation programme and has set a new standard in this market. The mission of Energiesprong International is to scale this approach to other markets. Energie-sprong uses the social housing sector in each market as the launching market for these solutions, with a view to later scale to the private home-owner market (*energiesprong.org*).

Germany (chapter 6)
Policies with the highest impact in Germany are classified as 'fiscal', 'financially supportive' and 'normative/regulatory policies'.

- Fiscal measures refer to taxes and charges on electricity and gas prices. Taxes and charges are amongst the highest in Europe, fuel prices are at an average level. The energy taxes of the Netherlands are considered to have lesser impact. As a result of taxes and charges, the energy bill for German households has risen significantly (in comparison with the Netherlands 30% higher). Whether the tax-component of the high electricity price has helped to increase the share of renewable electricity, or the latter has caused electricity prices to rise, seems to be the subject of an ongoing debate. The relationship between the two is striking though, as can be seen is Figure 5.

- Financial supportive policy measures refer to those that provide financial resources and grants to end-users. A difference with the Netherlands is the higher budget that has been allocated to this policy type, and the longer period of time that will be maintained per policy measure. In other words, it is more predictable and there is continuity. Until 2020, Germany expects that most of the savings will be achieved through the 'Energy Savings Regulation for new buildings', combined with the different schemes that provide financial incentives.

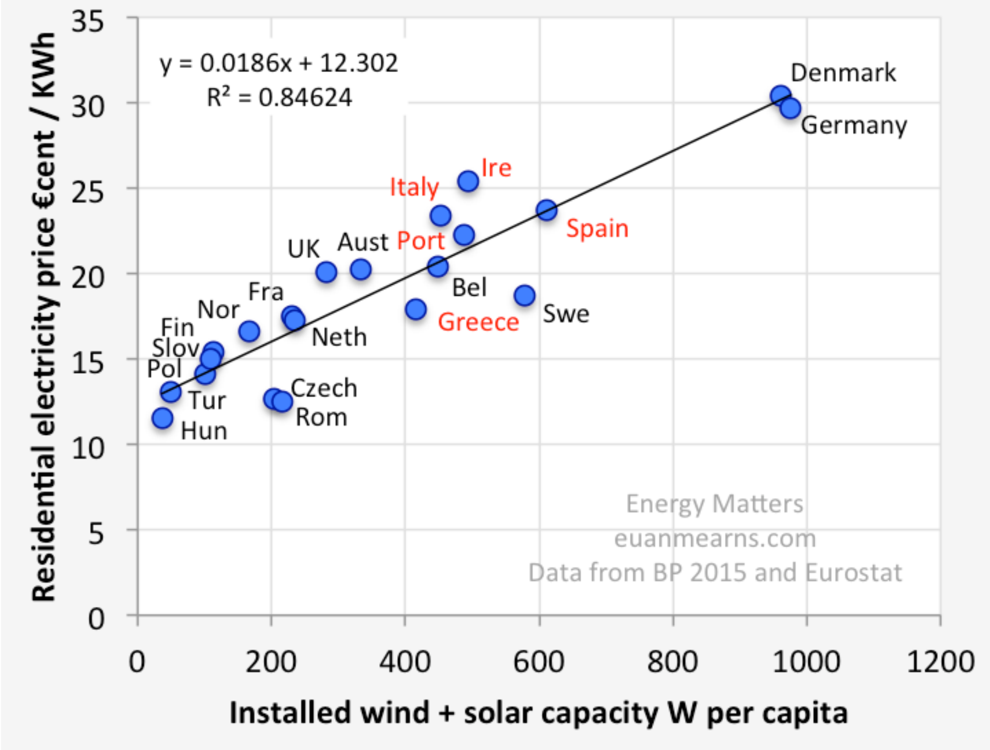
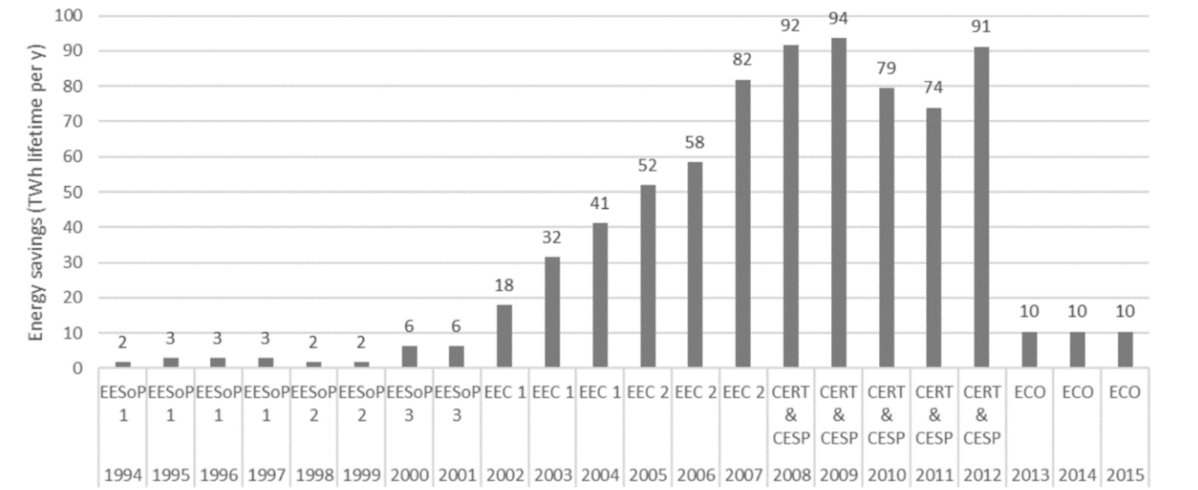


Figure 5 The relationship between the electricity price and the installed wind and solar capacity graph (*ktwop.com, 2014*).

According to international literature, Germany is one of the European leaders in terms of savings achieved within the existing stock of dwellings. At the same time, it has been found that Germany does not correct its policy evaluations for reducing factors such as free-riders and the rebound effect, which can have a large impact on the amount of savings reported, with reductions of up to 50%.

The UK (chapter 7)

The UK is relying on regulation such as the 'Building Regulations' and the EPC, in addition with market-based instruments such as the 'EEO' to improve energy efficiency. The Netherlands has considered introducing an EEO in the past, however recent experience in the UK suggests there are some pitfalls in the design of the scheme to achieve long-term energy efficiency goals. One lesson to be learnt from the UK experience with the EEO and the Green Deal is that time must be given for the introduction of new schemes and that trusted institutions should be used for delivery to market, thereby increasing consumer and investor confidence. The EEO in its current form, with a reduced budget, is on its own an insufficient instrument to reach efficiency improvement targets in the residential sector and other measures need to be introduced. The below graph shows the energy savings from EEO in the UK.



Data sources: Lees (2006, 2008), NAO (2016) and Ofgem (2003, 2005, 2006, 2007, 2008, 2013)

Figure 6 Energy savings from EEO 1994-2015, accumulated savings from new actions each year (copy of Figure 41)

The UK is moving towards increased private sector investments and the involvement of local authorities to stimulate a market for energy efficiency and reduce the increasing costs to suppliers and consumers.

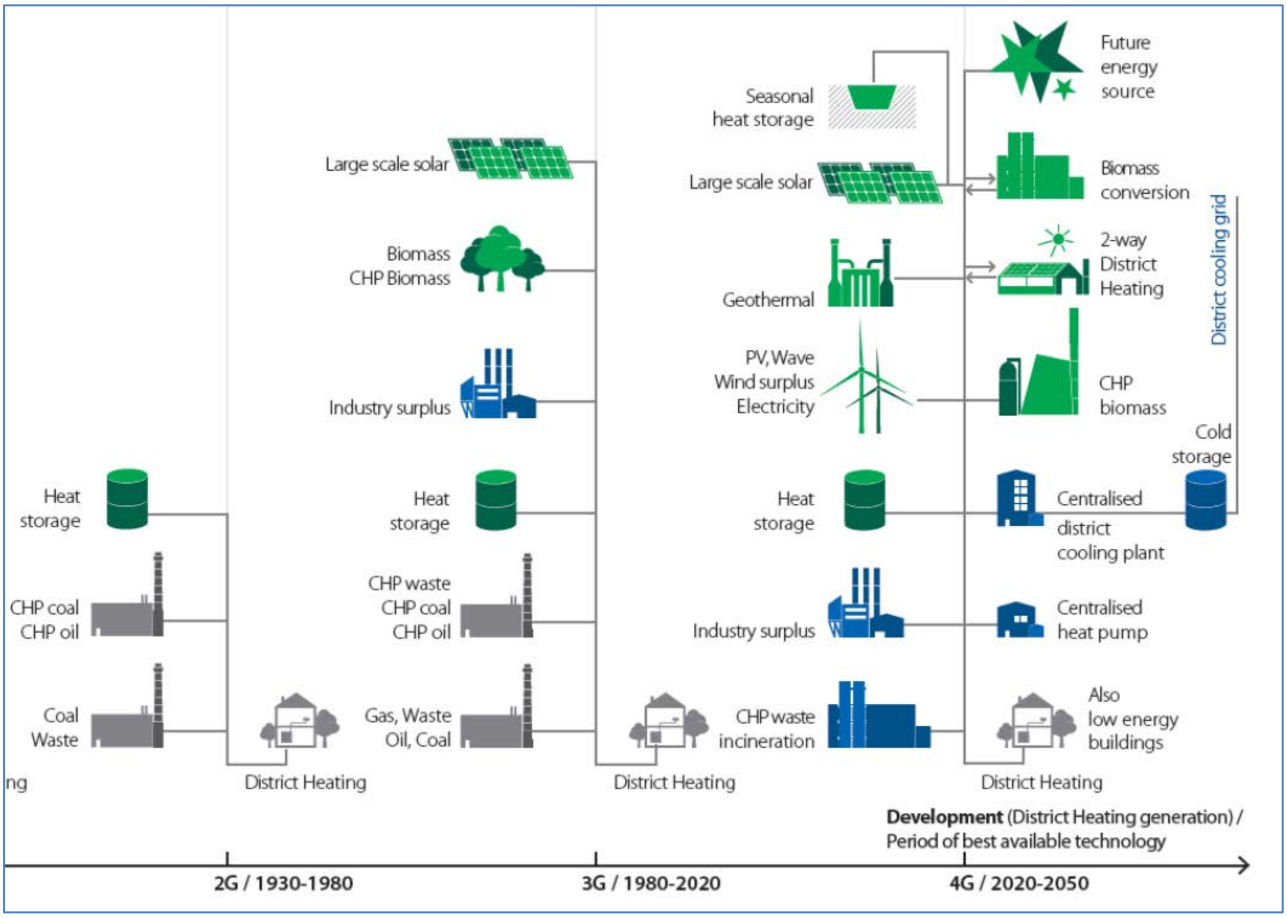
The British government has experimented with the Green Deal as a tool to overcome split-incentive barriers and reduce reliance on government subsidy through increased private investment. However, it's failure has demonstrated that the public is reluctant to switch from decades of free subsidies to one that is based on pay-as-you-save loans and higher upfront costs. The German KfW loan scheme with lower interest rates has proved far more successful.

Another lesson learnt from the 'Golden Rule' is that the promotion and design of schemes should not be restricted to energy bill savings, but reflect multiple benefits that improvements to energy efficiency can bring such as CO_2 savings, improved comfort and well-being.

The UK is considered as a country that performs relatively high quality project evaluations. Strong institutions and a government department both monitor and evaluate to uphold standards in evaluation. Ex-post evaluations are fed into a large database that can be used to make ex-ante estimates. It factors in free-riders, the rebound effect and removes double-counting. Smart-metering and billing will increase the observed data available for policy evaluations.

Denmark (chapter 8)
In comparison with the other three countries, Denmark has a relatively small number of energy-saving measures targeting the household sector. In the past decades however, Denmark has significantly reduced the CO_2 emissions in this sector by using advanced district heating technologies and decreased the energy demand in the household sector. The below graph shows the flexibility of the present and future district heating system by combining several technologies and energy sources (northsearegion.eu).

Figure 7 The flexibility of the present and future district heating system of Denmark, by combining several technologies and energy sources (northsearegion.eu).



In Denmark, all three high-impact energy efficiency policy measures are classified as legislative/normative, and only one of them is designed at a national level. More specifically, similar to all European countries, Denmark has adopted the Building Regulations and Energy Labelling of Buildings EPBD measures, which have been proved to have a high-impact in the national energy strategy. Furthermore, the national legislative measure Strategy for Energy Renovation has a high-impact on the renovation of the existing building stock. Besides these, there are several low-impact ongoing measures which aim to provide information (information / education) to both consumers and to energy distributors.

Apart from the measures that exclusively target the household sector, the Danish energy agenda contains several cross-cutting/general measures which also highly effect the energy-efficiency and related CO_2 emissions of dwellings. For instance, the Energy Efficiency Obligation scheme, is an EU-related measure which is used to realise the targets of article 7 of the EED. The EEO has shifted the responsibility for realising energy savings towards the energy companies. These companies have been given the freedom the choose themselves the sectors and technical measures that are, according to them, most cost-effective. Note that in the UK, the EEO focuses on the residential sector only, and so-far has been aimed mainly at poor households, often living in poor-quality dwellings.

The energy savings in the household sector resulting from the Danish EEO scheme have been claimed to be inaccurate, due to uncertainties in the methodologies used by the energy companies, who evaluate their own projects. Savings are over-estimated since they have been calculated and based on 'deemed data' (assumptions in an ideal situation), instead of using real measurements.

The Danish Energy Agreement, is a relatively recent cross-cutting measure which contains a broad range of initiatives aimed at the expansion of renewable heat in the household sector.

Denmark has the highest electricity price in Europe, and the highest share of taxes and charges paid by households. Although the gas price is not the highest, it still belongs to the top-6 in Europe, with again the highest share of taxes and charges paid by households (figures for 2016).

General themes in the Dutch discussion about making dwellings more sustainable (chapter 9)
In the Netherlands, a few general themes can be identified in the search for a strategy to reduce the energy consumption within the residential sector. Themes such as these are inevitably part of the negotiations for the national climate agreement in the Netherlands. In these negotiations, most attention goes to existing buildings. New buildings must comply with strong building codes and will not be connected to the natural gas grid. The challenge is how we can reduce the CO_2 emissions of existing buildings. The following text is a free translation of the Dutch 'Design of the Climate agreement', taken from the introduction to the chapter that relates to the built environment (klimaatakkoord.nl):

'To achieve the climate goals for 2030, we need to increase the pace of renovations to a rate of 200,000 dwellings a year from 2021 onwards. In this, municipalities play a crucial role. Together with residents and building owners the best solution for each district needs to be identified to move away from the traditional natural gas heated boiler. Per residential area, the solution may vary. Dense, high-rise, old building blocks could be combined with a heat district system. New houses in a spacious area need all-electrical solutions. Many neighbourhoods will keep on using natural gas until they potentially switch to green gas or hydrogen. Applying additional insulations and hybrid boilers could be a part of the interim solution.

But the state of the houses is not the only factor; the wishes of residents and other challenges in the neighbourhood determine the pace and the outcome as well. In many places, housing corporations can make tens of thousands of homes more sustainable in the coming years and connect to a different heating supply system than natural gas, under the condition that the monthly rent and energy bills do not rise together. This way tenants get a better home and at the same time equal or lower monthly costs. An accelerated move away from natural gas is also possible in new buildings.

To make this all possible, many agreements are needed:

- Agreements between municipalities, residents and building owners to shape neighbourhoods towards a sustainable future.
- Agreements about how considerable cost reductions can be achieved in the installation of heat district networks and when applying insulation and heat pumps in the dwellings.
- Agreements about an adjustment of the energy tax, in which we will make electricity cheaper and natural gas more expensive.
- Agreements about more sustainable heat taken from underground or from surface water, used directly (geothermal heat) or by electrical heat pumps
- Agreements about financial incentives to renovating dwellings, with attractive loan conditions

As will become clear to a certain extent from chapter 5 as well, in the Netherlands the decision-making process is slow and arduous, involving wide consultation. Consensus is vital. The Dutch will keep talking until all parties agree in some way. However, if a decision has been made, it is acted upon with support from the same stakeholders. All in all, this can be more effective than a decision that has been taken quickly.

With the country information we have gathered so far, in chapter 9 we reflect on some themes that are part of the Dutch debate and of the Design of the Climate agreement:

- Policies to stimulate insulation
- Building-related finance and other financing structures abroad
- Experiences with switching to district heating
- Connecting existing dwelling to district heating
- Increasing the share of renewables locally and in district heating
- Lowering the retrofit costs

What about the services sector? (chapter 10)

According to Eurostat, more than half of the population, living in these four countries, have a job. According to OECD, three quarters of the work force, works in the 'services sector', also called the tertiary sector. There are of dozens of buildings types that belong to the services sector, such as offices, warehouses, schools, swimming pools, sports accommodations, hotels, nursery homes, car garages, shops, supermarkets, museums, theatres, etc. All these buildings consume energy as well.

As a reference; in the Netherlands, the services sector uses one-and-a-half times more electricity compared to the residential sector, and almost half of the gas consumption. Although the services sector occupies in the Netherlands 35% of the total building stock floor area, it is responsible for almost 40% of the total energy consumption, making this an important sector to consider. This is shown in Figure 8.

The figure shows as well that the UK is performing relatively best; because amongst the countries the surface area of the UK services sector occupies the largest share (38%) of the total built environment (residential + services), but the related energy consumption is relatively low (just over 30%).

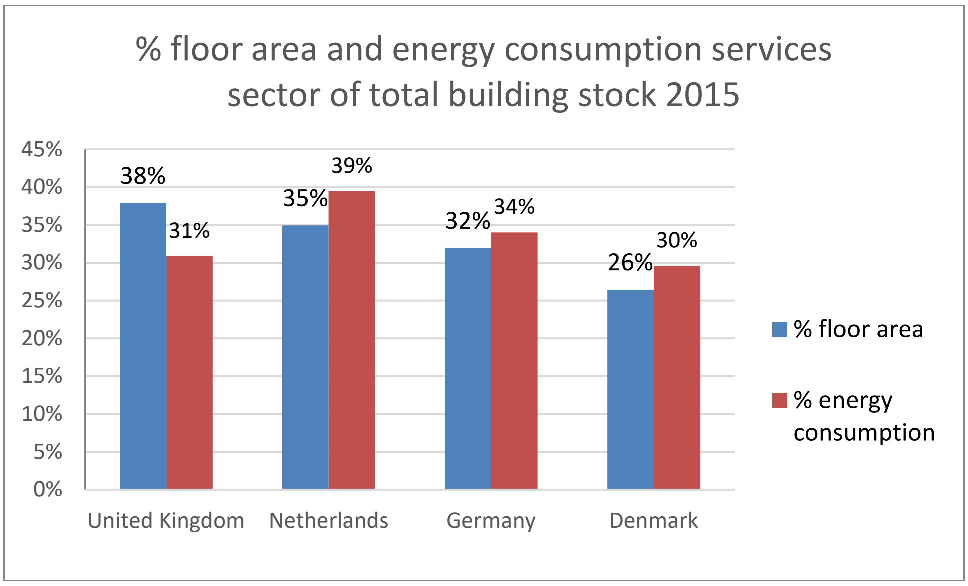


Figure 8 Floor area occupied by the services sector and related total energy consumption, as a percentage of total building stock (dwelling plus services). Source: several, calculated

In an additional, though smaller study, we have compared the energy policy portfolio of the four countries to bring down the energy consumption of the services sector. Chapter 10 gives you some results, but more importantly, will lead you to the two additional internship reports with more information and outcomes for the distinguish countries.

Recommendations for further research

Recommendation mentioned in chapter 2

- Although we are confident that the CO_2 emission intensities of the countries in *Figure 10* show the right trend in comparison to each other, the exact numbers could be improved, using additional National energy data.
- The share of fossil fuels in districts heating systems could be decarbonised by carbon capture and storage (CCS), lowering the (allocated) CO_2 emissions of delivered heat even further. The possible additional benefit of district heating has not yet been analysed in this study.

Recommendation mentioned in chapter 3

- Repeat this study for France, Slovakia, Ireland and Norway, countries that are performing well according to international literature.

Recommendation mentioned in chapter 4

- Although the database of Mure (in combination with Odyssee) has been proven to be very useful for us, we came across a few unclarities and irregularities. If a country comparison is performed again, it would be good to discuss these beforehand, and possibly to improve some aspects of the database.

Recommendation mentioned in chapter 5

- To give more binding strength to Dutch retrofit policies, investigate the way Sweden is checking the ex-post retrofit performance by taking into account the use of actual measured energy consumption.
- Investigate the effect of behavioural processes, such as overestimating risks and dealing with the hassle of a renovation, to improve the impact of Dutch retrofit policies.

Recommendation mentioned in chapter 9

Since we have added this chapter at the last stage of this study, some questions will need further research in order to deliver a satisfying answer. These have been added to section 0 as recommendations.

- The experiences abroad with other financing methods then already described in chapter 9, such as revolving funds, requires further research.
- District heating systems in Nordic countries started back in the fifties of the last century. Search for countries that have studies that describe recent experiences with connecting *existing* dwellings to district heating.
- Investigate what other countries do to lower the costs of their (scaled-up) insulation programme of the existing dwelling stock.

Content

1 Introduction

1.1 Reason for this study

This project has been carried out to support the work of PBL... The Netherlands is looking for a strategy to accelerate the retrofit pace of the older housing stock in a cost-effective way, as part of the set environmental objectives:

- The national government stimulates 1.5% energy saving per year to reduce CO_2 emissions. In 2050, the energy supply must be almost completely sustainable. The emission of CO_2 (greenhouse gases) is then 80-95% less compared to 1990 (rijksoverheid.nl).
- New dwelling construction must be (almost) energy-neutral from 2020 onwards. That means that a building generates as much energy as consumed (rijksoverheid.nl).
- All rental housing corporations have energy label B or better from 2020 onwards. 80% of residential rental homes in 2020 have energy label C or better.
- Every year, 300,000 existing homes and buildings are made more energy-efficient. The government has agreed this with the construction, installation and energy sector.
- A quarter of all houses must be disconnected from natural gas by 2030 at the latest. These two million homes will receive insulation and electric heat pumps, or sustainable district heating (trouw.nl)

Naturally, other European countries have set themselves comparable objectives. In this study we have compared the national policies of four EU-countries to reduce the energy and CO_2 emissions of space heating in the residential sector. We will look at types of policy measures and their (historical) impact. It is good to realize though, that a quantitative comparison (energy consumption and CO_2 emission) or a qualitative comparison (types of policy programmes) between countries is difficult to make. Since countries have made historical choices, carry different cultural aspects, have or do have not access to natural energy resources and are doing economically well or less well, we feel that nothing is really good or wrong here. But we are indeed able to make interesting **observations**. These observations could **inspire** the Netherlands and any other countries in making certain decisions for the future though. Learning 'what went well and 'what went badly' could certainly be beneficial to future energy related debates.

In the present ongoing negotiations for the national climate agreement in the Netherlands, most attention goes to existing buildings. Although this was not the main reason to perform this study at the start, it has made the outcomes even more relevant.

1.2 Reading guide

In **chapter 2**, we will look at policy measures and non-policy factors that influence the energy and CO_2 emission intensity of space heating in general. Non-policy factors influence both significantly, which is important to understand when comparing the success rate of countries with each other.

What share of the historical energy- and CO_2 emission reduction can be contributed *solely* to a countries policy programme is hard to answer, but some studies have tried to do so. This will be discussed in **chapter 3**.

In **chapter 4** we make a high-level comparison of the relevant policy programmes of the four countries that have been selected in this study. We will compare the types of policy measures countries have chosen historically, and their relative impact.

The country chapters
While chapter 4 has compared the portfolio of policy measures of each country 'at a high level', the following 4 country chapters dive further into the details for each country. Chapter 5 looks at the Netherlands, chapter 6 at Germany, chapter 7 at the UK and finally chapter 8 at Denmark. The chapters have the same structure, after the introduction the policy portfolio and the individual policy measures will be described for the residential sector. The next section gives an indication of the impact of policy measures that target the energy consumption of space heating of existing dwellings specifically. Other relevant aspects of policies will be discussed, such as financial incentives to stimulate the uptake of energy savings actions. From chapter 4, we know that evaluating the energy savings effect (and their cost-effectiveness), is a challenge. Therefore, a section also describes the evaluation strategy of the country, before the chapter ends with some conclusions for that country.

In **chapter 9**, questions arising from the present Dutch Climate Agreement negotiations will be addressed, using information from the previous chapters. In this chapter some policy elements of additional countries will be discussed, as well as additional international literature that could be relevant in answering the question.

In an additional, though smaller study, we have compared the energy policy portfolio of the countries to bring down the energy consumption of the **services sector**. The results can be found in (Paliouras, 2019) and (Holdsworth-Morris, 2019). As an introduction, some aspects of the services sector are already mentioned in **chapter 10**.

2 Understanding policy measures and non-policy factors that influence the energy and CO_2 emission intensity of space heating (by Sipma, J.M.)

2.1 Introduction

In this research, we have compared the national policies of four EU-countries to reduce the energy and CO_2 emission intensity of space heating in the residential sector[2].

When comparing countries, the question automatically rises, which country has performed best over the previous decades. This question is very difficult to answer due to several reasons, which we will discuss in this chapter and the next. It is important to understand that answering this question is certainly not the goal for this research. Still, it is important to realise what factors have influenced the intensities that we are looking at.

There have been several studies that have tried to answer the same question. These studies will pass by in the next chapter. The most comprehensive study that has been used most intensively in this research is Odyssee-Mure, which is an on-line database at the same time. It has been filled with an abundance of sector-related data; including data for the residential sector. Data relates to quantitative sector information and qualitative policy measures. The data has been collected by the countries themselves. Although the latter could give the impression that Odyssee-Mure is perfectly filled with invaluable data, the user still needs to be careful whilst interpreting the data and drawing conclusions.

2.2 Chapter summary

From this chapter it will become clear that besides policy measures, non-policy factors have had a significant effect on bringing down the energy and CO_2 emission intensity in the four countries that are examined. Non-policy factors relate in general to demographical- structural- and cultural factors, and more specifically to population growth, increasing dwelling sizes and decreasing household sizes. Building codes, a typical policy instrument, have made new buildings over time more energy efficient. Although not quantified in this report, we know that the combination of new dwellings and building codes have reduced the average energy intensity of the stock drastically, without any additional policy measures.

Obviously, new dwellings will become existing dwellings over time. To reduce the energy intensity further, the older stock needs to be demolished or retrofitted. Both go slowly. If every building would have been built to last for 75 years, the demolition rate would be around 1,3%. In reality, in the Netherlands, the demolition rate is only around 0,16%, and in most other EU countries it is far less. The retrofitting rate is low

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[2] The energy intensity is described as the energy consumption each square meter (MJ/m^2) of useful floor area in a dwelling. When taking into account the CO_2 emissions of the types of fuel used to produce space heat, the energy intensity can be transformed into a CO_2 emission intensity, giving the related CO_2 emissions each square meter ($kg\ CO_2/m^2$).

as well, but it is still 10 times higher compared to the demolition rate. Countries have a portfolio of different types of policy measures that will be discussed in chapter 4 and the respective country chapters.

The CO_2 emission intensity can be lowered even further when more renewable energy becomes involved. This could be done at the demand- and supply side. The demand side refers to the dwelling itself; e.g. by using wood pellets in wood stoves, or applying electrical heat pumps. The supply side refers to district heating that could use a large share of renewables as biomass, geothermal heat, solar energy and again heat pumps. The supply side refers as well to the electricity production that could decrease the (allocated) CO_2 emissions of electrical heat pumps in general by increasing the share of renewable energy sources as wind, hydro, solar, biomass and biogas.

Although a little out of the scope of this study, it is interesting to realise that Denmark uses it's district heating system as well as a Demand Side Management (DSM) strategy. The flexible system provides a buffer for heat in general, but is at the same time able to absorb excessive renewable electricity production.

Non-policy factors and policy measures have had a combined lowering effect on the energy and CO_2 emissions intensity in all four countries. Observations that we can make:

1. On average over the four countries, the energy intensity lowered by 30% and the CO_2 emission intensity lowered by 41%.
2. The energy intensity in the Netherlands lowered the most (39%)
3. The energy intensity in Denmark lowest the least (17%), but at the same time the CO_2 emission intensity lowered the most (54%)
4. The CO_2 emission intensity of the UK lowered the least (32%).

The interesting question now is what part of the reduction has been realised through policy measures only. As mentioned previously, this is very difficult to calculate, but some studies have tried to do so. The next chapter will discuss this matter.

2.3 The development of the energy and CO_2 emission intensity

The two figures below have been made using Mure data and have become our starting point to understand what factors have made intensities come down since the year 2000. Figure 9 gives the energy intensity for space heating in dwellings between 2000 and 2016 for the four countries of our research. Figure 10 gives the same for the CO_2 emission[3].

[3] Figure 9 is constructed with original Odyssee data. In Odyssee, the CO_2 emission of district heating and electricity consumption are not allocated to the residential sector. Therefore, we have constructed Figure 10 ourselves, combining Odyssee data with country specific data. All fuel types allocate their CO_2 emission to the residential sector in Figure 10.

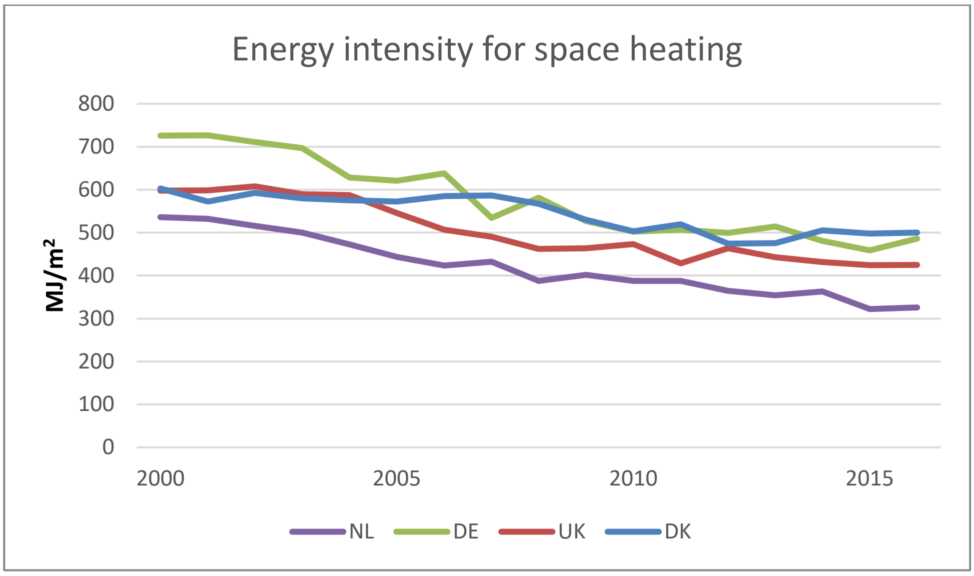


Figure 9: Energy intensity for space heating dwellings between 2000 and 2016, corrected with national heating degree days. Source: Odyssee.

Recommendation: although we are confident that the CO_2 emission intensities of the countries show the right trend in comparison to each other, the exact numbers could be improved, using additional National energy data.

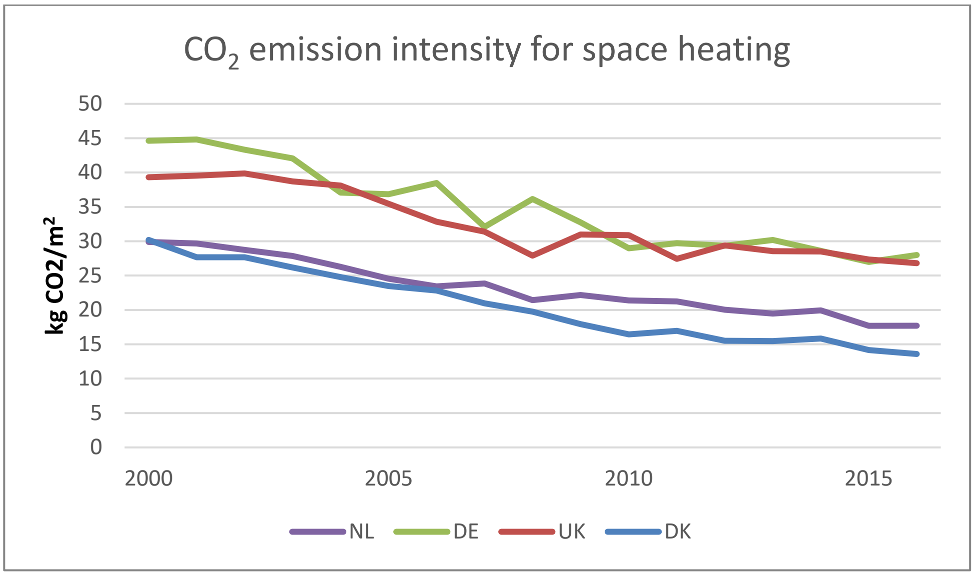


Figure 10: CO_2 emission intensity for space heating dwellings between 2000 and 2016, corrected with national heating degree days. Calculated with several data sources.

We can conclude that:
1. For all countries, both the energy- and CO_2 emission intensities came down since the year 2000
2. The energy intensity of Denmark seems to have decreased slower compared to the other countries, but at the same time Denmark's CO_2 emission intensity has reduced fastest.

2.4 Policy measures and non-policy factors

Can we also conclude which of these countries has performed best in reducing the energy consumption and related CO_2 emissions in the residential sector, as a result of applying national policy measures? We think not. Besides policy measures, there are several non-policy factors that have influenced these countries over the years, as mentioned in the below overview.

Energy- and CO2-intensity came down from 1990 onwards

1. Construction of new dwellings that are better insulated

Non-policy factors

- Demographical factors (growth rate)
- Cultural factors (reducing household size)
- Structural factors (larger buildings in general)
- Structural factors (district heating) -> CO2

Policy measures

- Building code new dwellings
- Renewable energy -> CO2

2. Retrofitting existing dwellings

Policy measures

- all EU and National policies that we evaluate

Non-policy factors are called ‘other explanatory factors’ and described as structural-behaviour- and cultural changes. Non policy-factors have simply resulted in the need for more buildings, at that moment constructed as a ‘new’ building, following certain ‘building codes[4]’. The more stringent the building code at the moment of construction, the more energy efficient the building; a typical policy measure.

Naturally, a new building becomes an existing building after a few years; e.g. when building codes have been redesigned/sharpened. In the domain of existing buildings, the onus lies with policy measures to reduce the energy consumption further.

Building codes and retrofits reduce the energy intensity by applying additional insulation and/or more energy efficient heating systems, compared to a previous period. Obviously, this reduces the CO_2 emission intensity at the same time. This takes place at the ‘demand side’; which is the dwelling itself. Although not influencing the energy intensity, another way of reducing the CO_2 emissions in the residential

[4] A building code is a set of rules that specify the standards for constructed objects such as buildings. Buildings must conform to the code to obtain planning permission, usually from a local council. The main purpose of building codes is to protect public health, safety, general welfare, (and to control energy consumption, as they relate to the construction and occupancy of buildings. The building code becomes the law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority. Building codes are generally intended to be applied by architects, engineers, interior designers, constructors and regulators but are also used for various purposes by safety inspectors, environmental scientists, real estate developers, subcontractors, manufacturers of building products and materials, insurance companies, facility managers, tenants, and others. Codes regulate the design and construction of structures where adopted into law`.

sector, is by increasing the share of renewable energy at the supply side. If a dwelling is heated through an electrical system, a higher share of wind- , solar-, and/or hydro energy will achieve this. If a dwelling is connected to a district heating system, a higher share of sustainable biomass, biogas or geothermal will do so as well. Note that district heating systems can be quite complex, since even solar energy and electrical heat pumps could be part of the system, the latter possibly using sustainable electricity.

In this chapter an analysis of certain policy measures and non-policy factors have been performed. The goal is not to determine their exact contributions to the decreasing trends in Figure 9 and Figure 10, but to understand their general dynamics. In the following sections, only the main observations are mentioned together with some illustrating graphs.

2.5 The development until 1990

Let's start at the beginning, literally. At the beginning of the previous century, dwellings often were built using a single brick wall. The typical cavity wall method of construction was introduced in Northwest Europe and gained widespread use from the 1920s. Initially cavity widths were extremely narrow and were primarily implemented to prevent the passage of moisture into the interior of the building. The widespread introduction of insulation into the cavity began in the 1970s (as well sparked by the oil crises), with it becoming compulsory in building regulations during the 1990s.

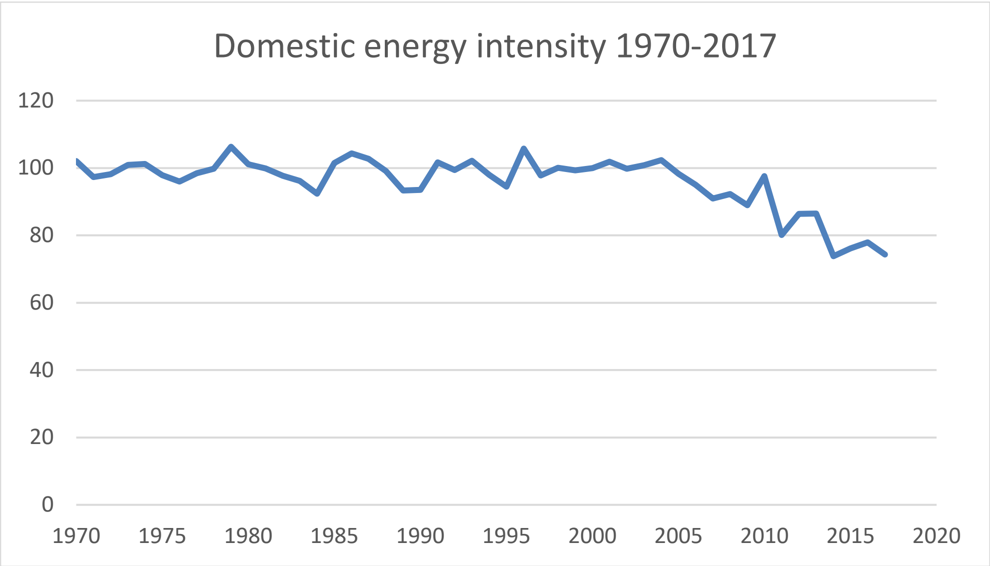


Figure 11: The household energy intensity in the UK; the year 2000 is set at '100'. Source: (Waters, 2018)

Odyssee data only starts from 1990 onwards. From the above we can assume that many countries have used cavity insulation already in earlier years. The UK, where less dwellings have been built with a cavity, might be an exception. For the UK we have found the development of the average energy consumption per household, starting from 1970 onwards (see *Figure 11*). This is the total household energy consumption, so including electricity for appliances is included. The year 2000 is set as '100'. As can be seen, in the UK, the energy intensity only comes down after 2004. In the UK-chapter we will see that this coincides with the moment that national policies such as the EEO were scaled-up and specific measures were put in place to insulate dwellings without a cavity from the outside.

Obviously, when a country is making significant effort to increase the performance of their building stock at an early stage, later on, there is less energy to be saved, or it comes at a higher cost. This is a factor to be taken into account when comparing countries.

2.6 Heating degree days

Figure 9 and Figure 10 have been corrected by Odyssee for national heating degree days. Therefore, the sequence of the countries does not say anything about their performance. The more heating degree days a country has, the colder it generally is and the larger the heat demand becomes (at similar insulation grades). Out of these four countries, Germany generally has the highest number of heating degree days, the Netherlands the lowest, as shown in *Figure 12*.

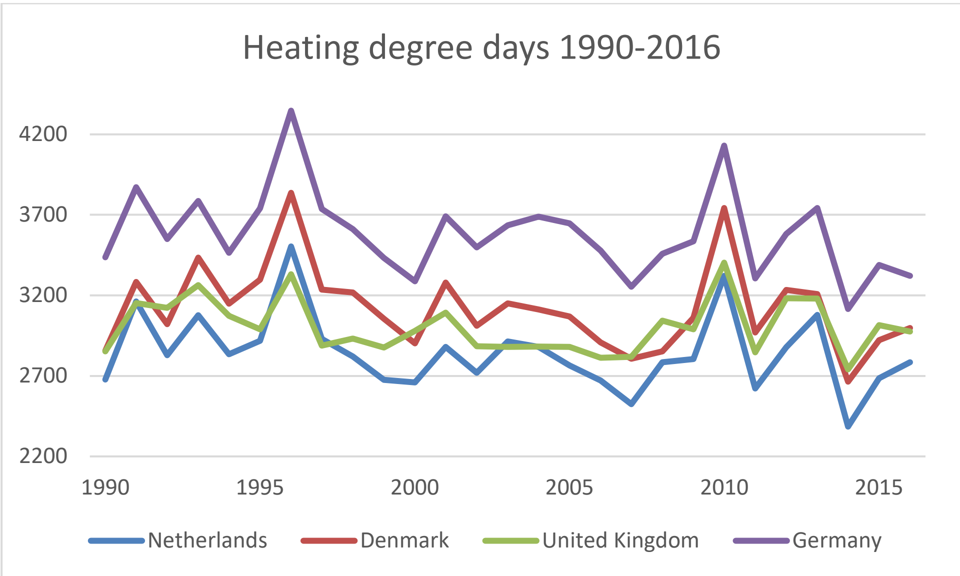


Figure 12: Heating degree days 1990 – 2016. Source: Odyssee.

Depending on the dwelling size and the energy price (recall the 1973 oil crisis), a cold climate will raise the energy bill at the end of the year. This might be an incentive for the house owner to invest in energy savings measures, as cavity insulation and/or a more efficient heating system.

2.7 A demand for new dwellings due to non-policy factors

Several non-policy factors have increased the demand for new dwellings. In appendix A these have been examined more extensively. In this section, the main observations are given.

- About 25 years after 1990, on average for our four countries, 19% of the total stock exists out of dwellings that have been built after 1990. The reason behind it is population growth, a decrease of average household size and a modest demolition rate.

- Due to the fact that new dwellings became larger at the same time, this share expressed in *floor area* (m^2) went even faster. Of the total stock in 2016, around 40% has been built after 1990, as shown in *Figure 13*.
- The growth was the highest in the Netherlands, for Denmark the lowest. One could therefore conclude that the Netherlands has had the best opportunity to increase the quality of the total stock from the perspective of demand for new dwellings.

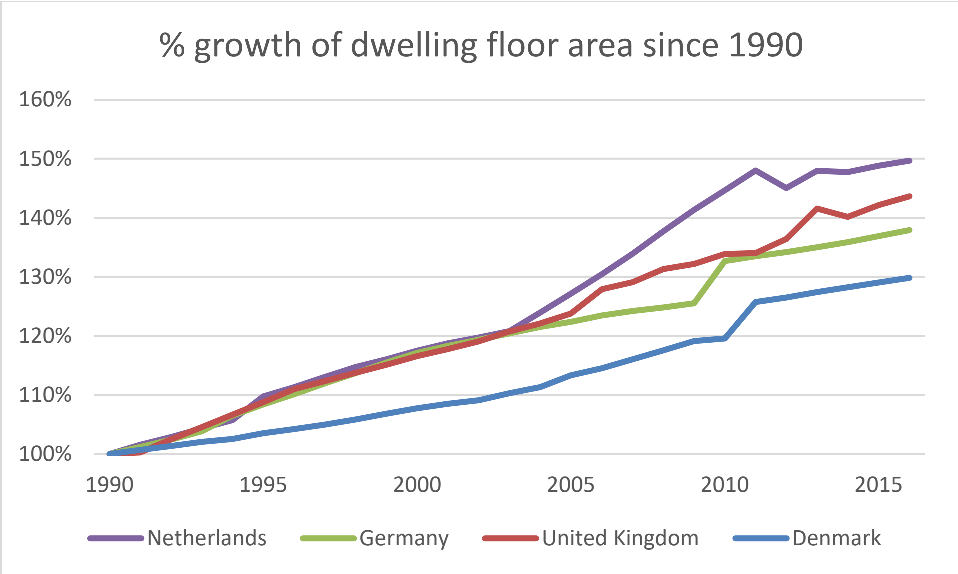


Figure 13: Percentage growth of dwelling floor area since 1990. Source: Odyssee.

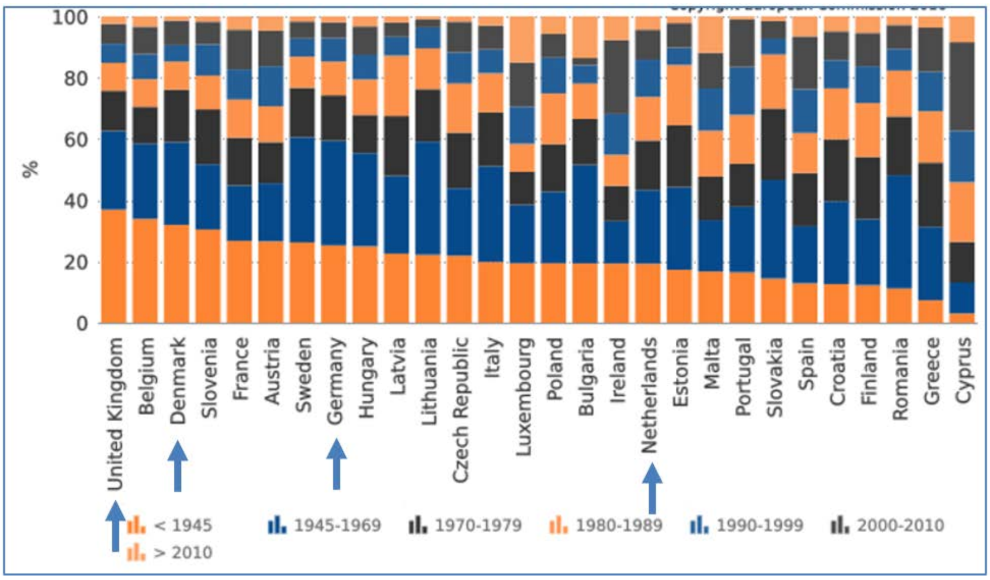


Figure 14: Breakdown of residential buildings by construction year (2014). Source: European Commission, Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings, 2016. p. 107

Figure 14 shows the breakdown of residential buildings by construction year for EU-countries, as is was in 2014. The share of buildings constructed before 1990 is pretty much the same for the UK, Denmark and Germany; around 85%. In the Netherlands, the percentage lies around 70%, demonstrating the higher share of dwellings built after 1990.

2.8 The development of the building code of new dwellings

The ‘big’ question is with what building code the dwellings of the previous section have been constructed; a typical policy measure that has made new dwellings more energy efficient over time (see footnote 4).

In the year 2013, 94% of new dwellings in Denmark already had an A-label, while in the Netherlands the majority (87%) still had a B-label. Even worse, the UK still constructed a large share of C-labels (29%). One could therefore say that the Netherlands missed the previous mentioned opportunity and that Denmark was ahead of the others.

2.9 Retrofitting rate of existing dwellings

Figure 14 does not show which part of the existing dwelling stock already has been retrofitted. Figure 15 shows the ‘major renovation rate’ per country. It can be seen that Norway and France have the highest rates, followed by Slovakia and Austria. Germany (1.5%) is in fifth position, the Netherlands is lagging behind (1.0%). For the UK (Sandberg et al, 2016) states the renovation rate at 1,6%. No data has been found for Denmark. The retrofitting rate generally is low, but still 10 times higher as the demolition rate.

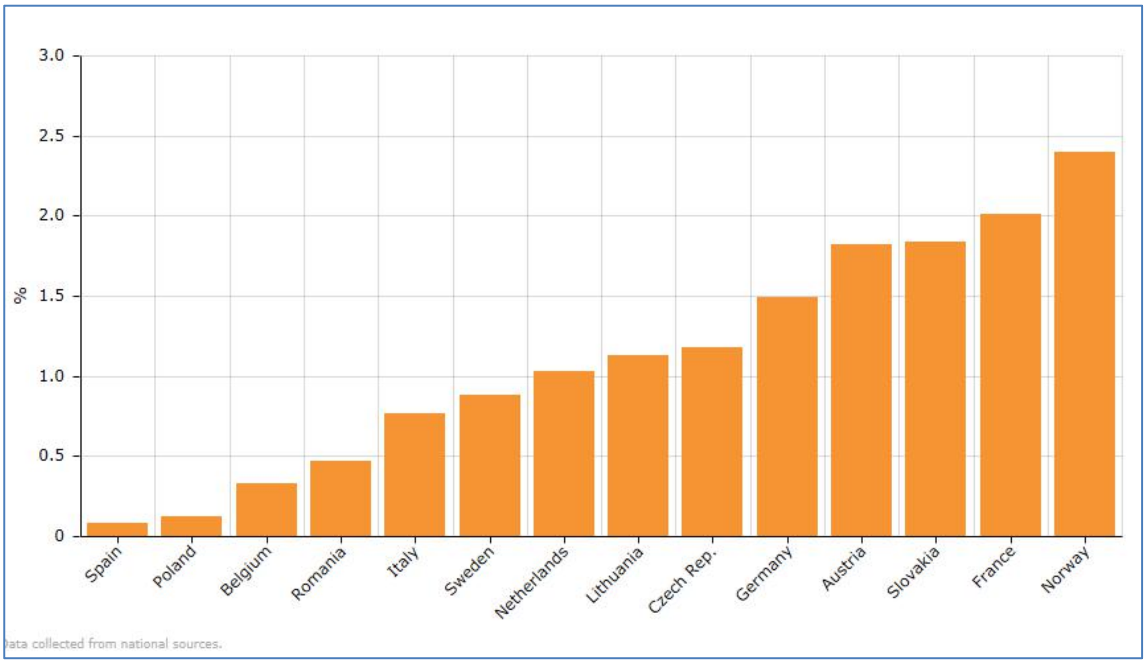


Figure 15: 'Major renovation equivalent' rate for dwellings in different EU countries (source: ZEBRA2020)

2.10 The development of the Energy Label of existing dwellings

Similar to new dwellings, the ‘big’ question is with what quality the existing dwellings of the previous section have been retrofitted. A deep renovation in the Netherlands, could be different from one in Denmark. EED Article 4, part of EU policies, says about deep renovations:

‘The strategy should address cost-effective deep renovations which lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels leading to a very high energy performance’

Countries have chosen their own approach to make the EED part of their national policy. In the Netherlands the building code dictates that a deep renovation should reach the quality level of a new buildings. When a dwelling has been retrofitted, it receives an Energy Label, as well called Energy Performance Certificate (EPC). The database ZEBRA has compared the labels that countries give to their dwellings and the related energy consumption. It appears that the F and G-labels of the Netherlands relate to E-labels in other countries and that the Dutch A++ label is comparable with the A label in most other countries, as shown in Table 1.

Table 1: The relation between energy labels given by EU countries and the calculate energy consumption Source: ZEBRA.

National EPC classification

Corresponding primary energy (kWh/m²/year)

EPC class	France	Austria	Sweden	Germany	Netherlands	Denmark	Portugal	Belgium
Label A	<50	<80	< 50	<50	A++ / (EI: <= 0,5)	< 20	≤25	45,00
Label B	51-90	81-120	100,00	51-100	A+ / (EI: 0,51 < 0,7)	< 30.0 + 1000 / A	26-50	95,00
Label C	91-150	121-160	150,00	101-150	A / (EI: 0,71 < 1,05)	< 52.5 + 1650 / A	51-75	150,00
Label D	151-230	161-280	200,00	151-250	B / (EI: 1,06 < 1,3)	< 70.0 + 2200 / A	76-100	210,00
Label E	231-330	281-340	300,00	251-350	C / (EI: 1,31 < 1,6)	< 110 + 3200 / A	101-150	275,00
Label F	331-450	341-400	400,00	351-400	D / (EI: 1,61 < 2)	< 150 + 4200 / A	151-200	345,00
Label G	>451	>400		>401	E / (EI: 2,01 < 2,4)	< 190 + 5200 / A	201-250	

2.11 Demolition of existing dwellings resulting in additional new dwellings

Obviously, a new dwelling has a certain lifespan. If every building would have been built to last for 75 years, the demolition rate would be around 1,3%, which is about the renovation rate of Germany. In reality, in the Netherlands, the demolition rate is around 0,16% only (statline.cbs.nl), in most other EU countries even far less (citeseerx.ist.psu.edu). In theory, this would mean that dwellings would last for 600 years. This obviously cannot be the reality, somewhere in the future, the demolition rate will increase, but for the short- and middle term, demolition will not contribute significantly to a better performing dwelling stock.

2.12 Using renewable energy such as wood pellets and heat pumps for local space heating

The higher the share of renewables that reach the residential sector, the lower the final CO_2 emissions. Renewables can reach the residential sector directly, e.g. by burning wood pellets inside the dwelling, or indirectly through electricity consumption or district heating. This section is about the renewables that reach dwellings directly. As can be seen from *Figure 16*, the share of locally used renewables is by far the largest in Denmark, which we therefore will take forward as the example for this section.

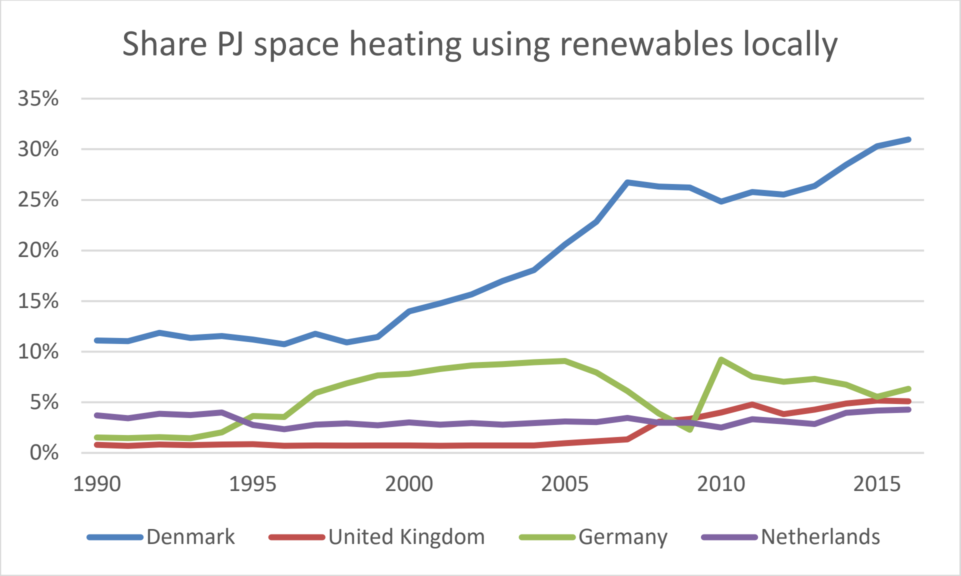


Figure 16: Share of space heating using renewables locally. Source: Odyssee

In Denmark, in 2016, 31% of the energy consumption for space heating is derived from a renewable source. This is about the energy consumption at the demand side, in the dwelling itself, e.g. wood pellets in wood stoves. Woody renewables with 85% percent form the largest share within the total renewables, as shown in *Table 2*. More than half of the wood chips, fire wood and wood pellets are imported from other countries.

The electricity consumption for local heat pumps is responsible for 4% of the total energy consumption for space heating and is the only 'type of renewable' that has CO_2 emissions attached to it[5]. Denmark both has the highest number of heat pumps installed in the residential sector (ehpa, 2014), and the highest share of renewables used within their national electricity generation. Therefore, heat pumps make a positive contribution by way of lowering CO_2 emissions.

[5] We have chosen a COP of 4, and therefore divided the CO_2 emission related to electricity consumption (DEA, 2016) by 4 as well.

Table 2: The share of renewables by type within the total renewables used as a local fuel for space heating. Source: (ADEMA, 2017; DEA, 2016)

Type of renewable	PJ	% of total energy consumption for space heating	% of renewables used locally for space heating	kg CO_2/GJ:
Electricity for heat pumps	6,2	4%	12%	25
Wood chips, fire wood, wood pellets, wood waste and straw	42,4	26%	85%	0
Bio-methane and gas works gas	1,3	1%	3%	0
Total renewables locally used	49,8	31%	100%	3,1

2.13 Using a high share of district heating with a high share of renewable energy

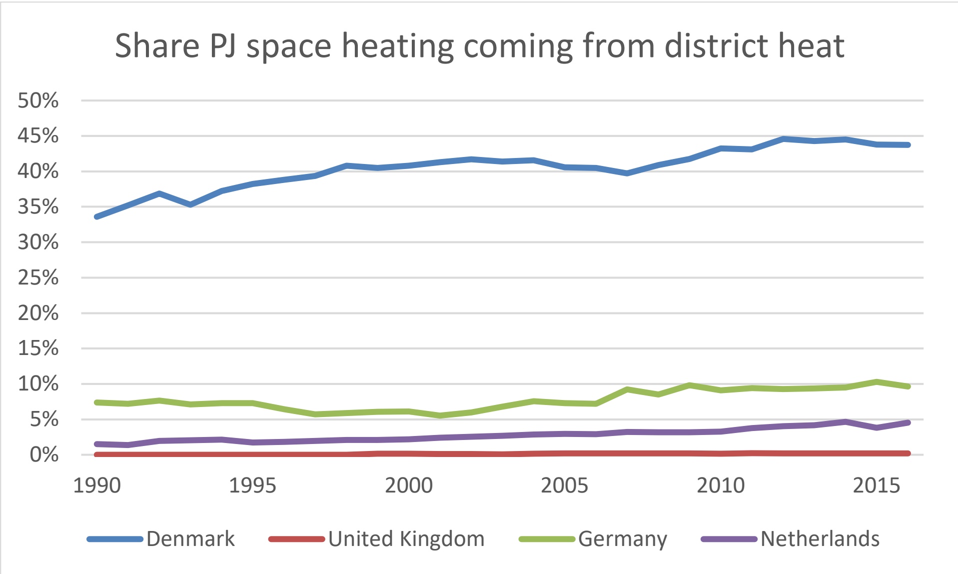


Figure 17: Share of district heating for space heating in dwellings Source: Odyssee

District heating has the highest share in Denmark, as shown in *Figure 17*. In 2016, around 44% of the energy consumption of space heating came from district heating. UK a share of 0,2% with hardly any dwellings connected to a heat district system.

There has been a significant change in the fuel used in the production of district heating since 1990 in Denmark. Production of district heating based on coal has fallen from about 50% to the current 13.7%. The corresponding percentage based on renewable energy has increased from around 20% to 52.5% of district heating production in 2016 (DEA, 2016). Within this share of renewables, *Figure 18* shows that wood is the main type of renewables used. See as well Figure 45.

Recommendation: it would be interesting to analyse for the four countries of this study what share of renewables reach space heating in the residential sector through (1) local combustion, (2) heat district and (3) electricity consuming heating devices as heat pumps.

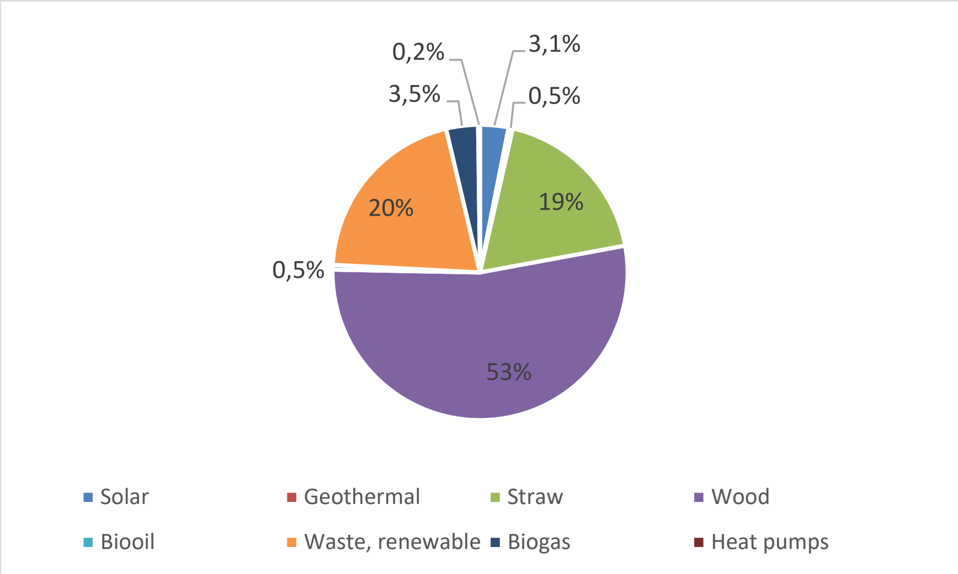
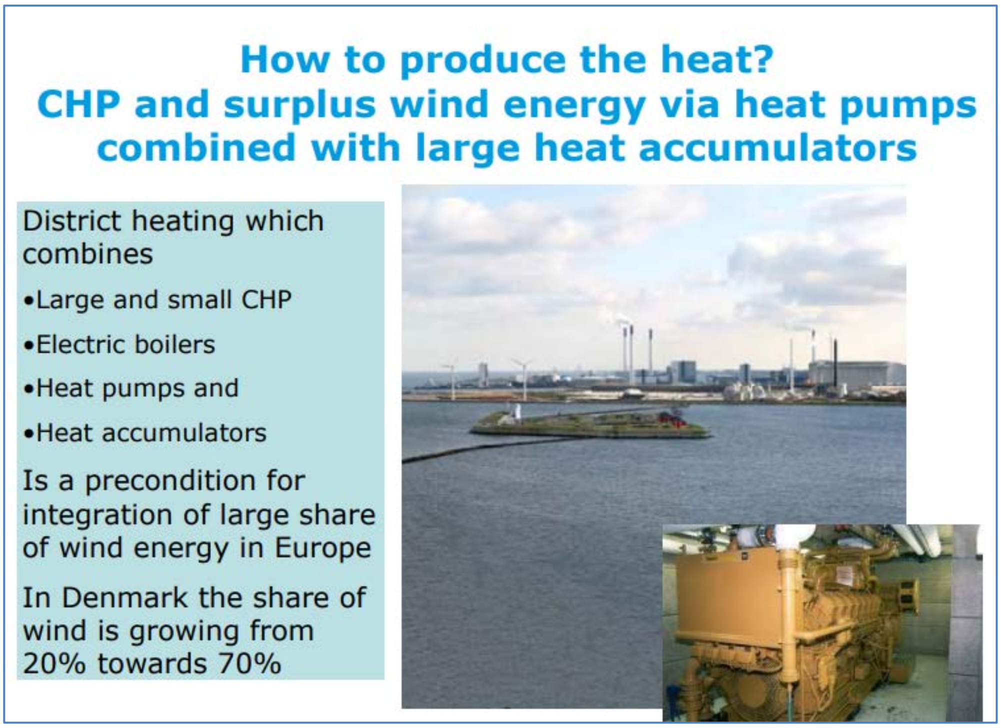


Figure 18: Share of type of renewable within the total renewable energy consumption for district heating production in Denmark. Source: (DEA, 2016)

Demand side management

A bit out of scope, it is interesting to realise that Denmark uses it’s district heating system as well as a Demand Side Management (DSM) strategy, as mentioned in the below slide, taken from (Ramboll, 2009). The flexible system provides a buffer for heat in general, but is at the same time able to absorb excessive renewable electricity production.

Recommendation: the share of fossil fuels in districts heating systems could be decarbonised by carbon capture and storage (CCS), lowering the (allocated) CO_2 emission of delivered heat even further. This possibly additional benefit of district heating has not yet been analysed in this study.



2.14 Combined effect for intensities and type of fuel used for space heating

Energy and CO_2 emission intensities between 2000 and 2016

Non-policy factors and policy measures had a combined lowering effect on the energy and CO_2 emission intensity in all four countries. *Figure 19* shows the percentage reduction of the intensities between 2000 and 2016. Observations that we can make:

1. On average over the four countries, the energy intensity lowered by 30% and the CO_2 emissions lowered by 41%.
2. The energy intensity in the Netherlands lowered the most (39%)
3. The energy intensity in Denmark lowest the least (17%), but at the same time the CO_2 emission intensity lowered the most (54%)
4. The CO_2 emission intensity of the UK lowered the least (32%).

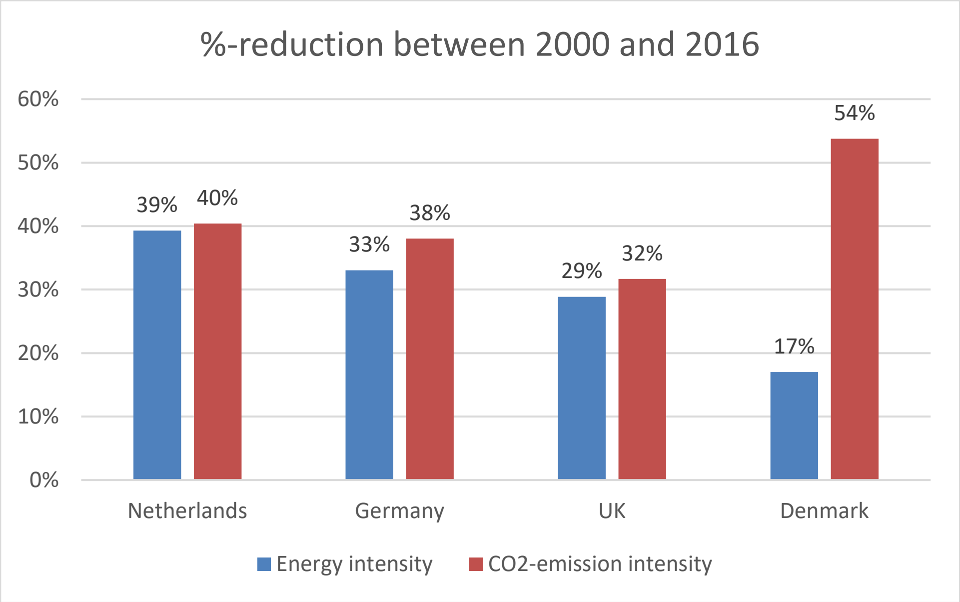


Figure 19: The percentage reduction of the energy and CO_2 emissions intensities between 2000 and 2016. Calculated with several data sources.

The interesting question now is what part of the reduction has been realised through policy measures only. As said before, this is very difficult to calculate, but some studies have tried so. The next chapter will discuss this matter.

Share of fuel by type for space heating 2016

In *Figure 20* the share of fuel by type is shown, used for residential space heating in 2016. The share of natural gas is the largest in the Netherlands, followed by the UK and Germany. Germany still uses a substantial share of oil (27%). The share of electricity is the highest in the UK, where a significant share of dwellings (commonly low-income households not connected to the gas grid) still use electricity for space heating (storage heating/resistance). The share of locally used renewables, which includes the electricity consumption of heat pumps, is clearly highest in Denmark, as is the share of heat provided though heat districts.

In *Figure 20* the related share for CO_2 emissions are given. The CO_2 emissions of gas, oil and coal are locally generated; the CO_2 emissions related to electricity consumption and delivered heat have been allocated to the residential sector. Obviously, the higher the share of renewables within the national electricity production and heat districts, the lower the CO_2 emissions of each delivered kWh and MJ of heat in the dwelling. The CO_2 emissions of locally used renewables only originates from the electricity consumption of the heat pumps, that have been made part of the renewables by Mure. It is assumed that the other types of renewables, such as straw, wood chips, fire wood, wood pellets, are completely sustainable, and therefore don't create CO_2 emissions that need to be taken into account. The same counts for biogas, biomethane and gas works gas, that according to the Danish statistics don't account for CO_2 emissions (DEA, 2016). The most striking observation of *Figure 20* is of course the Danish situation.

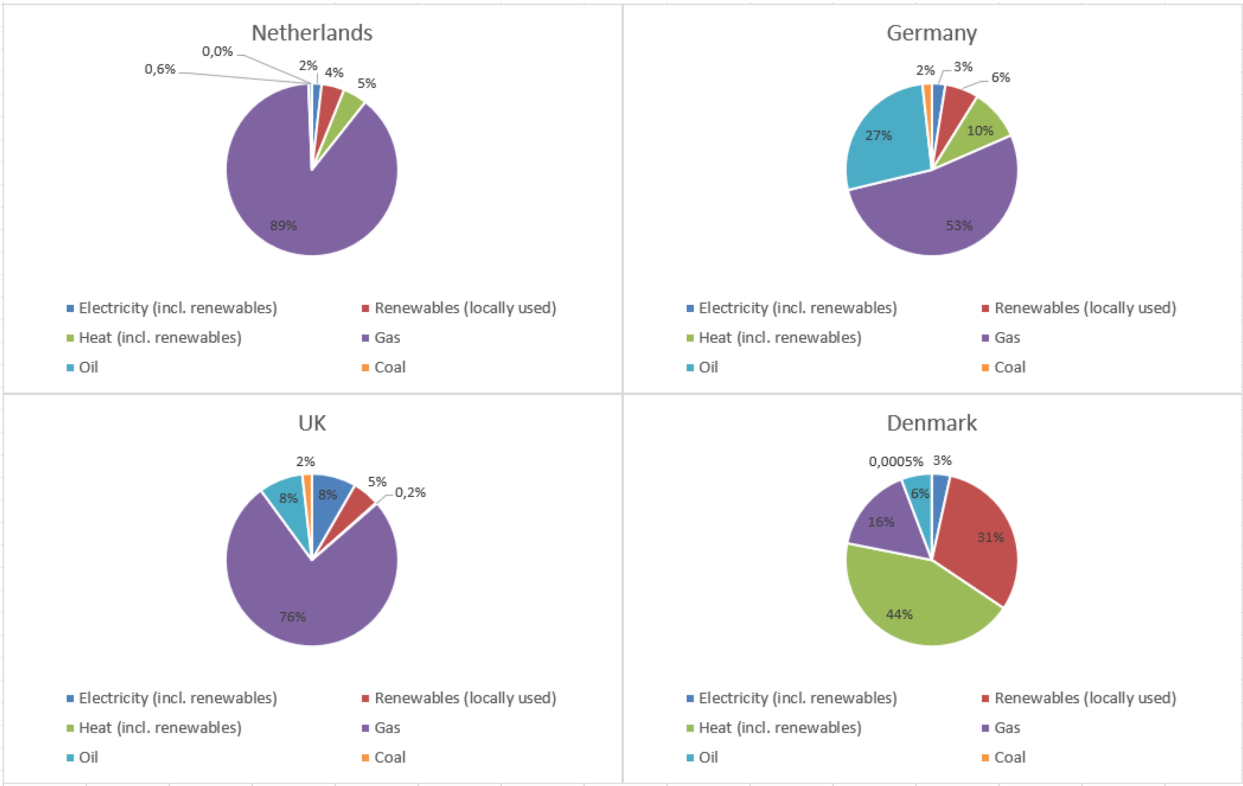


Figure 20: The share of fuel by fuel type for space heating 2016

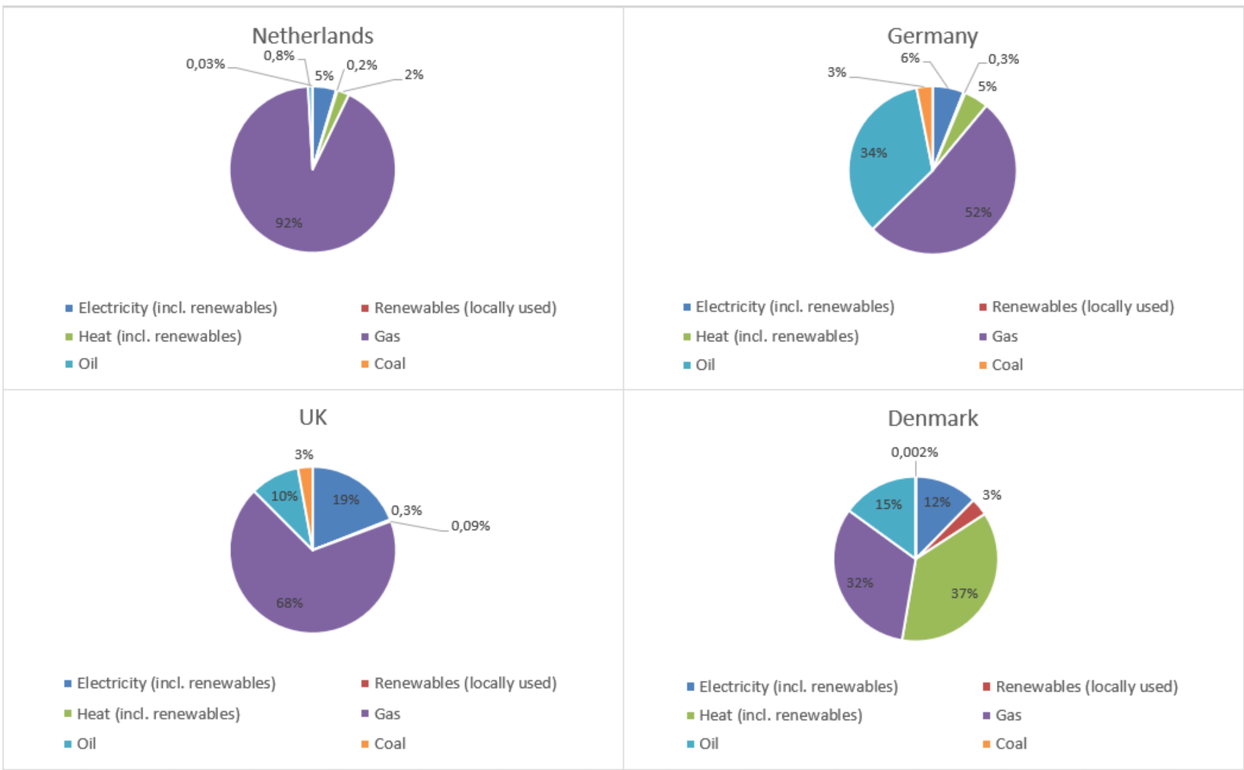


Figure 21: The corresponding (allocated) CO_2 emissions for the fuels of Figure 20

3 Best performing countries that have reduced the energy demand and CO_2 emissions for space heating, according to literature (by Sipma, J.M.)

3.1 Introduction

In the previous chapter a quantitative comparison has been made between the countries for the energy and CO_2 emission intensity. We have concluded that all intensities have reduced since 2000 due to non-policy factors and policy measures. What share can be contributed solely to policy measures is hard to answer, but some studies have tried to do so. These will be discussed in this chapter.

Of course, it would be purely a coincidence if exactly the four countries that we are interested in were to appear in an existing study. This is not the case. However, we have found (only) two relevant studies that compare EU countries with each other, over a certain period of time. These are better describes as databases, from which we have used one already in the previous chapter.

- Odyssee-Mure database (ADEMA, 2017)
- Zebra2020 (ENERDATA, 2017)

The Odyssee part of Odyssee-Mure looks at the energy intensity, as we have seen in the previous chapter. The Mure part looks at the (impact of) policy measures that countries have taken. ZEBRA compares the renovation rate of countries.

Other aspects that make the comparison difficult
Studies in general indicate that each country has its own way of reporting, over a number of years, within specific system boundaries. A study by Broc et al. (2017) looked at the 'Impacts and cost-effectiveness of major energy efficiency policies for existing buildings' and made the following remark;

"*There have been many reviews about how energy efficiency policies for existing buildings work, but more rarely about the details of their effective impacts and costs, mainly due to difficulties in accessing data. The National Energy Efficiency Action Plans enable to know what policies are implemented and how. But details about their impacts and costs can often be found in national language only, and rarely in a single report (if available at all).*"

"The comparison shows how risky too quick comparisons of macro results may be. A full understanding of the results from different measures requires entering into the details of their characteristics and background. Despite detailed evaluation reports, the information found do not allow to re-compute data in a harmonised way to obtain comparable indicators because of data limitations."

A study by Schumacher et al. (2012) indicates that reported information on policies and measures is often limited to qualitative assessments and that the assessment of quantitative impacts is often lacking. Moreover, ex-post evaluations are not always carried out and/or are inconsistently reported by the different EU Member States.

With similar reasons it is difficult to make a direct comparison between meta-studies in general, because of e.g. the inclusion/rejection of the utility sector, the period to which the calculations relate, and the assessment method used.

Good to realise; although the comparison is difficult, there *is* a relation between policies and retrofits

Figure 22 gives for the UK the number of energy efficiency measures taken within the residential sector, together with a timeline that shows when certain policy has been put in place. Qualitative conclusions can be drawn from the connection between major policy changes and the change in the number of measures carried out each year. It is clear that after new increased targets are set, the total number of measures increases substantially. At a certain moment, the boiler measures decrease, as more focus was placed on the importance of improving efficiency through insulation measures. The more recent reduction in the total number of measures is in line with the scaling back of the targets and budget. For more details, see the UK chapter.

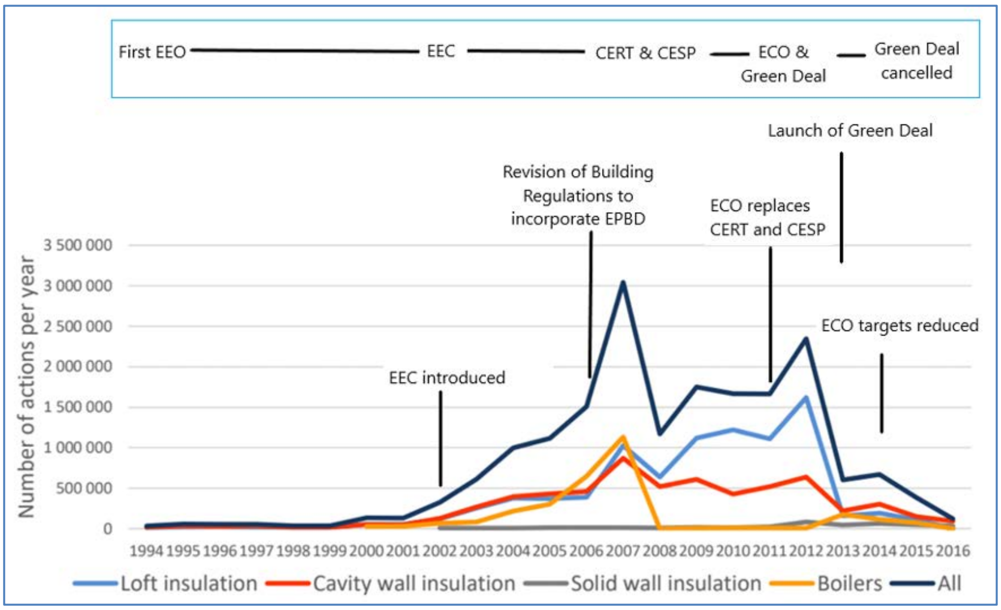


Figure 22: Influence of policy changes on the installation of energy efficiency measures in the UK

3.2 Chapter summary

Table 3 shows the relative position of the countries selected in this study, according to the examined databases. The country in which the policy measures scores best to reduce the energy consumption for space heating in the existing dwelling stock has been given the value '1', with its cell coloured green. The country that scores the worst is given the value '4' and is coloured red. Between two countries a database may place a whole list of other EU countries.

Table 3 Countries that are identified as the leaders in this study, according to the examined databases.

Country	**Odyssee** Based on the reduction of the energy intensity between 2000 and 2015.	**Mure** Based on the quantitative yearly effect of policies to reduce the energy consumption for space heating.	**Zebra2020** Based on the yearly rate of deep renovations of existing stock.
	Figure 23	**Table 5**	**Figure 15**
Netherlands	1	3	2
Germany	2	1	1
UK	3	2	Not mentioned
Denmark	4	4	Not mentioned

Observations in comparison with all EU-countries:

- In general, compared to the EU as a whole, the Netherlands, Germany and the UK are performing quite well in reducing the energy intensity in the residential sector.
- The case of **Denmark** is different. Denmark did not increase the energy efficiency of the dwelling stock to the same extend as other EU countries did. But at the same time, Denmark has reduced the (allocated) CO_2 emissions by making sure a significant share of the heat demand is met through renewable energy[6].
- A few other countries that could be doing well are (mentioned by MURE, ODYSSEE, *and* ZEBRA): **France, Slovakia** and possibly **Ireland** (highest score in MURE but not mentioned in ZEBRA) and **Norway** (highest renovation rate according to ZEBRA, but as a non-EU country it is not mentioned in Odyssee-Mure)

Recommendation: repeat this study for France, Slovakia, Ireland and Norway

Observations within the four chosen countries

- It becomes clear that **Germany** is doing relatively well. Germany is assessed relatively well both in the previous chapter and in the examined databases of this chapter.
- The **UK** occupies an intermediate position in the databases
- The performance of the **Netherlands** is unclear. According to Odyssee the Netherlands scores best. According to Mure though, the impact of relevant policy measures fall into the middle category, just as the 'major renovation rate' according to ZEBRA.

In the next chapters, the portfolio of policy measures in each country will be described and evaluated, just as will the impact of different types of policy measures. We will become aware that we should be careful when comparing reported savings though.

[6] In this final version of this report, the study ZEBRA (ENERDATA, 2017) has been removed from this chapter, since it only compares the achievements of countries for the year 2011. The situation for Denmark is the same though. In terms of 'energy efficiency', their policies influencing the built environment does not score so well, but in terms of 'renewables' and 'overarching', Denmark scores relatively well.

3.3 The Odyssee part of Odyssee-Mure

Introduction

Odyssee is a database of energy saving statistics and calculated energy saving indicators for the EU-28 countries. It is an open-source database of Enerdata with data updated annually by different country teams, consisting of researchers working for various European energy research institutes. National databases are used in the Odyssee database. For example, in the Netherlands figures from the National Bureau for Statistics (CBS) are often used for Dutch energy statistics. The full name of the database is "Odyssee-Mure", because there is also a Mure part. The Mure part of the database contains separate policy instruments with descriptions of their workings as well as quantitative evaluations. This overview contains the policies from the various National Energy Efficiency Action Plans (NEEAPS). More about this in the next section. Other databases (such as ZEBRA2020) as well as scientific publications (Gynther, Lappillone, and Pollier 2015; Laes et al. 2018), which we also use in this study, use Odyssee-Mure. The energy saving indicators in Odyssee provide a first impression of the relationship between the policies in the countries we have chosen, both qualitatively and quantitatively. A lot of information will come from this database, including also for the individual countries.

Energy intensity trend for space heating

Firstly, we want to compare the energy intensity trend for space heating of the selected countries. As discussed in chapter 2, the comparison will not immediately be conclusive about how well countries are doing in terms of energy savings policies in existing buildings.

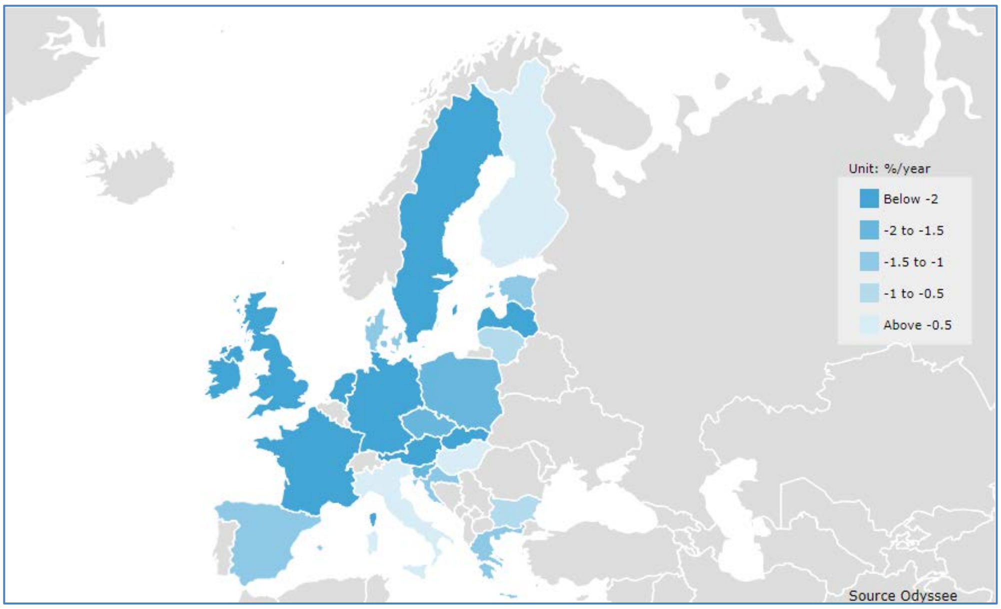
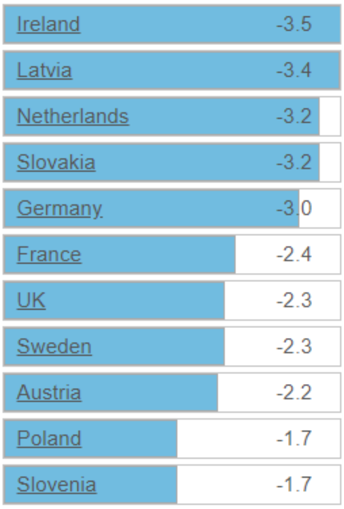


Figure 23: National trends in energy consumption for space heating (climate-adjusted) per dwelling in the period 2000-2015 (source: Odyssee)

Figure 23 shows the trend (climate-adjusted) between 2000 to 2015. The darkest shade of blue represents countries with the largest decrease in energy intensity. The decrease is 3.2% per year for the Netherlands, followed by Germany (3,0%), the UK (2,3%) and Denmark (1,3%). This is the same sequence as found in section 2.14, which is logical, since the same data has been used



Only Ireland (3,5% per year), and Latvia (3,4% per year) show an even stronger decrease in energy intensity then the Netherlands. The first observation is that the Netherlands appears to be doing relatively well compared to other EU countries

Excluding non-policy factors and the effect of new buildings

The so called 'ODEX' is the index used in the Odyssee project to measure the energy efficiency progress in main sectors such as the residential sector. The indicator represents a better proxy for assessing energy efficiency trends than the traditional energy intensities, as they are cleaned from structural changes and from other factors not related to energy efficiency, which include the impact of new buildings.

'In some countries, there is a slow down or even a deterioration of energy efficiency progress for heating since the mid-nineties. Such changes should not be interpreted as a reduction of energy efficiency, as technical savings have not actually stopped, with all the extra policy measures implemented in the late nineties and the continuous addition of new dwellings that are much more efficient. This situation rather reflects negative behavioural savings, due to higher indoor temperature. This means that the actual energy efficiency progress is under estimated.'

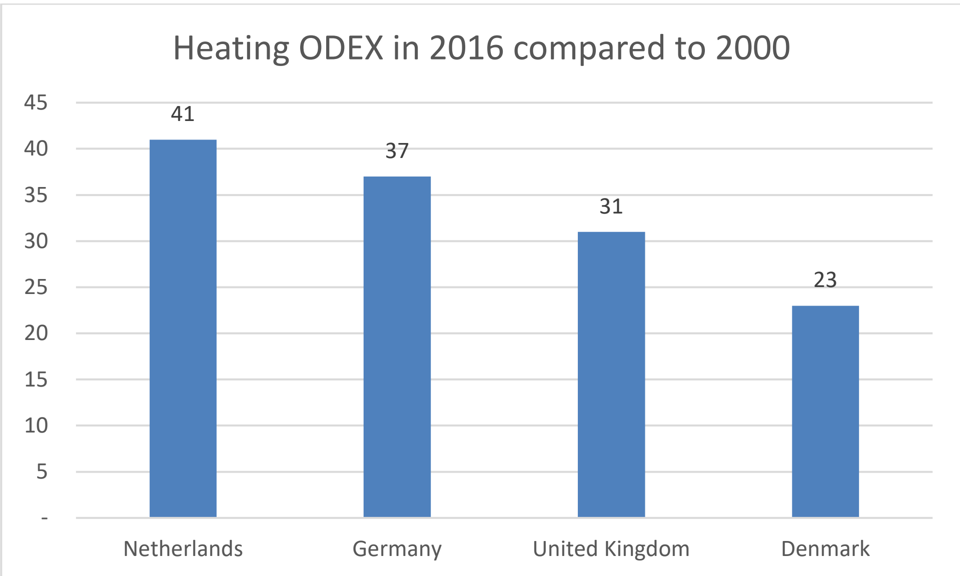


Figure 24: The higher the ODEX, the more energy efficient existing dwellings have become due to policy measures.

Figure 24 shows that the policy measures in the Netherlands have resulted in the highest improvement of the energetic quality of their existing dwelling stock. The sequence of countries is the same as found earlier and in section 2.14, where we were not able to exclude non-policy factors from the results. This means that Denmark scores least, but we know as well that Denmark scored best in lowering the CO_2 emission intensity by increasing the share of renewables that can be allocated to the residential sector.

3.4 The Mure part of Odyssee-Mure

Introduction
The Mure database contains an extensive and detailed overview of energy-related policy instruments per country. It also quantifies what these instruments have delivered in terms of energy savings, although the numbers seem not to come from the countries themselves, but are estimated within Mure. With this reason the numbers should be seen as indicative (and are omitted in the final version of this report.

The database includes current policy instruments ('ongoing'), but also completed policy instruments. An overview of policy instruments can be obtained by country and by sector in tabular form. In Mure a distinction is made between households and the tertiary sector (synonymously termed the services sector), here we only look at households. For each policy instrument there is a link to a descriptive document of usually 1 to 2 pages. It briefly describes the policy instrument and includes quantitative evaluations where appropriate.

Number of policy instruments in the selected countries
Table 4 shows how many policy instruments are used in existing housing construction in the selected countries. We limit ourselves to measures aimed at (reducing) the demand for heat (insulation measures and boilers). A distinction is made between national policy and EU related policy, such as the EPBD (European Energy Performance of Buildings Directive). Although the EPBD is transposed into national policy, in Mure it has been labelled as EU policy[7]. It makes sense to look at both national policy and EU-related policy because each country also implements EU policy in its own way. Mure has added a level of impact to it (high, medium, low). It is not exactly clear to us whether this includes both ongoing and completed measures, and how exactly the impact has been determined. Nor is it clear what period the mentioned savings relate to.

Table 4 shows that Germany uses the most instruments; and Denmark the least. Overall, this concerns (more than) 80% national policy and 20% EU policy[8]. In relative terms, the Netherlands has the highest national policy share (13 out of 14 measures),

[7] We have found irregularities here though; this remains the interpretation of the national expert entering the data. This counts as well for other items that can be labelled at individual policy measures.

[8] EU policies include (parts of) the EBPD directives that (still) makes an impact, and sometimes Eco-design. It is so far not known to us why e.g. the UK mentions (parts of) the EPBD directive multiple times, but other countries not. Nor, why some countries include Eco-design but others not. We do see Odyssee-Mure as a very interesting and comprehensive source of information but feel the need as well to improve some elements of it.

while the UK relies relatively more on EU policy (4 out of 10 measures). In the country chapters, these measures will be discussed more in depth. In this section we first only focus on their quantitative impact, according to Mure.

Table 4: Number of current policy instruments for space heating only (insulation and boilers) in existing dwellings per country (source: Mure)

Country	Number of national policy instruments	Number of EU related policy instruments	Total	% of Total
Germany	19	3	22	39%
United Kingdom	10	4	14	25%
Netherlands	13	1	14	25%
Denmark	5	2	7	12%
Total	**47**	**10**	**57**	**100%**
% of Total	**82%**	**18%**	**100%**	

The impact of the policy instruments

The impact of the policy instruments in terms of energy savings according to Mure is shown in Table 5. The table is arranged from left to right by country with the largest combined percentage saving effect. This makes it clear how countries relate to each other[9]. The combined impact with interaction of policies also takes into account the interaction of policy instruments.

Table 5: Combined impact per country for current policy instruments aimed at space heating (insulation and boilers) in existing dwellings, including EU related policy (source: Mure)

Ranking:	**1**		**2**		**3**		**4**	
Country:	**Germany**		**UK**		**NL**		**Denmark**	
	Energy saving [PJ]	**Energy saving [%]**	**Energy saving [PJ]**	**Energy saving [%]**	**Energy saving [PJ]**	**Energy saving [%]**	**Energy saving [PJ]**	**Energy saving [%]**
Sum of impacts (without interaction)	162	6,7%	72	4,2%	13,1	3,5%	4,7	2,5%
Combined impact (with interaction)	115	4,8%	51	3,0%	8,6	2,3%	4,3	2,3%

We see that Germany does relatively best out of the chosen countries. Germany has an average energy saving rate of 6.7% per year. This is 4.8% per year when the interaction of policy instruments is taken into account, as policy instruments sometimes focus on the same measures and there is overlap. This is followed by the UK (3.0%), the Netherlands (2.3%) and Denmark (2.3%). On average, the

[9] These saving rates differ from the percentages in Figure 23. Here it should be considered as the total percentage of yearly savings for the residential sector. It is unknown to us what period it considers.

overlapping effect of the measures is around 30% (not shown in the table). For Denmark this overlap is only 9%, which seems logical given that Denmark also has fewer policy measures according to *Table 4*.

The main difference with the previous section and with section 2.14 is that the Netherlands now lost its first place and is downgraded to third place.

3.5 ZEBRA2020

Introduction

Zebra2020 is a monitoring tool that uses data from, among others, Odyssee-Mure (Enerdata 2018c). This tool makes it possible to display indicators on the status of energy (performance) development of buildings in selected European countries. Here, for example, you can find a comparison of the in-depth renovation rate in different countries.

The in-depth renovation rate

"A major challenge for the EU is the low rate of deep renovation of the existing building stock that would reduce energy consumption and thus emissions. The current renovation rate amounts to between 1–2% of the total stock, but could be significantly increased: 35% of the EU's building stock is over 50 years old (European Parliament, 2016). The deep renovation rate of residential buildings differs significantly between the EU member states: with 2% in France, 1.5% in Germany, to 0.12% in Poland and 0.08% in Spain" (Zebra2020, 2017).

It has already has been mentioned a few times that a direct comparison between countries is difficult to make. To enable better comparisons between countries, ZEBRA has developed an indicator for the 'major renovation equivalent'. Major renovations (as defined in Article 2 of the EPBD recast) occur when the total cost of the renovation in relation to the building envelope or its systems exceeds 25% of the value of the building, or more than 25% of the surface area of the building envelope undergoes a renovation. In the absence of an official European definition, the ZEBRA consortium assumes that a major renovation can reduce the final energy demand of a building for heating by 50 to 80% (range depending on the country, defined by national experts according to the current efficiency of the building stock).

We have used ZEBRA already in section 2.9 where we have discussed the low rate of retrofits. Figure 14 in that section showed that Norway and France have the highest rates, followed by Slovakia and Austria. Germany (1.5%) is in fifth position, the Netherlands is lagging behind (1.0%). No data has been given for the UK and Denmark; but from (Sandberg, 2016) we found that the UK has a renovation rate of 1,6%; which is relatively good. The retrofitting rate generally is low, but still 10 times higher than the demolition rate.

4 Policy measures of the selected countries evaluated, that have reduced the energy demand and CO_2 emissions for space heating (by Sipma, J.M.)

4.1 Introduction

In chapter 2 we have concluded that the energy demand and CO_2 emissions for space heating (each square meter of dwelling) have been reduced since 2000 due to non-policy factors and policy measures. In chapter 3 we have tried to eliminate the non-policy factors from this reduction, in order to find the contribution of the policy measures only. This has led to some conclusions over which countries have performed best, and which less so.

In this chapter we will dive deeper into the portfolio of policy measures of the four chosen countries. This chapter originated from the four individual country chapters that will follow afterwards. In this chapter, overarching observations are made, based on the choices countries have made in their battle to reduce the energy consumption that we are looking at. There is nothing really good or wrong here just *observations.* A certain policy portfolio that works in a specific country, might not work somewhere else, due to many reasons (e.g. decisions made in the past, cultural differences, differences in technical and financial infrastructure, economic growth, etc.). Observations made could *inspire* countries while making certain decisions for the future though. Learning ‘what went well’ and ‘what went badly’, is the highest feasibility of this study.

The Netherlands is searching for an alternative to a dependence on natural gas, in combination with environmental goals that need a much higher retrofitting rate than is currently the case. The Netherlands might get inspiration from other countries in their search for their best suitable direction.

Although we will still look at the *relative impact* of certain policy measures (low, medium, high impact), the quantifications have been left behind for now. A significant share of information in this- and the following chapters has been distilled from the database Mure, as part of Odyssee-Mure (ADEMA, 2017).

4.2 Chapter summary

In Mure, several **types of policy measures** have been identified, e.g. defined as legislative, financial, fiscal or cross-cutting. These definitions are commonly accepted, although variations can be found across literature. Table 8 shows the list taken from Mure.

Besides well-known EU related policies such as the EPBD and Eco-design that apply to member states, countries have chosen to implement **Energy Efficient Obligations** (EEO), or follow a so-called ‘**alternative route**’. The latter expression, following an alternative route, comes directly from the EU and will become more clear in the following sections. The EEO is another EU-related policy and it has been adopted by both the UK and Denmark. Germany and the Netherlands have chosen to follow the alternative route.

When having an EEO in place, the responsibility is shifted towards the utility sector. We have observed that therefore the UK and Denmark have in general less national policy measures implemented in comparison to Germany and the Netherlands. Still, the UK has quite a lot of financial measures, probably since their EEO does not cover the complete residential sector. Another reason is the fact that the UK is a constituent country with devolved powers that needs distinguished financial incentives for several autonomous sub-regions. The UK and Denmark, not surprisingly report a high impact for their EEO approach. Other types of measures are supporting the EEO.

In their searches for an alternative route, Germany and the Netherlands have made different choices. The Netherlands is searching for **collaboration** with all kinds of different stakeholders involved (e.g. the government, housing corporations, construction- installation and energy companies), which must be a cultural imbedded approach. There are also some national-legislative measures added though. In Germany on the contrary, **national-legislative** measures are more dominant in numbers. These types of measures have also been reported to yield a high impact, supported by measures that have the character of financial/fiscal and/or information/education type policies.

In most countries, **energy taxes** are important, although in Germany they are the main driver. The highest electricity prices and shares of related electricity taxes are in place in Germany and Denmark. While in Germany the high electricity tariff is one of the main pillars of the designed alternative route, Denmark uses the tax-income to finance the EEO programme. Denmark, together with the Netherlands, has the highest gas-taxes.

The chapter ends with a section explaining why we should be careful interpreting evaluations of policy programmes and reported energy savings. The calculating of energy savings is in general complex, and sometimes exaggerated for several reasons. Since national policy programmes all have their own system boundaries, period of monitoring, evaluation methods and correcting factors, it is even harder to compare the success rate of countries with each other. Since countries have made historical choices, carry different cultural aspects, have or do have not access to natural energy resources and are doing better economically or less so, we feel that nothing is really good or wrong here. But we are indeed able to make interesting **observations**. These observations could **inspire** the Netherlands and other countries in making certain decisions for the future though. Learning ‘what went well’ and ‘what went badly’ could certainly be beneficial for future energy related debates.

4.3 Different types of policy measures

In Mure, several types of policy measures have been identified. These are commonly accepted. Although variations can be found across literature. Table 6 shows the list taken from Mure.

Table 6: Types of policy measures according to Mure (*odyssee-mure.eu*)

Level c1	**Level c2/c3 (examples)**
Legislative/Normative	Mandatory Standards for Buildings
	Regulation for Heating Systems
	Other Regulation in the Field of Buildings
	Mandatory Standards for Appliances
Legislative/Informative	Mandatory labelling
	Mandatory energy efficiency certificates
	Mandatory audits
Financial	Grants / Subsidies for investments
	Grants / Subsidies for audits
	Loans/Others
Fiscal/Tariffs	VAT Reduction
	Income tax reduction
	Linear electricity tariffs
Information/Education	Voluntary labelling
	Information campaigns
	Detailed energy/electrical bill
	Regional and local information centres
Co-operative Measures	Voluntary/Negotiated agreements
	Voluntary DSM measures of suppliers
	Technology procurement
Cross-cutting	Eco-tax on electricity/energy
	Eco-tax on CO_2 - emissions

To this table 'Market-based measures' can be added (epatee.eu):

- energy efficiency obligations (EEO)
- energy efficiency auctions/tender systems
- emission trading systems, Clean Development Mechanism (CDM) and Joint Implementation programmes (JI)

These are defined by the EPATEE project, which will be discussed further in section 4.9. There is a strong historical link between the experts behind Odyssee-Mure and EPATEE.

To avoid confusion: a country could have a general *policy programme* to reduce the energy demand and CO_2 emissions in the residential sector. The programme consists of several *policy measures* that interact with each other in order to reach the goals set by the programme. The right side of Table 6 shows a list with examples of policy measures, taken from Mure. A policy measure often belongs to one '*type*' of policy measure, but we have seen that sometimes it has two types attached to it as well. This could make the subject confusing. The reason is that a policy measure often does not just have one of the specific demarcated descriptions as given in Table 6.

As an example; the UK policy measure *[HOU-UK23 Smart Metering and Billing] (measures-odyssee-mure.eu)*, has been entered as policy measure types 'Legislative/Normative' and 'Information/Education'; both of which are probably right.

And the [*GEN-UK11 Green Deal] (measures-odyssee-mure.eu)*, has been entered as policy measure types 'Financial Measures' and as 'Market-based Instruments'; both are probably also right.

> Recommendation: although the database of Mure (in combination with Odyssee) has been proven to be very useful for us, we came across quite some unclarities and irregularities. If a country comparison is performed again, it would be good to discuss these beforehand, and possibly to improve some aspects of the database.

One should also realise that this information has been entered by country-experts, sometimes leading to irregularities. The EU-related policy measure ‘EPBD’ sometimes is entered (correctly) as legislative/normative, in other cases it has been entered as (incorrectly) legislative/informative. Some countries have, probably wisely, added both ‘legislative/normative’ and ‘legislative/informative’ to ‘their’ EPBD. There are even more variations entered with (combinations of) ‘Financial’, ’Fiscal/Tariffs’ and/or ‘Information/Education’, supposedly these are not necessarily always wrong.

The last thing to point out is that the country-expert has the choice to add a policy measure to a certain sector. Clearly in this report the interest is the household sector. However, sometimes a policy measure is placed into the ‘General cross-cutting’ sector, although it also influences the household sector. The best example for this is the EEO of Denmark…..

[GEN-DK6 EU-related: Energy Efficiency Directive (EED) - Directive 2012/27/EU - The energy efficiency obligation scheme], (measures-odyssee-mure.eu)

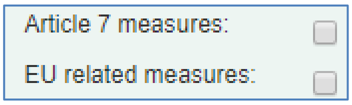
…..labelled with the type ‘Co-operative’ and placed in the sector ‘Cross-cutting’.

In this and the following chapters, we therefore sometimes have made our own choices in order to cover all measures that influence the energy demand and CO_2 emissions of the residential sector.

In reality, a policy programme, together with supporting policy measures, will stimulate ‘real action to be taken’. The term ‘action’ is used (in EPATEE) when speaking of the actions implemented on the side of the end-user, and can either be:

- technical: e.g., replacement of a boiler, installation of insulation
- organisational: e.g., implementation of an energy management system
- behavioural: e.g., lowering the temperature of the thermostat

4.4 EU related policies



In Mure, there is a filter option for policies designed by the EU, these are always described as ‘Legislative’. In practice, EU-policy is often transformed into a nationally acceptable form. Still it remains an ’EU’ policy measure in Mure to make the distinction with national invented policy measures. Often ‘EU policy’ has a national background; the ‘energy efficiency obligation’ for example started in the UK and was later turned into an EU policy (see next section).

The main EU-policies influencing the residential sector are:

- EU general: each country has to implement the ‘Energy Performance Buildings Directive EPBD, making new and existing buildings over the years less energy-intensive (MJ/m^2). The EPBD is a Legislative-Normative policy programme that focuses on the quality of the building itself (the heat demand) and on heating equipment such as boilers and heat-pumps (filling in the heat demand). Making use of renewable energy (heat, electricity, green gas) is indirectly linked to the EPBD (and stimulated by other EU-regulations). More district heating (as in Denmark) and renewable electricity used by electric heat pumps provide the building with a better label/certificate and lowers the final CO_2 impact. Although countries can choose their own strategy for implementing the EPBD nationally, and although there are quite some differences between countries in terms of organisation, effectiveness and enforcement (especially for existing buildings), is it still a mandatory EU-directive that needs to be implemented and reported on.

- EU general: each country is automatically influenced by the Eco-design directive. This directive makes sure that electrical appliances become less energy-intensive over the years. It is mandatory for the producing sector/market, but only informs the end-user about energy efficiency. This includes lighting, but as well heating, ventilation and cooling and even electric motors (e.g. part of electric heat pumps). Therefore, eco-design also influences the energy intensity of space heating in dwellings. The Netherlands is one of the few countries in Europe that provides subsidies for energy efficient appliances, as an additional measure to stimulate buying appliances that have been labelled as highly efficient. This additional financial measure has proven to be very useful; energy efficient appliances have relatively quickly reached a high market share in the Netherlands (Luttmer, 2006).

- EU general: there are more EU regulations that influence directly or indirectly the energy consumption of space heating in dwellings and/or the related CO_2 emissions. These can be seen as 'general' policy measures and are often 'cross-cutting' through all end-user sectors. Whether these should be directly or indirectly linked to the residential sector (read: 'had a high impact reducing the energy consumption'), is up for discussion. The following two examples are present in several countries, but the link to the UK is given:

[GEN-UK10 EU-related: Promotion of Electricity from Renewable Sources (Directive 2001/77/EC) - Feed In Tariff], measures-odyssee-mure.eu

[GEN-UK10 EU-related: Promotion of the Use of Energy from Renewable Sources (Directive 2009/28/EC) - UK12_Renewable Heat Incentive], measures-odyssee-mure.eu

4.5 A closer look at Energy Efficiency obligations (EEO)

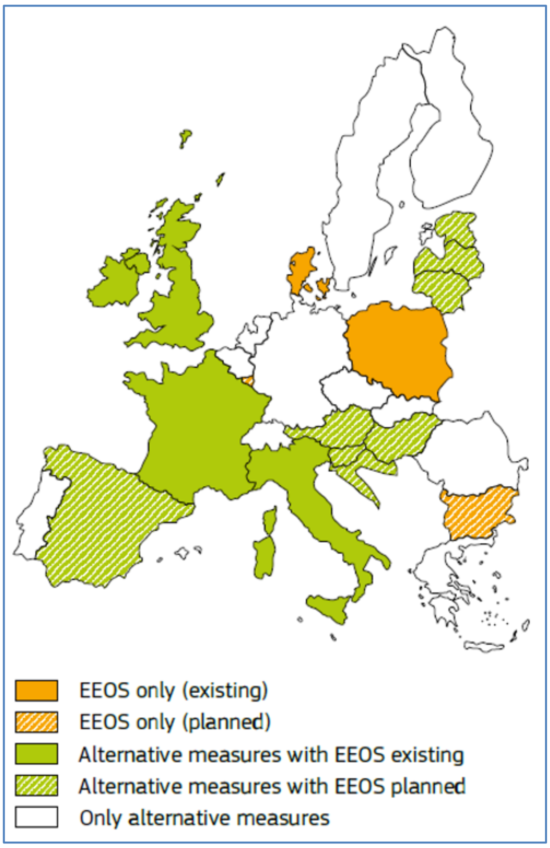
Slightly different to the previous EU regulations is the Energy Efficiency Obligation (EEO) under article 7 of the EED:

*'Under the Energy Efficiency Directive, EU countries must set up an energy efficiency obligation scheme. This scheme requires **energy companies** to achieve yearly energy savings of 1.5% of annual sales to final consumers.*

In order to reach this target, energy companies need to carry out measures which help final consumers improve energy efficiency. This may include improving the heating system in consumers' homes, installing double glazed windows, or better insulating roofs to reduce energy consumption (ec.europa.eu).

*EU countries may also implement **alternative policy measures** which reduce final energy consumption. These measures could include:*

- ***Energy-taxes** or CO_2-taxes*
- ***Financial incentives** that lead to an increased use of energy efficient technology*
- *Regulations or **voluntary agreements** that lead to the increased use of energy efficient technology*
- *Energy labelling schemes beyond those that are already mandatory under EU law*
- ***Training and education**, including energy advisory programmes'*



As explained above, a country is free to choose to implement the EEO and/or to follow an 'alternative routes'. The 2016 graph of Figure 25 shows the choice countries have made. Germany and the Netherlands have chosen to implement only alternative measures. Denmark and the UK have implemented EEOs, but the UK has made a combination with alternative measures.

Figure 25 Status of Article 7 EED measure, EEO, (ECI, 2016), *ec.europa.eu*.

We will see that utility companies tend to invest in projects that are, according to them, most cost-effective. This could be outside the residential sector, as shown in *Figure 26*. Therefore, despite what Figure 25 indicated, Denmark still has measures to persuade end-users in dwellings to invest in energy saving actions, outside the EEO scheme.

The longest-established EEOs have been those in the UK and Denmark, both in operation in some form for around 20 years. These EEOs have delivered higher savings than in other EU countries and therefore could be seen as front runners (Fawcett, Rosenow, & Bertoldi, 2017). Other countries have modelled EEO schemes on the Danish and British experiences; even the EU Article 7 policy is to a large extent built on the Danish experience with their energy efficiency obligation scheme (Bertoldi, 2015).

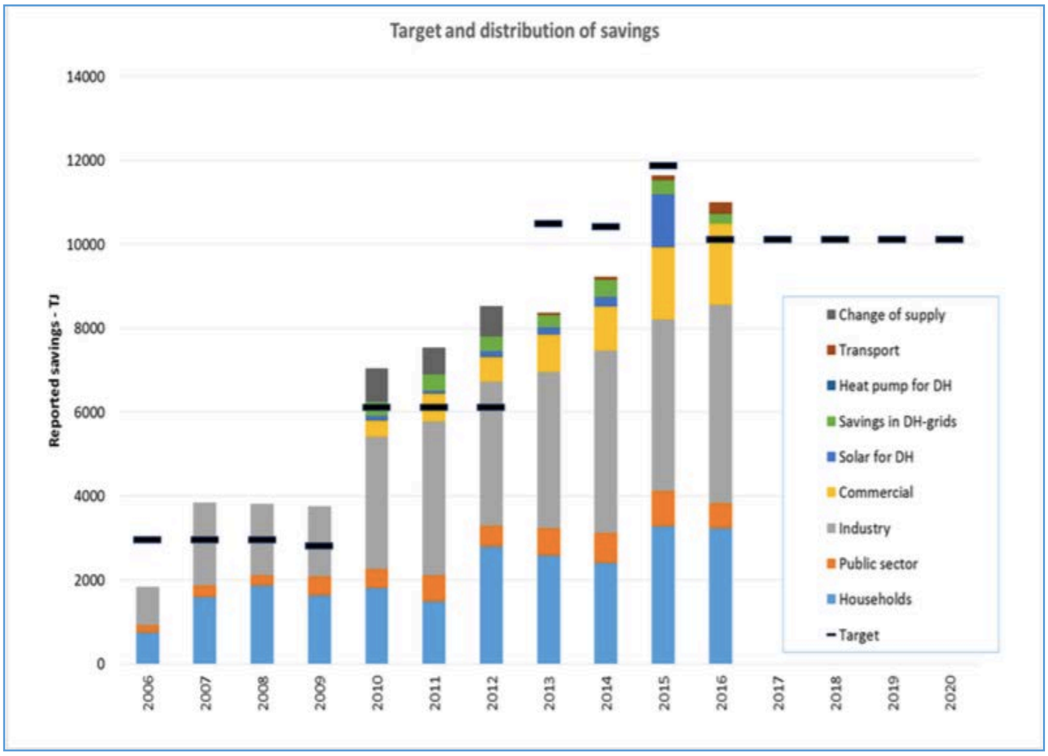


Figure 26: Sectors where Demark has realised savings under the EEO. The black line represents the target for the utility sector, set by the government. (DEA, 2014)

Differences in implementation, sectors, subgroups and measures

The way the EEO has been implemented differs quite substantially from country to country. In **Denmark**, savings in all end-use sectors are allowed (transport was added in 2013). Fuel switching is only allowed if it reduces consumption. This means that energy savings will be realised in the most cost-effective way. If this would be within (or indirectly influencing) the residential sector, the energy intensity obviously will come down. If not, savings will be realised in other end-user sectors such as in industry (Bertoldi, 2015).

In the **UK** the obligation started at a relatively low level, but eventually became a major climate change mitigation policy. The EEO is for England, Scotland and Wales.[10] The obliged parties have been electricity and gas supply companies with customers above a certain number. It has focused solely on the residential sector for most of its life. It was designed to complement Green Deal, which is a financing programme for energy efficiency measures. As such, it targets **higher cost measures** and **lower income households**; there has been a consistently strong focus on delivering a significant proportion of subsidised or free measures to low income groups. Due to the design of the scheme, mainly cheaper measures have been carried out. Sub-obligations have attempted to target higher cost measures, but the scheme becomes increasingly expensive and targets were reduced and the budget cut.

[10] There is no EEO in Northern Ireland (due to legislative barriers), instead they use a voluntary scheme

Responsibility utility sector versus convincing end-users

The more dominant the role of the EEO within the residential sector, the more dominant the responsibility of the utility sector in order to save energy, the less (additional) measures are needed to convince end-users to take actions.

The magnitude of this dominance by itself depends upon:

- whether the EEO is only targeting the residential sector (UK) or is implemented as a cross-sectoral measure (Denmark),
- whether the EEO focuses on the entire residential sector (Denmark) or only on a subgroup, such as lower income households (UK),
- what technical actions the utility sector is applying. Are these affecting the heat demand at the end-user in the residential sector (insulation, changing heat boiler)? Or is the utility sector expending the district heating and increasing the share of renewable energy that will *not* lower the heat demand, but the CO_2 emissions instead.
- These choices could change over time when a country updates it's EEO regulation.

4.6 Gas- and electricity prices, taxes and levies per country

The budget for policy programmes needs to come from somewhere. One possibility is to finance the (residential) energy policy programme (partly) through the gas- and electricity prices, taxes and levies.

- Denmark and Germany have the highest 2016 **electricity prices** across the EU, see Figure 27.
- As well, residents pay in these countries the highest **electricity tax and levies** (see *Figure 28*). Denmark, together with the Netherlands have relatively high **gas prices** (see *Figure 29*) and have the highest 2016 **gas taxes and levies** in Europe (see *Figure 30*). The UK has in both cases a relatively low energy tax.
- In Denmark the utility sector uses the received income to finance the EEO programme that they are responsible for. In Germany the tax remunerations go to governmental initiatives for sustainable energy like wind energy, and feeds the needed budget for the **long lasting financial subsidies** for end-users that Germany is known for.
- According to Mure, the electricity tax of Germany has a much larger impact compared to the one in Netherlands. A German household payed in 2014 on average 245 euro more for their electricity consumption; which is 30% more compared to the Dutch household[11].

[11] To make the comparison, according to an on-line source, an average German family uses 3,500 kWh per year, just like an average Dutch family. The Dutch pay 23 cents per kWh, of which 0.23 cents per kWh goes to renewable electricity production. German households pay 7 cents per kWh more than Dutch households. On an average electricity consumption of 3,500 kWh per year that is 245 euros per year (Baal, 2014), (www.energieoverheid.nl).

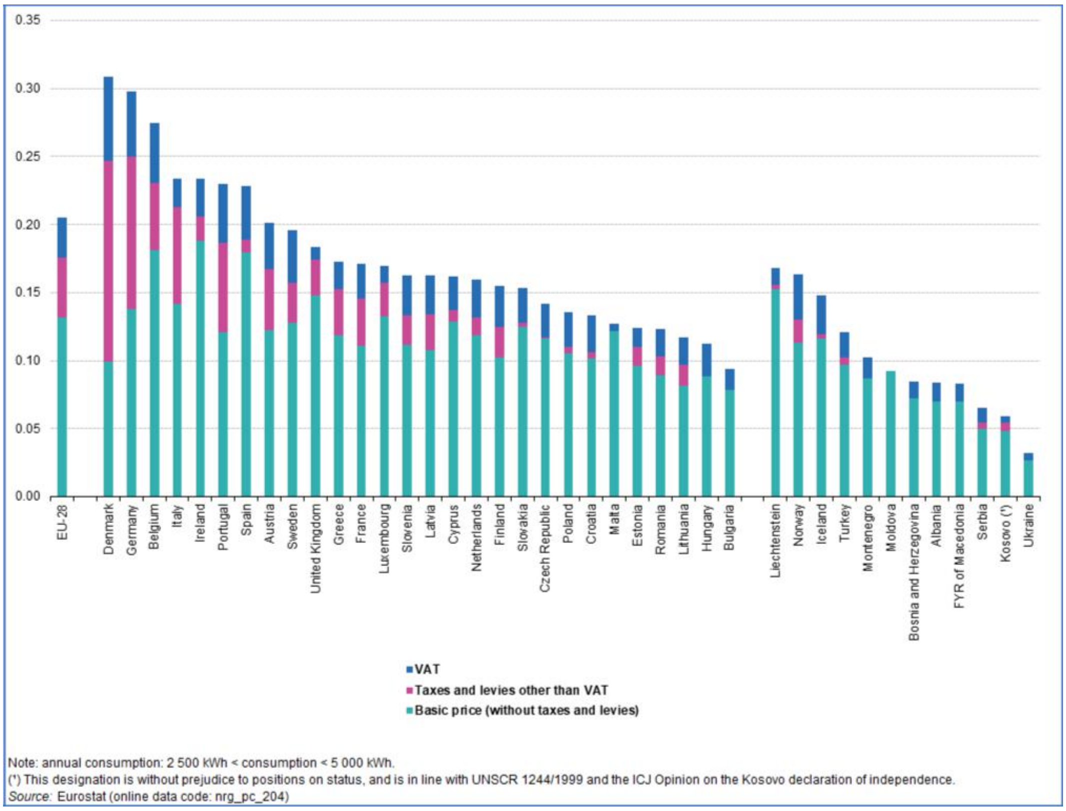


Figure 27: Electricity prices in Europe for households, 2016 (EUR per kWh) (ec.europa.eu)

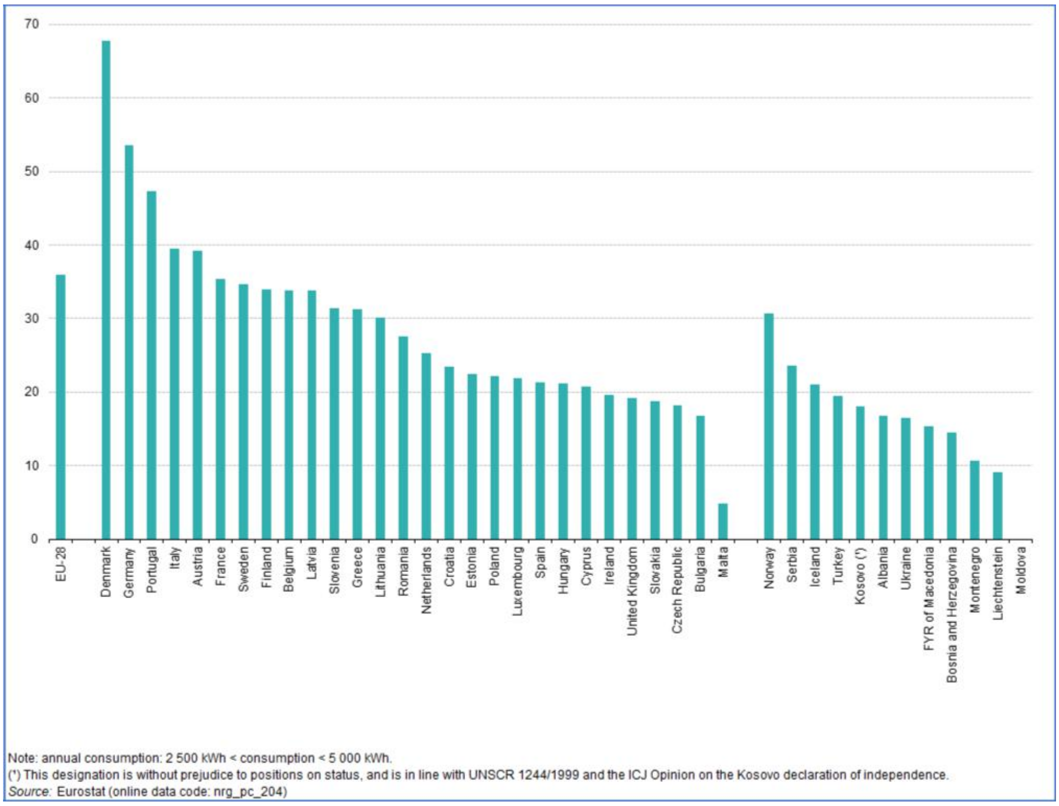


Figure 28: Electricity prices; share of taxes and charges paid by households, 2016 ec.europa.eu

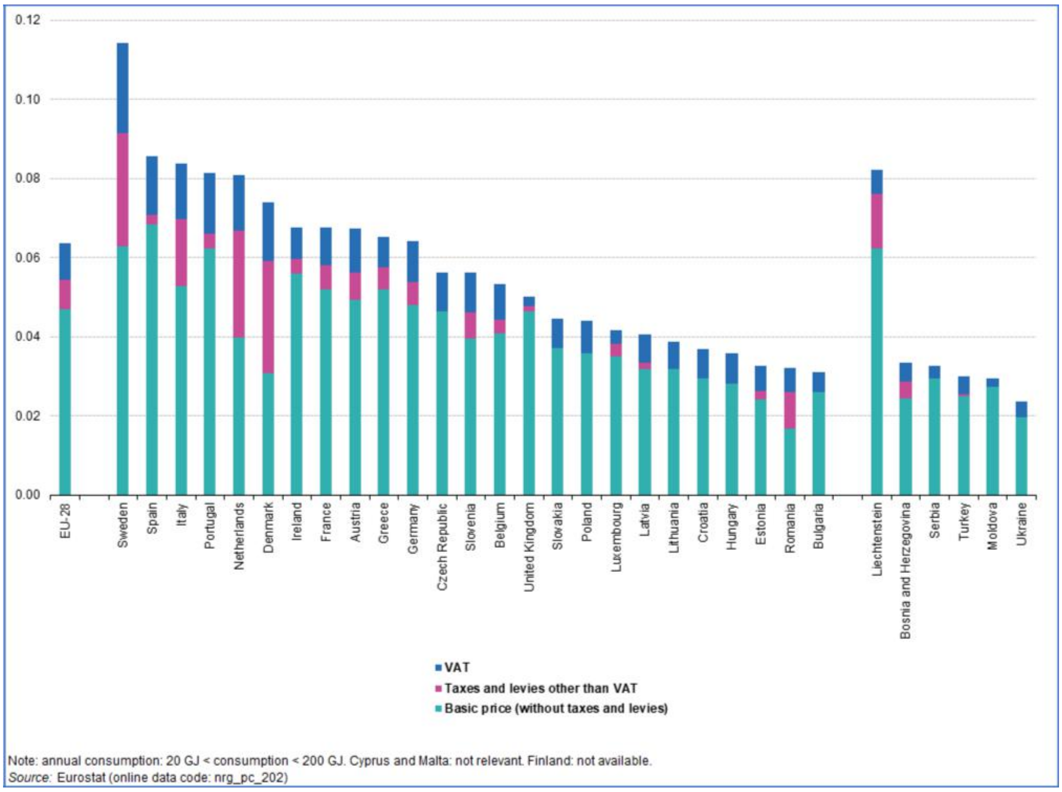


Figure 29: Gas prices in Europe for households, 2016 (EUR per kWh) ec.europa.eu

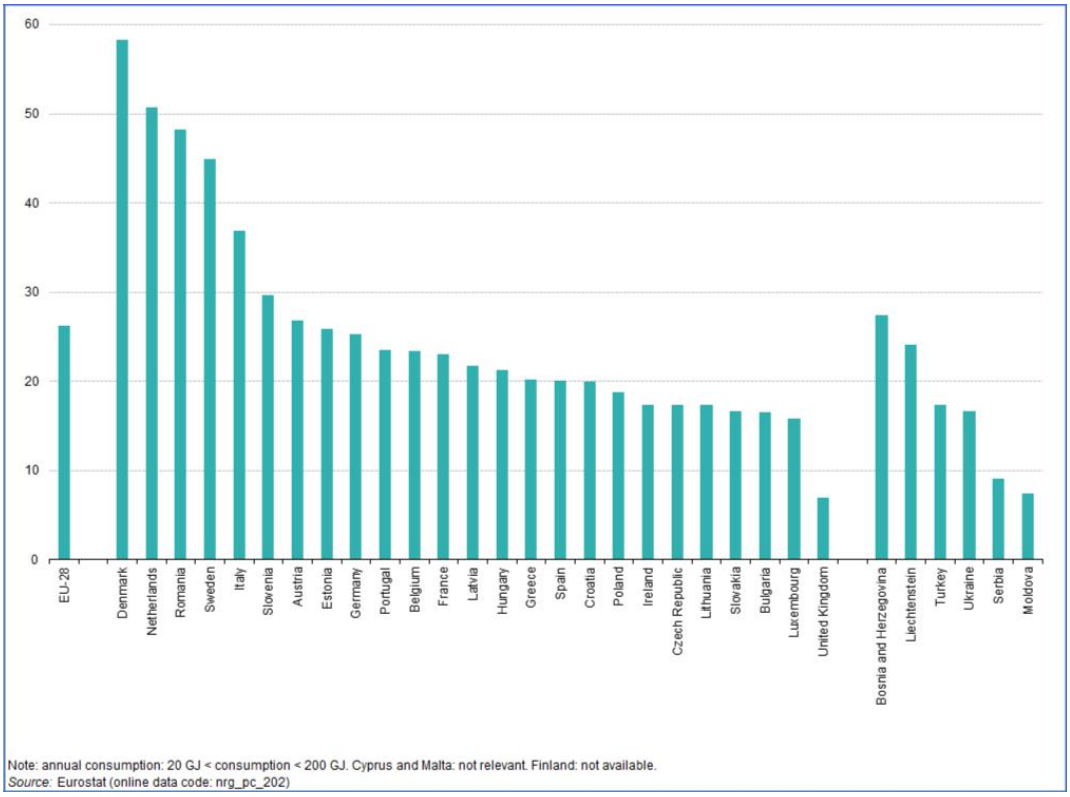


Figure 30: Gas prices; share of taxes and charges paid by households, 2016 ec.europa.eu

4.7 Total number of policy measures by type per country

Within Mure, for each country we have gathered the policy measures that have an effect in reducing the energy consumption and/or CO_2 emissions for space heating within the residential sector[12]. The below figure gives the number of policy measures by 'policy measure type'; see section 4.3 for an explanation of policy measure types. We have excluded the EU introduced EPBD and Eco-design policy measures, since these would appear in the tables for all countries. As explained earlier, these have been transformed into national suitable policy programmes, but are still described as 'EU' policies in Mure.

This section is only meant to understand the relation between strategic policy choices that countries have made (e.g. introducing the EEO, or following the 'alternative route'), and additional policy measures of a certain type that are needed to make the strategy successful. In the individual country chapters we will dive deeper into specific policy measures.

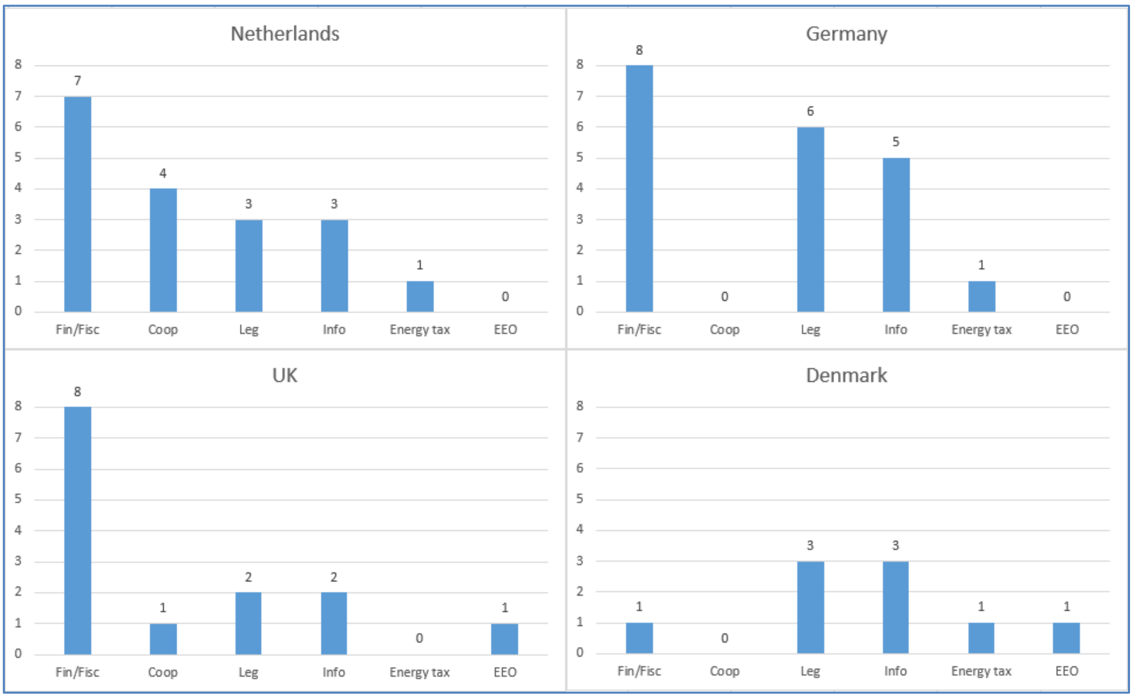


Figure 31: Total number of policy measures by type

[12] In Mure, different search queries regarding more-or-less the same topic often yield different overviews of policy measures. Therefore we constructed these tables ourselves, using several queries. We have combined policy measures that relate to new and existing buildings, since sometimes the difference was difficult to make. As explained in the beginning of this chapter, a policy measure can have been labelled with more than one policy type. If so, the most dominant type (according to us) has been chosen. Most policy measures belong to ongoing policy programmes, have been evaluated in the past for their impact and still have an impact. Some policy programmes and their policy measures are completed by now, but still have an impact, according to Mure. Some measures that just recently have been started and therefore have not been evaluated yet, have been added by us to get the complete picture.

Some observations at a high level:

- The Netherlands and Germany, countries that follow the '**alternative route**', have relatively a large number of measures in comparison to the UK[13] and Denmark, that follow the **EEO route**. An exception is the 8 financial measures of the UK. The EEO of the UK focuses strongly on lower income households, which only forms a subcategory of the residential sector. Therefore the UK, needs additional financial incentives to stimulate the remaining part of the residential sector (see the UK country chapter for more details). Since the UK is a constituent country with devolved powers, it needs financial incentives for several autonomous sub-regions such as for Scotland and one for Northern Ireland, increasing the total number of distinct financial policy measures even further. In general; some regions have individual measures and some shared measures.

- In their searches for an alternative route, Germany and the Netherlands have made different choices. The Netherlands is searching for **collaboration** with all stakeholder involved (e.g. the government, housing corporations, construction-installation and energy companies), which must be a cultural imbedded approach. There are some **national-legislative** measures added though. In Germany on the contrary, the national-legislative measures are more dominantly present.

4.8 The reported impact of policy measures by type per country

Most of the individual measures from the previous section already have been evaluated by their owners; the respective countries. In Mure though, they simply have been given a 'high', 'medium', or 'low' impact. There are savings numbers in energy-units given as well, but these are for one country all the same for policy measures that have the same level of impact and are therefore not really useful. It looks as the connection with the national evaluations have been lost here. Therefore, we have tried to come up with our owns system[14] as presented below. Do remember that we have excluded the by the EPBD and Eco-design policy measures from the graphs, as explained in the previous section. These EU related measures in Mure are present for all countries and could have received a low', 'medium' or 'high' impact. The reason for this difference could come from the transformation into suitable national policies, but is not known to the authors of this report.

Note to the reader: the relativizing section 4.9 should be taken into account while comparing the success rate of policy programmes, policy measures and even countries.

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[13] We could have included two more EU-related financial measures;
- 'Promotion of Electricity from Renewable Sources' supporting households as well with air-source heat pumps, ground and water source heat pumps, biomass boilers and biomass pellet stoves and solar thermal panels (Directive 2001/77/EC)
- 'Feed In Tariff' that focusses as well on domestic scale microchip. , both technologies as well as well (Directive 2009/28/EC)

[14] A measure get 3 points when the impact according to Mure was 'high, 2 for 'medium' and 1 for 'low' All measures of the same type are added up and divided by the number of measures of that type.

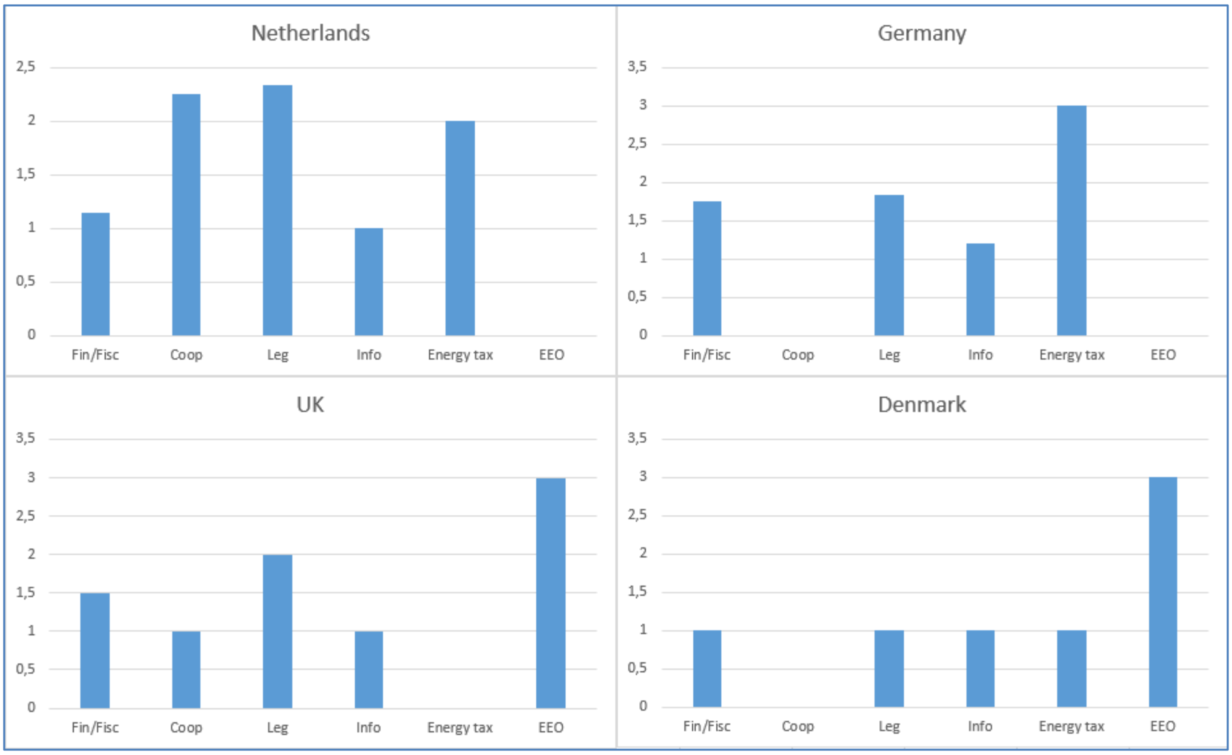


Figure 32: Indicative impact of the measures of Figure 31. The y-axes shows the impact calculated with footnote 14, but the magnitude mentioned is not really important.

Some observations at a high level:

- The UK and Denmark, that follow the **EEO route**, not surprisingly reported a high impact for their EEO approach. The other types of measures are supporting the EEO. The UK has additional national-legislative and financial/fiscal policy measures that seems to have a higher impact compared to Denmark, possibly since their EEO is not covering the whole residential sector, nor the whole country (see section 4.5).

- The Netherlands, following the **alternative route**, cooperative measures, national-legislative and energy-tax all contribute to a higher impact, supported by measures that have the character of financial/fiscal and information/education types of policies.

- In Germany, following the **alternative route** as well, the energy tax is the main driver, followed by national-legislative and as well supported by financial/fiscal and information/education.

But how sure are we that the impact of policy measures are as described by the country reports and/or as indicated by Mure? We simply are not, as explained in the following section.

4.9 Putting the reported impact into perspective

We know already that it is hard to add an impact to a policy measure, e.g. because of the influence of non-policy factors. Countries still try their best to calculate the reached energy savings. There is even an obligation to do so towards the EU. If you were able to avoid the impact of non-policy factors, the evaluation of a policy programme still remains complex since:

- There are several (combinations of) evaluating methods that could be used to calculate reached energy savings, depending on factors such as data availability, budget and accuracy. Methods are often described as ‘deemed, measured, engineering, econometric regression, stock modelling and energy consumption indicators’. The methods are described in documents as (Eichhammer, 2008; EPATEE, 2017; Ruegg & Jordan, 2018; SeeAction, 2012).
- There are several way to find out how often an energy savings action (e.g. insulation) has been implemented by end-users; a number that is needed to find the total savings of a policy programme. An evaluation could e.g. use (a combination of) market share statistics, equipment sales data, a survey that reveals the diffusion and uptake of energy efficiency solutions or some kind of indicator that shows the share of a specific equipment or practice in the market (a ‘diffusion indicator’).
- There are several ‘normalisation’, adjustments and correction factors involved, called the ‘prebound effect, rebound effect, performance gap, free-rider effect, spill-over effect, multiplier effects and double-counting interaction of individual measures’, leading to ‘gross savings’ or ‘net savings’, summarised briefly in (EPATEE, 2017).

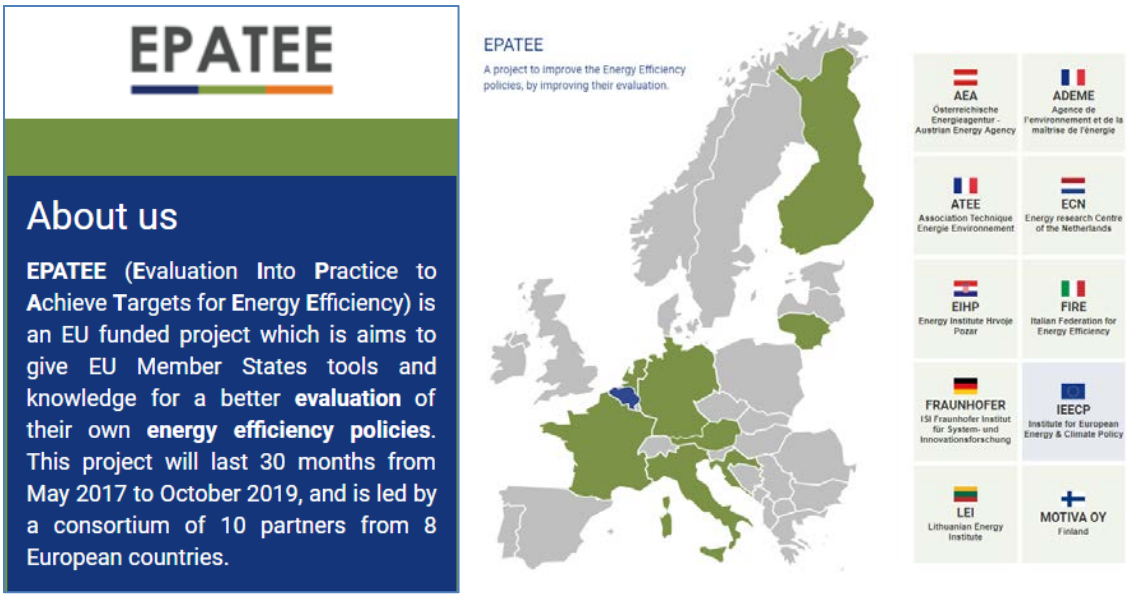
Since national policy programmes all have their own system boundaries, period of monitoring, evaluation methods and correcting factors, it is even harder to compare the rate of success of countries with each other. On top of this, the real details of an evaluation are often mentioned in reports written in the national language; too complex and too time consuming to take into account in meta-studies. And last but certainly not least; countries as well:

- have made historical choices (EEO versus the alternative route),
- carry different cultural aspects (debatable effecting size of households and dwellings, rebound & prebound effects, performance gaps),
- have or do have not access to natural energy resources (gas/biomass),
- are doing well economically or less well (debatable effecting free riders, spill-over & multiplier effects),

These are all factors that make a quantitative comparison between the countries difficult. To the authors of this report, it feels as nothing is really good or wrong here, but we are able to make interesting observations. These observations could inspire countries in making certain decisions for the future though. Learning ‘what went well’ and ‘what went badly’.

EPATEE and EMEEES

EPATEE stands for Evaluation into Practice to Achieve Targets for Energy Efficiency (epatee.eu). This is one of the EU initiatives to improve evaluations of policy programmes in general, in which ECN.TNO is involved. It builds further upon the EMEEES programme, which stands for Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services (emeees.eu)



The 'knowledge database' of EPATEE (epatee-lib.eu) contains meta-studies, country-studies, reports, articles and guidelines on (aspects of) evaluations of policy programmes. Some general findings concerning the countries selected for this study are:

- Germany generally does not take into account adjustments and correction factors, and therefore often overestimates the impact of a policy programme. One article found in the EPATEE database explains:

  "*A common theme emerging from studies is that disregard of free-riding will likely yield an overestimation of the true program success, thereby encouraging the government to pursue potentially unfavourable programs and complicating the task of optimally allocating scare public resources. The paper takes up this theme in the context of home renovations in Germany and found a free-rider share* approaching 50 %." (Groche, 2012).

- The UK on the contrary does include these factors and therefore often delivers evaluations report of a relatively high quality[15]. Another EPATEE article explains:

  "*To make robust judgments of an energy efficiency programme's economic effectiveness, we need to know how much energy and CO_2 is actually being saved through the financial support it provides. But most evaluations of home retrofit energy efficiency programmes depend on calculated, rather than measured, levels of energy consumption. This fails to take into account the discrepancies that have been observed in practice, between calculated and actual energy consumption both before and after refurbishment. Evaluations of*

[15] As an example, The National Energy Efficiency Data Framework (NEED) contains data based on observed savings related to energy efficiency measures (therefore accounts for free-riders and avoids double counting). It is used for ex-ante evaluations as well, which are a requirement for all new policies. There are a variety of databases and information available in the UK, which makes evaluation assessments more accurate.

energy efficiency programmes ideally need to consider rebound effects, free rider effects, reduced savings due to insufficient technical quality, and discrepancies between actual and calculated pre-refurbishment energy consumption. This paper investigates and compares evaluations of two prominent energy efficiency programmes in Germany and UK; the Germans CO_2-Building Rehabilitation Programme and the UK's Supplier Obligation. We show that evaluations of the UK's Supplier Obligation explicitly address most of the reduction effects whereas this is not the case for the German's CO_2-Building Rehabilitation Programme."(Rosenow, 2013)

- The impact of the EEO is often exaggerated since the utility sector has the benefit of reaching their targets as soon as possible.

  "With regard to the savings accredited in energy efficiency obligation schemes that existed when the EU's Energy Efficiency Directive entered into force, economic literature attests this policy instrument to effectively deliver additional savings at low costs. This paper relativizes these optimistic results and shows that accredited energy savings are likely to be significantly overestimated compared to the real savings achieved in course of the scheme. First, bargaining processes increase accredited savings per measure. These include bargaining on the volume of the savings target, standardised saving values, discount rates, and the lifetimes of measures. Second, arbitrary methods of measurement are an integrated element of obligation schemes to minimise excessive administrative costs. However, it is shown that arbitrary methods of measurement incentivize overestimation of real savings. Both aspects imply that real savings are lower than accredited savings, querying the policy instrument's actual effectiveness and efficiency." (Moser, 2017).

  In Denmark, the utility sector is obliged to state that energy savings have been 'calculated properly', without submitting the exact calculation method. Often the quicker, cheaper but less accurate 'deemed savings' method is used, instead of measuring the savings, ignoring e.g. prebound- and rebound effects.

  "The evaluation concluded that while the energy distribution companies meet their overall saving obligation, the net savings impact are about a third of the savings reported by the obligated parties. Further it was found that while energy savings in the public and business sector have a high net impact, some subsidies given under the EEO are inappropriately high. The net impact in the residential sector, on the other hand, was found to be very low. The evaluation recommended that the new EEO design addresses the additionality issues in order to ensure that savings realised in the residential sector are more cost-effective from a socioeconomic perspective. The evaluation has resulted in noticeable adjustments of the design of the Danish EEO, e.g. introduction of a 1 year payback-time limit for projects receiving subsidies, a minimum baseline for insulation products, and specification of documentation requirements." (Bundgaard, 2013)

  Figure 33 shows that Denmark uses the 'deemed savings' method predominantly in the residential sector. In 2012 a second evaluation of the Danish Energy Efficiency Obligation was conducted:

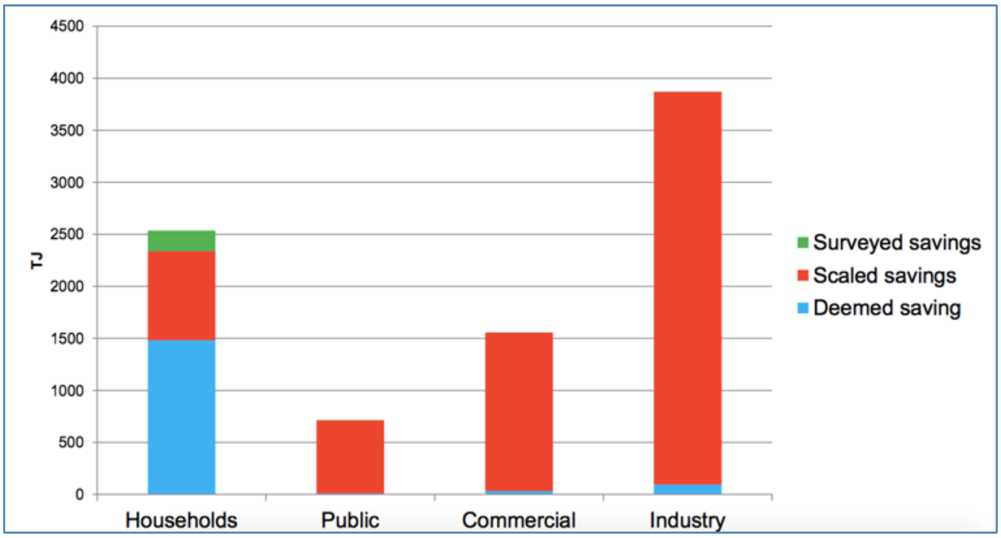


Figure 33: Denmark uses ‘deemed savings’ predominantly in the residential sector.

The information of this section should be taken into account when comparing the success rate of policy measures, policy programmes and countries.

5 Policy in the Netherlands (by R.J.M. Niessink)

In chapters 5, 6, 7 and 8, the policy portfolio and other relevant aspects of the selected countries will be described. Information from these chapters have fed into chapter 4, where to a certain extent the comparison between the countries has been made. As well, occasionally a comparison is made in the respective country chapters.

The chapters all have the same general structure, after an introduction the policy portfolio and their individual policy measures will be described for the residential sector. This includes all household measures, including those that target the energy consumption of appliances. This relates to some so-called ‘radar graphs’ in Mure, which are quite difficult to understand. The Dutch and German chapters show the graphs, and the Dutch chapter explains it. But in the other country chapters only the conclusions are given. Policy measures in Mure have been given a ‘type of policy measure’, as explained in section 4.3. The next section gives an indication of the impact of policy measures that target the energy consumption of space heating of existing dwellings specifically. The table provided comes from a different search query in Mure and includes the relative impact of the policy measure (low, medium or high). Possibly Mure and/or this table is not complete; if found in other sources and/or in other Mure queries, relevant additional policy measures will be discussed.

Then, financial incentives that stimulate the uptake of energy savings actions are looked at. From section 4.9, we know that evaluating the energy savings effect (and their cost-effectivity), is a challenge. Therefore, a section tries to describe the evaluation strategy of the country. Instead of a chapter summary at the beginning, there is a concluding section at the end.

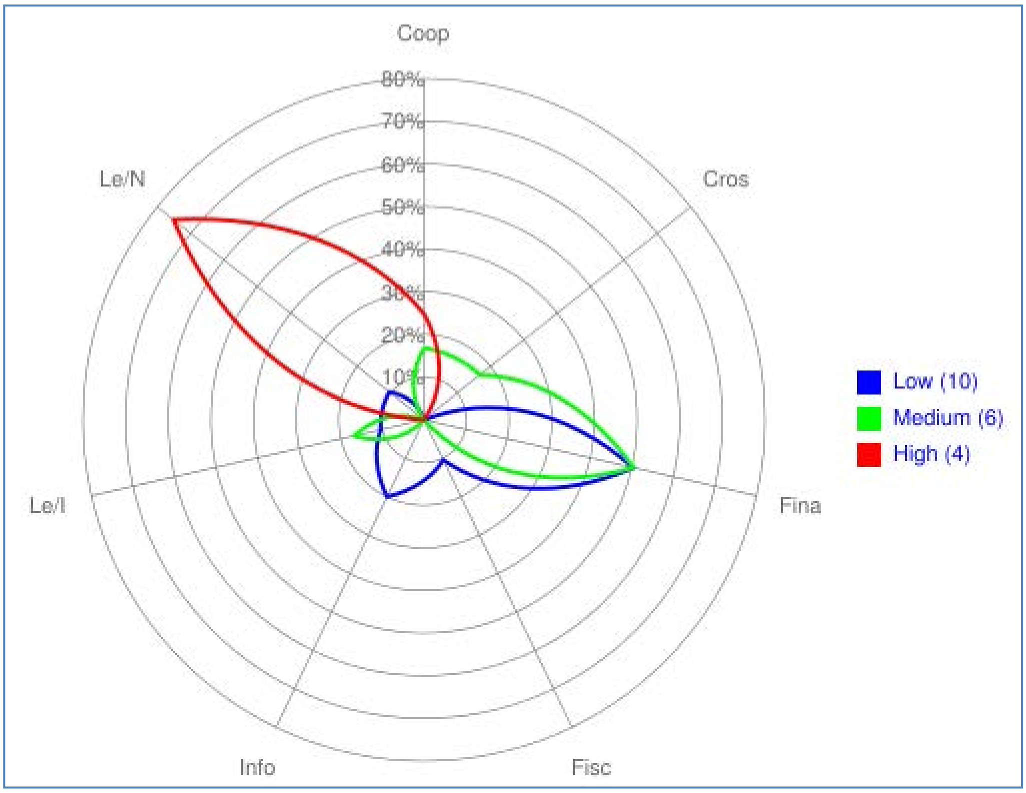
5.1 Country policy introduction

In the previous sections we have seen that the energy intensity in the Netherlands lowered most from the year 2000 onwards (section 2.14). At first sight, it seems as though the Netherlands is doing well. But at the same time the average retrofitting rate is 1%, low when compared to the other EU-countries (section 2.9). The need for new buildings was highest in the Netherlands compared to the other countries selected for this study (section 2.7), which has probably significantly influenced the reduction of the energy intensity. It appears that the F and G-labels of the Netherlands relate to E-labels in other countries and that the Dutch A++ label is comparable with the A label in most other countries (section 2.10). Altogether, the performance of the Netherlands is unclear (section 3.2).

The Netherlands and Germany, both countries which follow the ‘alternative route’, have a relatively large number of measures in comparison to the UK and Denmark, who follow the EEO route (section 4.7). In this chapter we will dive deeper into the Dutch policy programme.

5.2 Current policies in the Netherlands, residential sector

Presently ongoing; EU and National policy measures, residential sector



Legenda of the Graph Labels

Coop: Co-operative Measures
Cros: Cross-cutting with sector-specific characteristics
Fina: Financial
Fisc: Fiscal/Tariffs
Info: Information/Education
Le/I: Legislative/Informative
Le/N: Legislative/Normative

Figure 34: Radar graph with ongoing policy measures for the Dutch residential sector, organised by 'policy type'

The radar graph of *Figure 34* shows all policy measures in the Dutch residential sector, i.e. not only policy for insulation measures and boilers (as in section 5.3), but also policy measures for energy-efficient household appliances, cooking, lighting, hot water, space cooling and renewable energy (behind the meter). Measures for new construction are also included. It is a mixture of EU-related and national measures, with national measures usually dominating. The graph is a bit complicated to read, therefore we will start off with an explanation.

One policy measure can have multiple types allocated to it; e.g. the Dutch 'Smart meters introduction' has been described as a 'Financial' and 'Information/Education' type of measure. Both types only can have one level of impact. In practice, this policy measure has been counted twice under ‘Low’. This means, when added up, the numbers mentioned between brackets, do *not* represent the number of policy measures. In practice though, only a few policy measures have been labelled with more than one policy type. Therefore, to keep things simpler, in the below explanation we will use the numbers as representing ‘policy measures’.

The figure can be read as follows:
- Colours indicate the relative impact per policy type: blue = low, green = medium, red = high.
- For the Netherlands, 10 times a policy measure has been labelled with ‘low impact’; 8 have a medium impact and 4 a high impact.
- The axes represent the different types of policies. The figure shows the percentage on the total number of policy measures that fall within a certain type of policy. If you watch carefully, the percentages of one colour (level of impact) adds up to 100%

Main conclusions for the Netherlands:
- **Dominant policy types:** the figure shows that the policy for households is characterised by normative legislation (that have a high impact) and a relatively large number of financial measures (that have a low/medium impact). Legislation here also includes, for example the Buildings Decree and the Energy Performance Standards (EPN) for new buildings[16].
- **High impact policy types:** the figure shows that approximately 75% of the high impact rated policy measures are of the normative legislation policy type. The remaining 25% belong to Co-operative measures (Coop); adding up to 100%.

Presently ongoing; EU policy measures only, residential sector

If we zoom in to only the EU contributions of the previous figure (not shown), we observe that 2 EU related policy measures are present, which are both ‘Legislative/ informative’. The impact is considered as low and medium. If we deduct in our mind the EU-policy measures from Figure 34, then we have an indication of the types and impact of the national designed policies. A conclusion would then be that the national impact is considered as far larger compared to the EU related impact.

Completed policy measures with a high impact, by period, residential sector

Another option in Mure is to choose for ‘completed high impact’ policy measures only, and to divide the radar graph further into three implementing periods. Main conclusions for the Netherlands:
- **Completed versus ongoing:** not much has changed over the last three decades. Within the completed policy measures, legislative/normative and financial types dominate.
- **Comparing periods**: before 1988 the legislative/normative type of policy measures dominated, financial and cooperation only have been added after 2003, and are still part of the ongoing portfolio.
- **High impact share:** until 2003 the legislative/normative policy measures made a high impact. After 2003 cooperative policy measure took over. Now, both of these have a high share in ongoing policy measures .

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[16] Please remember that the impact of the policy for new and existing buildings are related to each other; a good execution of new construction quality has a lower savings potential for the existing building later on.

5.3 Impact by policy measure, space heating only

Table 7: Overview of policy instruments for space heating in existing dwellings (insulation and boilers) in the Netherlands

Code	Measure title	Types group	Qualitative Impact
HOU-NLD7	The Building Decree (2002, 2012 onwards) (Bouwbesluit, 2002 en vanaf 2012)	Leg-norm/invest	High
HOU-NLD24	Change in the Home Valuation System (Aanpassing woningwaarderingsstelsel)	Leg-norm/invest	High
HOU-NLD21	More with Less plan (Meer met Minder)	Coop/broad (VA-sector)	High
HOU-NLD32	Reduced VAT rate on labour costs for insulation and glass and for maintenance an renovation of residential buildings (Verlaagd BTW tarief)	Finan-fiscal/invest	Medium
HOU-NLD1	Energy Tax (Energiebelasting)	Cross-cutting/taxes	Medium
HOU-NLD38	Incentive energy performance rented sector (Stimuleringsregeling energieprestatie huursector (STEP))	Finan-fiscal/invest	Low
HOU-NLD6	Optimal energy infrastructure (OEI)	Coop/broad (VA-sector)	Low
HOU-NLD20	Heat distribution law (warmtewet)	Leg-norm/use	Low
HOU-NLD34	Introduction Smart Meters (Uitrol slimme meters)	Finan-fiscal/invest	Low
HOU-NLD31	Innovation Agenda for the Built Environment (Innovatieagenda energie gebouwde omgeving)	Finan-fiscal/invest	Low
HOU-NLD33	Block by Block approach (Blok voor Blok)	Finan-fiscal/invest	Low
HOU-NLD15	MilieuCentraal, COEN (Consumer & Energy) and HIER campaign	Inform/broad (center, etc.)	Low
HOU-NLD17	EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU) - Energy performance certificate for buildings/ Energy label for houses (Energieprestatie Certificaat Gebouwen/Energielabel woningen)	Leg-inform/focus (label)	Low

Table 7 gives an overview of the evaluated policy measures used in the Netherlands to reduce energy consumption for space heating and the corresponding impact, described as ‘high, ‘medium’ or ‘low’. It comprises out of measures that have been completed and evaluated, and out of measures that are still running but have been evaluated for their impact so far. The first column contains a hyperlink to the measure in question.

The Mure database should contain all policy measures currently affecting the implementation of energy saving measures. However, a number of measures are missing in this table, these are relatively new measures for which no savings figures have yet been estimated. These measures are described in the next section.

The three policy measures that have the highest impact in terms of energy savings in existing buildings are:

1. Building Decree. The Buildings Decree (which covers both new and existing buildings) stipulates that in the case of a 'large-scale renovation' (in which at least 25% of the outer shell is replaced) the building must be renovated to the level of new construction (Buildings Decree online, 2012).

2. Change in the Home Valuation System. This policy was introduced in 2011. It does n*ot* concern private home ownership but focuses on the rental sector. We do mention it, however, because of its high impact. The housing valuation system determines the maximum rent on the basis of the characteristics of the house. Within this system, points are awarded for quality aspects of homes, such as floor space and facilities. The rental prices depend on the total number of points. Because implementation of energy measures such as insulation was only marginally rewarded in the rent assessment system, landlords cannot recoup investments in energy saving. This policy measure concerns a change in the rent assessment system whereby energy saving measures lead to more points in the future, allowing housing corporations to recoup their investments by increasing rents. The rising rent will be offset by lower energy costs for the tenants. The impact of this measure is assessed as 'high', a quantitative evaluation has not yet been carried out (RVO.NL and Ministry of Economic Affairs 2016a).

3. More with Less plan. In order to achieve energy savings in existing owner-occupied and private rental homes in the period 2008-2020, the 'More with less' covenant was agreed (it ran from 2008-2012) with energy companies, the installation sector and the construction sector. These parties have jointly set up a programme to support home owners in introducing cost-cutting measures. The support consists of information and assistance with the implementation. The latter is done via a tailor-made advice. In an ex-ante estimate, the energy savings of the measures are calculated at 13-32 PJ primarily in 2020 (RVO.NL and Ministry of Economic Affairs 2016b).

   According to Odyssee-Mure, this measure belongs to the high-impact category. The fact that the programme runs until 2020 is doubtful in view of the fact that little or nothing has been heard about the covenant for years. According to a Dutch expert, no one has concluded that it no longer exists, but in reality, it does not impact the residential sector anymore. This indicates as well that we must be careful when interpreting the measures of the other countries.

Measures that are more focused on private home ownership and that have had a medium impact are:

- Reduction of the VAT rate or labour costs for applying energy saving technical measures

- The regular tax on gas and electricity. Around 44 percent of the total energy bill for 2016 consisted of taxes, compared to 40 percent a year earlier. As a result of agreements in the Energy Agreement, the energy tax rates were temporarily increased as of 1 January 2018 until 2019. This increase will be reversed in 2020 (gaslicht.com). A small part of the money that the government 'collects' with the energy tax is spent on stimulating renewable energy sources.

5.4 Other policies in the Netherlands not yet evaluated in Mure

There are also a number of ongoing measures that have not (yet) been evaluated in Mure; two of which are grants and one loan:

Table 8: Policy measures for existing dwellings in the Netherlands not yet evaluated in Mure

Code	Measure title	Status	Types group	Starting year
HOU-NLD40	National Revolving Fund for Energy Saving (National Energy Saving Fund)	Ongoing	Financial	2014
HOU-NLD39	The 'Save energy now' campaign (You save energy now)	Ongoing	Information/ Eduction	2016
HOU-NLD41	Energy-saving at Home subsidy scheme	Ongoing	Financial	2016
HOU-NLD42	Investment Subsidy for Sustainable Energy (Investeringssubsidie Duurzame Energie (ISDE))	Ongoing	Financial	2016

- National Energy Saving Fund. For some energy-saving measures, homeowners are eligible for a subsidy or energy-saving loan (National Energy Saving Fund 2018). The loan amounts to a maximum of 25,000 euros and in the case of a zero on the meter a maximum of 50,000 euros. The interest rate depends on the term of the loan and amounts to 1.9-2.7% per year.

- Energy-Saving at Home Subsidy Scheme. This is a national subsidy scheme for home insulation. The scheme was so popular that the subsidy pot for private individuals has been exhausted since April 2017. The subsidy is now only available for homeowners associations, housing associations and housing cooperatives.
- Renewable Energy Investment Grant (ISDE) subsidy. This subsidy can be used to finance parts of the investment in renewable energy technologies. The technologies for which subsidies can be requested are biomass boilers, pellet

stoves, heat pumps and solar boilers. The use of heat pumps and solar boilers is seen as a sustainable form of energy because it is 'sustainable behind the meter'.

- In addition, the (government) campaign "Save energy now" is running to encourage residents to make their homes more energy efficient. The campaign is aimed at homeowners of a home with label C or worse who are considering energy-saving measures but have not yet implemented them, for example because of the high costs, the preliminary research required or the nuisance created. Studies have shown that three quarters of people underestimate the return on insulation measures. The campaign is aimed at both owner-occupiers and owners' associations (source: Mure).

5.5 Other aspects of the policy

Agreements

In the Netherlands, various sectoral and multi-sectoral policy programmes have been set up over the years. Agreements have been made between governments, companies and other organisations. These agreements are voluntary. The aim is to work towards a common ambition level for renewable energy, energy savings and an acceleration towards a low carbon energy supply.

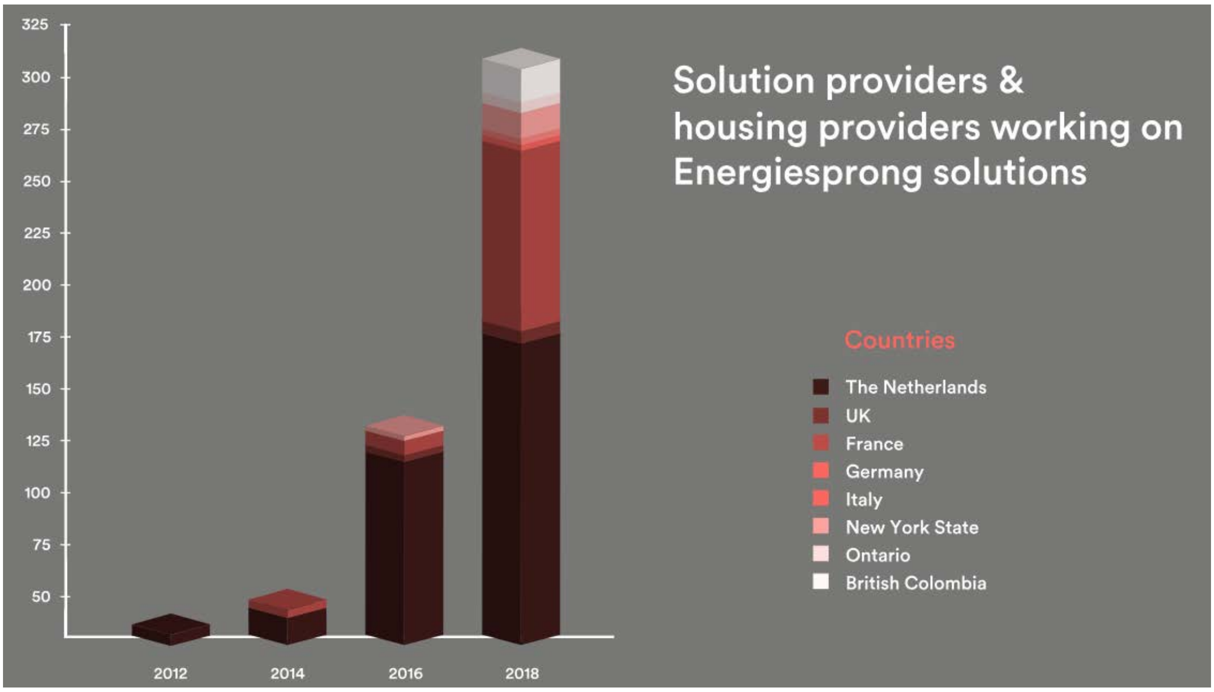
Examples of such agreements are:

- Clean and Efficient Programme (setting targets for 2020)
- More with less covenant (2008-2020)
- SER Energy Agreement for Sustainable Growth (2013-2020)
- Covenant on energy saving in the built environment (from 2018) (central government, 2018a)

The Energy Jump

The so called ‘Energy Jump’ (‘Energiesprong’ in Dutch), is a programme that started off in the Netherlands with positive results. It has since gone international with projects in the UK, France, Germany and Italy, as shown in the below graph (energiesprong.org):

Next page: copy of Figure 4 ‘Energiesprong is a revolutionary, whole house refurbishment and new built standard and funding approach. It originated in the Netherlands as a government-funded innovation programme and has set a new standard in this market. The mission of Energiesprong International is to scale this approach to other markets. Energie-sprong uses the social housing sector in each market as the launching market for these solutions, with a view to later scale to the private home-owner market (energiesprong.org).



Design of national policy

The policy in the Netherlands is in line with EU directives and European/International targets for climate and energy. In the climate agreement it has been agreed to achieve a 49% CO_2 reduction by 2030. The ambition is to be climate-neutral by 2050. At the time of writing, the negotiation for a new climate agreement is in progress.

Furthermore, the earthquakes in Groningen have had a major influence on the policy agenda and public opinion. Partly as a result of these developments, attention has been drawn to an accelerated transition to natural gas-free heated residential areas in the Netherlands.

5.6 Financial incentives

Since 2014, three new financial measures have been introduced for existing housing, including two subsidies and one low interest energy-saving loan (see section 5.4).

According to (Broc et al., 2017), the Netherlands has made an average annual amount of 100 million euros available for renovations over the period 2014-2017.

5.7 Evaluation of policy in the Netherlands

Who carries out the evaluation?

In the Netherlands, policy is evaluated by various organisations. These can be independent research institutes including ECN.TNO and PBL. Other organisations are RVO.nl, OTB (Delft) and the various (municipal) audit offices. It is clear that the evaluation is therefore very fragmented. There is no uniform evaluation method and reporting method. This makes it difficult to compare the cost-effectiveness of the policy measures used.

Estimates of the effects of proposed and adopted policy are made in the National Energy Outlook (NEV) of ECN, PBL, CBS and RVO.nl. In the study, a projection is made for the future energy system in the Netherlands. This concerns ex-ante estimates of the impact of policy using calculation models.

Effectiveness of existing construction policy in the Netherlands in a general sense

A policy study by PBL (Vringer, van Middelkoop, and Hoogervorst, 2014) states the following: *"In order to achieve the set targets with greater certainty, the pace of energy saving in existing buildings must be increased. This can be done in different ways. For both new construction and existing construction,* ***continuity*** *and* ***predictability*** *of policy increases the effectiveness of policy, especially since the preparation of investment decisions takes a long time. It must also be realised that adapting existing buildings is emotionally charged. Financial considerations are important but not always decisive. Policy can become more effective by taking into account not only financial motives, but also* ***behavioural processes****, such as overestimating risks, comparing oneself with others, and dealing with the hassle of renovation.*

The PBL study explains that energy savings in owner-occupied homes are slow. Owner-occupiers improve the home in small steps. The policy incentives are too weak to encourage a sufficient number of owners to take up more energy-saving measures. PBL therefore states that in order to achieve the policy objectives, more binding policy measures are needed (Vringer, van Middelkoop, and Hoogervorst 2014).

Examples case: SEEH scheme evaluation

The Subsidy Scheme for Energy Saving in the Home (SEEH scheme), mentioned in Table 7, has been evaluated (Government 2018b). The purpose of this evaluation was to provide insight into the number and type of applications and motives of owners/residents and Owners' Associations (VvE's) to apply for SEEH subsidy. An important point of attention here is the '**free rider**' effect. The survey shows that 72% of the respondents would take fewer measures without a subsidy, with a lower insulation value or would take measures later. Of the respondents, 6% would not take action. Around 22% of the respondents can be considered as free-riders; even without subsidies, this group would still take exactly the same energy saving measures.

Examples case: Effectiveness of the covenant More with Less

The covenant More with Less is part of an umbrella covenant consisting out of three sub-covenants, and has been evaluated by BuildDesk (Schneider and Jharap 2010). The program aimed to improve the energy label of 300,000 homes annually by at least two steps by 2020. The PBL study (Vringer, van Middelkoop, and Hoogervorst 2014) notes the following about the evaluation:

"Because the covenants are closely interwoven with other policy measures, it is not possible, according to Tigchelaar (2012), to determine the effect of the covenants, either quantitatively or as a separate measure. The parliamentary investigation (2012) reports that ex ante evaluations were carried out, but again the effect was

only established in combination with another policy measure; the Environmental Management Act. Moreover, the effect has not been confirmed ex post in ex post studies'.

This interdependence of measures obviously plays an important role in impact assessments and we should bear this in mind when interpreting impact assessments, for example those in Mure.

Buildings databases/registers

In order to properly evaluate policies, quantitative data is needed. The most relevant data sources on the energy performance of buildings and on data on buildings in general are: CBS statistics, label registration of RVO.nl and the RVO Monitoring Energy Saving Built Environment. At a regional level, monitoring data from Rijkswaterstaat's climate monitor is often used. This means that although the evaluation of policy measures is difficult, the Netherlands is collecting quite a substantial amount of data that can be used in such evaluations.

5.8 Conclusion

The type of policies that prevail in the Netherlands

The most successful Dutch policy for reducing the energy consumption within the residential sector is classified as 'Normative/Regulatory policy', followed by 'Cooperative'. The first one has an high impact in Germany as well.

- In addition to EU policy, the former includes, for example, **the Building Decree** (new buildings and **large-scale renovations**), but also the 'Adjustment of the housing valuation system' for the rental sector, and the Heat Law with a lesser impact.

- Cooperative refers only to the More With Less program, of which it is **doubtful** whether it still has impact.

The Netherlands not one of the retrofitting leaders in Europe

Although the Netherlands, according to international literature, is certainly not doing badly compared to other EU countries, it is not one of the leaders when it comes to retrofitting the existing stock. The reduction of the energy intensity might be quite large compared to the other three countries (see section 2.14); the retrofitting rate has an ‘average’ pace (see section 2.9). Possibly non-policy factors have dominated the reduction of the energy intensity more than policy measures did, as we have seen in Figure 13 with the Netherlands having the highest need for new dwellings.

The **budgets for financial support** could be larger and more continuous. **More binding policies** could be a way forward too. Although not part of the four selected countries in this study, we came across an example in Sweden that is an interesting example of a more binding policy measure.

Recommendation: to give more binding strength to Dutch retrofit policies, investigate the way Sweden is checking the ex-post retrofit performance by taking into account the using actual measured energy consumption

An example of more binding measures from Sweden

Sweden is the only country in Europe that currently allows the evaluation of energy performance for **new buildings** and **major renovations** on the basis of **actual measured energy consumption**. The final verification of the construction project must be completed within two years after completion or after the thorough renovation. The contractor is responsible for measuring the energy consumption and can decide how this measurement is carried out. However, this is usually done on the basis of the EPC procedure whereby energy invoices are collected by an independent energy expert who compiles the report; and increasingly remotely via smart meters. After the EPC report is delivered, the contractor, energy expert and the local government responsible should hold a meeting where the energy results are presented. Honestly it should be said that in reality only 6% of all local authorities impose sanctions when energy requirements are not met; but the Netherlands could do better (Groote, 2018).

Recommendation: investigate the effect of behavioural processes, such as overestimating risks and dealing with the hassle of a renovation, to improve the impact of Dutch retrofit policies.

Behavioural processes

Behavioural processes, such as overestimating risks, comparing oneself with others, and dealing with the hassle of a renovation are elements that should be part of effective policies (Vringer, 2014). At present, the Dutch policy does not pay enough attention to this. It is advisable to use behavioural processes more consciously in policy, for example by using bonus-malus schemes (in line with loss aversion), or by actively offering information on energy consumption compared to that of others. The latter relates to the 'real energy consumption' mentioned above at the Swedish example; it allows benchmarking on the basis of actual energy consumption, rather than on the basis of theoretically calculated consumptions.

6 Policy in Germany (by R.J.M. Niessink)

In chapters 5, 6, 7 and 8, the policy portfolio and other relevant aspects of the selected countries will be described. Information from these chapters have fed into chapter 4, where to a certain extent the comparison between the countries has been made. As well, occasionally a comparison is made in the respective country chapters.

The chapters all have the same general structure, after an introduction the policy portfolio and their individual policy measures will be described for the residential sector. This includes all household measures, including those that target the energy consumption of appliances. This relates to some so-called ‘radar graphs’ in Mure, which are quite difficult to understand. The Dutch and German chapters show the graphs, and the Dutch chapter explains it. But in the other country chapters only the conclusions are given. Policy measures in Mure have been given a ‘type of policy measure’, as explained in section 4.3. The next section gives an indication of the impact of policy measures that target the energy consumption of space heating of existing dwellings specifically. The table provided comes from a different search query in Mure and includes the relative impact of the policy measure (low, medium or high). Possibly Mure and/or this table is not complete; if found in other sources and/or in other Mure queries, relevant additional policy measures will be discussed.

Then, financial incentives that stimulate the uptake of energy savings actions are looked at. From section 4.9, we know that evaluating the energy savings effect (and their cost-effectivity), is a challenge. Therefore, a section tries to describe the evaluation strategy of the country. Instead of a chapter summary at the beginning, there is a concluding section at the end.

6.1 Country policy introduction

In chapter 2 and 3 it became clear that Germany is doing relatively well in retrofitting their existing dwelling stock and in bringing down the energy intensity. According to international literature, Germany is one of the leaders in Europe in this area. Germany follows, just as the Netherlands, the ‘alternative route’, instead of having implemented an EEO. Amongst the four selected countries for this study, Germany has the highest number of policy measures (section 3.4). In most countries, an energy-tax is important, but in Germany, it is the main driver. Denmark and Germany have the highest 2016 **electricity prices** across the EU (see Figure 27) and residents pay in these countries the highest **electricity tax and levies** (see Figure 28). Therefore, according to Mure, the electricity tax of Germany has a much larger impact compared to the one in Netherlands. A German household had in 2014 a 30% higher electricity bill compared to a Dutch household. In this chapter we will dive deeper into the German policy programme.

6.2 Current policies in the German residential sector

Presently ongoing; EU and National policy measures, residential sector

The shares per type of policy measure are shown in the below radar chart. See the Dutch chapter for an explanation.

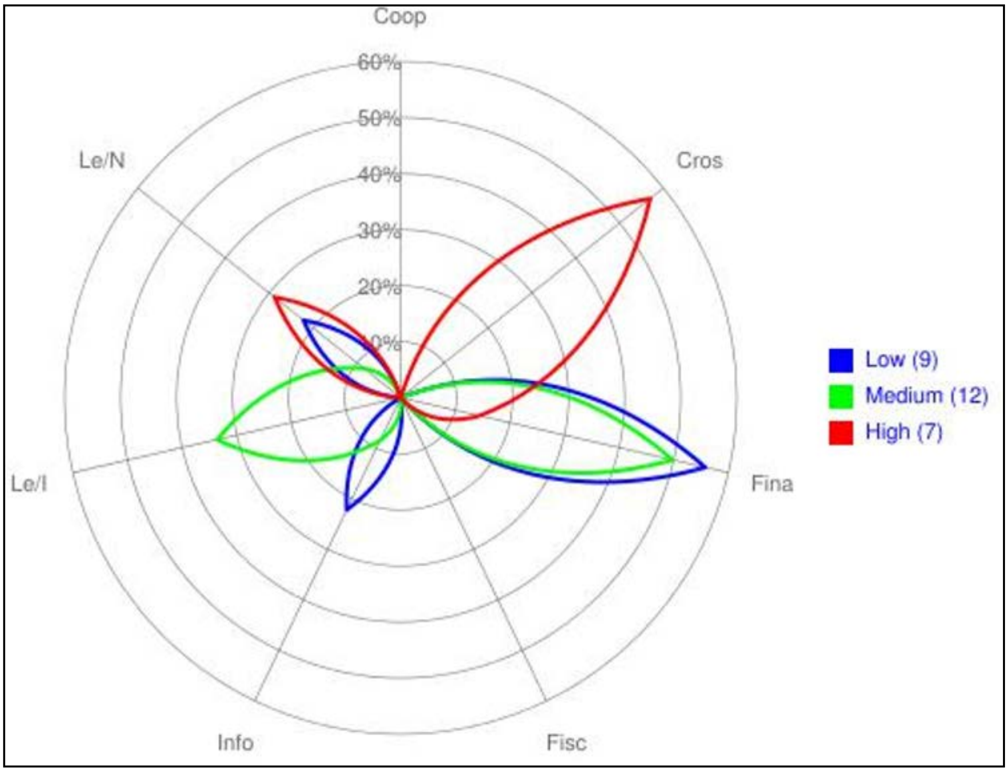


Figure 35: Radar graph with ongoing policy measures for the German residential sector, organised by ‘policy type’

Table 9 gives an overview for the Netherlands and Germany of the type of policy that is most common and has a high impact (impact category: high).

Table 9: Country overview of most common policy for the residential sector (represented by a 'C') and types of policy with a high impact (represented by an 'H')

Type/type of policy measure	Netherlands	Germany
Co-operative measures	H	
Cross-cutting with sector-specific characteristics		CH
Financial	C	CH
Fiscal/Tariffs		
Informative/Education		
Legislative/Informative		
Legislative/Normative	CH	H

Main conclusions for the Germany:

- **Dominant policy types:** The current policy in Germany is dominated by mainly financial measures, legislation, and cross-cutting policies. Cross-cutting policy focuses on several sectors at the same time. The share of policy measures in the category of normative legislation and regulations is considerably lower than in the Netherlands.

- **High impact policy types:** In Germany, as in the Netherlands, normative legislation and regulations (30%) have a high impact. A difference with the Netherlands is that the cross-cutting policy (55%) and financial regulations (15%) also have a high impact. The cross-cutting policy refers to the energy tax as we will see in the next section. In the Netherlands this is also the only cross-cutting policy, but it has a 'medium' impact. Unlike the Netherlands, however, Germany does not have any cooperative measures; whereas their impact in the Netherlands is high.

Presently ongoing; EU policy measures only, residential sector

If we zoom in to only the EU contributions of the previous figure (not shown), we observe that 3 EU related policy measures are present, which are either ‘Legislative/ informative’ or ‘Legislative/ normative’. The impact is considered as high and medium. If we deduct in our minds the EU-policy measures from Figure 34, then we have an indication of the types and impact of the national designed policies. A conclusion would therefore be that the national impact is considered as far larger compared to the EU related impact, as in the Netherlands.

Completed policy measures with a high impact, by period, residential sector

Another option in Mure is to choose for ‘completed high impact’ policy measures only, and to divide the radar graph further into three implementing periods. Main conclusions for the Netherlands:

- **Completed versus ongoing:** in contrast to the Netherlands, policy measures with a high impact seem to have shifted from Legislative only, towards the earlier mentioned combination that includes cross-cutting.
- **Comparing periods**: just as in the Netherlands, before 1988 the legislative/normative type of policy measures dominated, cross-cutting and financial measures have been added between 1988 and 2003, and additional financial measures after 2003. Both cross-cutting and financial measures are still part of the ongoing portfolio.
- **High impact share:** just as in the Netherlands, until 2003 legislative/normative policy measures made a high impact. Between 1998 and 2003 cross-cutting kicked in, followed by financial after 2003. Now, both of these have a high share in ongoing policy measures .

6.3 Impact by policy measure, space heating only

Table 10: Overview of policy instruments for space heating in existing dwellings (insulation and boilers) in Germany

Code	Measure title	Types group	Qualitative Impact
HOU-GER6	EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Savings Ordinance (Energieeinsparverordnung - EnEV)	Leg-norm/invest	High
HOU-GER11	Ordinance on Heat Consumption Metering (Verordnung über Heizkostenabrechnung)	Leg-norm/use	High
HOU-GER33	KfW Programme "Energy-efficient refurbishment" (former CO_2 Building Rehabilitation Programme)	Finan-fiscal/invest	High
HOU-GER28	Ecological Tax Reform (Energy and Electricity Tax) (Ökologische Steuerreform – Energie und Stromsteuer)	Cross-cutting/taxes	High
HOU-GER106	Further development of Energy savings ordinance 2014	Leg-norm/invest	Medium
HOU-GER64	Smart Metering	Leg-inform/broad (audit)	Medium
HOU-GER98	Replenishment of the KfW programmes for energy-efficient construction and renovation (Aufstockung KfW-Gebäudeprogramme)	Finan-fiscal/invest	Medium
HOU-GER100	Quality assurance and the optimization of existing energy consultation	Finan-fiscal/invest	Medium
HOU-GER101	Upgrading the CO_2 Building Renovation Programme	Finan-fiscal/invest	Medium
HOU-GER32	Market Incentive Programme for Renewable Energies in Heat Market (Marktanreizprogramm für erneuerbare Energien im Wärmemarkt– MAP)	Finan-fiscal/invest	Medium
HOU-GER48	National Top Runner Initiative (NTRI)	Inform/broad (center, etc.)	Medium
HOU-GER72	EU-related: Revised Directive for Labelling of Energy-related Products (Directive 2010/30/EU) - Energy Consumption Labelling Ordinance – revised version (EnVKV - revised)	Leg-inform/focus (label)	Medium
HOU-GER103	National efficiency label for old heating systems	Leg-norm/invest	Low
HOU-GER15	Small-Scale Combustion Plant Ordinance (Kleinfeuerungsanlagenverordnung)	Leg-norm/use	Low
HOU-GER9	On-site energy consultation (BAFA Vor-Ort-Beratung)	Finan-fiscal/info (audit)	Low
HOU-GER4	Energy Consultancy and Energy Checks of the Federation of German Consumer Organisations (Energieberatung und Energie-Checks der Verbraucherzentralen Bundesverband (vzbv)	Finan-fiscal/info (audit)	Low
HOU-GER99	Energy-Related Urban Renewal — Grants for	Finan-fiscal/invest	Low

Code	Measure title	Types group	Qualitative Impact
	Integrated District Concepts and Renovation Managers (Energietische Stadtsanierung – Zuschüsse für integrierte Quartierskonzepte und Sanierungsmanager)		
HOU-GER104	Heating Check (Heizungscheck)	Finan-fiscal/invest	Low
HOU-GER97	Energy efficiency checks for low-income households (Caritas)	Finan-fiscal/info (audit)	Low
HOU-GER34	Energy Efficiency Campaign (Initiative EnergieEffizienz)	Inform/broad (center, etc.)	Low
HOU-GER67	EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU) - Energy Savings Ordinance (Energieeinsparverordnung-EnEV) - revision 2013-2014	Leg-norm/invest	Low

Table 10 gives an overview of the evaluated policy measures used in Germany to reduce energy consumption for space heating and the corresponding impact, described as ‘high, ‘medium’ or ‘low’. It comprises measures that have been completed and evaluated, and measures that are still running but have been evaluated for their impact so far. The first column contains a hyperlink to the measure in question.

The four policy measures that have the highest impact in terms of energy savings are:

1. EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Savings Ordinance (EnEV). This is in principle the EPBD for new construction in Germany, but some measures also apply to existing construction. For example, standards are included where existing dwellings must comply in case of renovations, there is an energy performance standard for existing dwellings and specific inspections and assessments of heating installations (older than 15 years) are part of the measures.

2. Ordinance on Heat Consumption Metering. This means that heating meters must be installed to measure the (proportional) heat consumption of each user in the building. Since 1981, new buildings have had to be equipped with heat meters. Existing buildings must be equipped since 1984. The Regulation regulates the allocation of heating and hot water costs to buildings with two or more housing units. The Regulation should encourage users to save energy, as a large part of the invoiced costs of measured consumption depend on the consumption of the user himself (bbsr-energieeinsparung.de 2018). According to IEA, independent experts generally indicate that the energy saving effect of this scheme is 15% without comfort losses (BGBl 2017).

3. KfW Programme 'Energy-efficient refurbishment' (German: 'Energieeffizient Sanieren'). This is a housing renovation programme that provides grants and soft loans to banks. The amount depends on the degree of renovation. Individual

measures are also eligible for financial contributions. The programme runs from 2013 to 2019. The impact of this on energy saving is relatively high.

4. Ecological Tax Reform (Energy and Electricity Tax). This is the cross-cutting Eco-Tax on electricity and energy carriers (fuel oil, natural gas and liquefied gas) for the general public, owner-occupiers, and tenants. With this ecological tax reform, the German government aimed to encourage energy saving and promote renewable energy, and also to create jobs. The tax was introduced in 1999. This is a tax that is comparable to the regular energy tax in the Netherlands (see Mure measure HOU-NLD1). In Germany this measure falls into the high-impact category and in the Netherlands into the medium-impact category.

   A study by (BPIE 2014) shows that Germany expects that most of the savings until 2020 will be achieved through the Energy Savings Regulation for new buildings (EnEV - EU related; the first one above), combined with the different KfW schemes ("grants"; the third one above).

6.4 Other policies in Germany not yet evaluated in Mure

Table 11: Policy measures for existing dwellings in Germany not yet evaluated in Mure

Code	Measure title	Status	Types group	Starting year
HOU-GER26	KfW CO_2 Reduction Programme (KfW-Programm zur CO_2-Minderung)	Completed	Financial	1999
HOU-GER42	KfW Programme Housing Modernisation (KfW-Programm Wohnraum Modernisieren)	Completed	Financial	2005
HOU-GER109	Energy Efficiency Strategy for Buildings (ESG)	Ongoing	Leg-norm/invest	2015

There are also a number of measures that have not (yet) been evaluated in Mure; that also concerns two completed financial policy measures.

The Energy Efficiency Strategy for Buildings (ESG)

The Energy Efficiency Strategy for Buildings (ESG) mentioned in Table 11 is a kind of Energy Agreement for Germany and was agreed by the federal government in November 2015. The ESG consists of a plan for the development of existing measures and new measures to exploit the remaining savings potential. It outlines the steps to be taken to achieve a near-climate neutral building stock by 2050, based on a combination of energy saving measures and the use of renewable energy. The emphasis is once again on strengthening financing, both the financing of the designed programmes within the ESG and financial support for end users.

The following points, which relate to the existing housing stock, come from the fourth NAPE and summarise the measures that have been launched since 2014 under the ESG, all related to programme funding: (Fraunhofer Isi 2018)

- The majority of measures under the National Energy Efficiency Action Plan (NAPE)[17] target the construction sector. This includes an increase in **funding** for the CO_2 Building Renovation Programme (to EUR 2 billion per year), changes to the **market incentive** programme and the energy efficiency programme to **replace the tax incentives** originally planned.
- Since 2016, the Deutschland Macht's Effizient campaign (Germany makes it efficient) has provided information on the efficiency potential and **sources of funding** to those involved in the energy transition, with an emphasis on the construction sector. This concerns not only new construction but also renovations (deutschland-machts-effizient.de)
- The 'financing programme for heating optimisation' provides **funding** for low-investment measures to optimise existing heating systems.
- The ‘EnEff.Building.2050’ initiative provides **funding** for pilot projects for both new construction and for renovation that demonstrate ambitious energy concepts for buildings (projektinfos.energiewendebauen.de) and districts to encourage their wide acceptance.
- The Solar Construction/Energy-Efficient City initiative provides **funding** for research and development into energy-efficient and climate-friendly buildings and neighbourhoods. It focuses on technologies that improve energy efficiency and the integration of renewable energy, with a view to support the energy transition in buildings and cities. It again focuses on both new buildings and renovations (projektinfos.energiewendebauen.de)

6.5 Other aspects of the policy

Nothing to mention.

6.6 Financial incentives

Table 10 and Table 11 list no less than 14 measures that have a financial incentive aspect. According to (Broc et al., 2017), Germany has made available an average annual amount of 800 million euros for renovations over the period 2009-2015.

Although data is difficult to compare, according to Broc et al. (2017) the German government had made available a budget which is **8 times higher** in comparison to the Netherlands up until 2015. By way of comparison: the number of homes in Germany is 5.4 times higher. This therefore indicates that the budget for each dwelling is higher in Germany. However, we know by now, that a comparison such as this one is very difficult to make.

[17] Since December 2014, the Federal Government has set out its energy efficiency strategy in the National Action Plan on Energy Efficiency (NAPE) in conjunction with the 2020 Action Programme for Climate Protection. The NAPE is intended to gain support and buy-in from all the social actors for the task of increasing energy efficiency by highlighting possibilities and opportunities for them and ensuring that a commitment to energy efficiency is viewed positively. Based on an intelligent mix of consultancy, communication and information about worthwhile efficiency measures, funding and standards for new installations, the NAPE contains a set of instruments which incentivise increases in energy efficiency while also paving the way for the enormous potential to be harnessed. Both immediate tasks and areas of longer-term work are described in the NAPE (ec.europa.eu).

Energy fund (financial)

The Energy Efficiency Fund (EEF) is part of the German "Energiewende" (Odyssee-Mure, 2018). The fund includes loans and subsidies with relatively low interest rates.

APEE (financial)

In 2016, the Federal Ministry of Economic Affairs and Energy (BMWi) launched the Energy Efficiency Incentive Programme (APEE). This programme will finance the renovation of residential heating and ventilation systems, with a total of 165 million euros per year over the next 3 years in the form of loans and grants at low interest rates (Odyssee-Mure, 2018).

Law on the use of renewable heat

The law on the use of heat in buildings aims at an average share of 14% renewable energy for heating by 2020. The government offered support of up to € 115 million per year for the use of renewable energy for heating in the period 2009-2012. Support for solar collectors, boiler replacements and heat pumps were extended. However, the grants are only granted for existing buildings and for the "most" innovative technologies ", for example efficient heat pumps and small combined heat and power systems (Ecofys and WWF, 2011).

6.7 Evaluation of policy in Germany

Who carries out the evaluation?

In Germany, policy is evaluated by various organisations. These can be independent research institutes such as Fraunhofer Isi and Öko-Institut. The evaluation is therefore very fragmented. There is no uniform evaluation method and reporting method, this is similar to the situation in Netherlands. Comparisons with regard to the cost-effectiveness of the implemented measures are therefore difficult.

Examples case: Evaluation KfW - CO_2 Building Rehabilitation Programme

A study by Rosenow and Galvin (2013) indicates that the 'successful' KfW - CO_2 Building Rehabilitation Programme was poorly evaluated. Crucially, evaluations of energy efficiency programmes should include rebound effects, free-rider effects, reduced savings due to insufficient technical implementation quality and differences between actual and calculated energy consumption prior to renovation. This is not the case for the CO_2 Building Rehabilitation Program. When rebound and prebound effects are taken into account, the actual savings can only be half that estimated in the evaluation, without mentioning also possible free-rider effects.

Example case: Evaluation EnEV (Energy renovation standards for existing buildings)

An article by Galvin (2014) looked at why mandatory standards for thermal retrofits of existing dwellings in Germany have led to lower renovation rates than is necessary to achieve the energy and climate targets for this sector. The article indicates that the standards in the EnEV are too strict and inflexible for a large part of the existing building stock. Furthermore, EnEV overestimates the consumption in these buildings by 30% or more, thus overestimating the potential and thus the economic feasibility of the measure. Furthermore, according to Galvin, the economic assumptions in the EnEV are not in line with the financial reality: ultimately the (other) retrofit costs that do not directly contribute to thermal improvement are neglected. As an example of this, he states that (unjustly) low discount rates are assumed. In addition, investment returns and the growth of future fuel price increases are often ignored.

Buildings databases/registers

In order to properly evaluate policies, quantitative data is needed. At present it remains unclear exactly which databases are used in Germany. The European Entranze project of 2014 states the following (Entranze, 2014):

"At present, there are *no registers covering all renovated buildings or containing all EPCs issued. The most relevant data sources on the energy performance of buildings and on data on buildings in general shall be:*

- *Statisches Bundesamt (the equivalent of the CBS for the Netherlands);*
- *Database of buildings: 'Data collection for energy quality and for the modernisation trends in the German housing stock'. This is empirical data collection based on a sample of about 7500 dwellings. This is the most in-depth database that provides an overview of the current energy characteristics of the housing stock*."

6.8 Conclusion

The type of policies that prevail in Germany

Policies with the highest impact in Germany are according to Mure classified as 'fiscal', 'financially supportive' and 'normative/regulatory policies'. The latter one, has a high impact in the Netherlands as well.

- Fiscal measures refer to **taxes and charges on electricity and gas prices**. The first (tax) is at the highest level in Europe and a relatively large part of it is channelled into renewable energy generation. The second is at an average level. The energy tax of the Netherlands is considered to have a lesser impact according to Mure. As a result, the energy bill for German households has risen significantly (in comparison with the Netherlands 30% higher). Whether the tax-component of the high electricity price has helped to increase the share of renewable electricity, or the latter has caused electricity prices to rise, seems to be the subject of an ongoing debate. The relationship between the two is striking though, as can be seen in Figure 36.

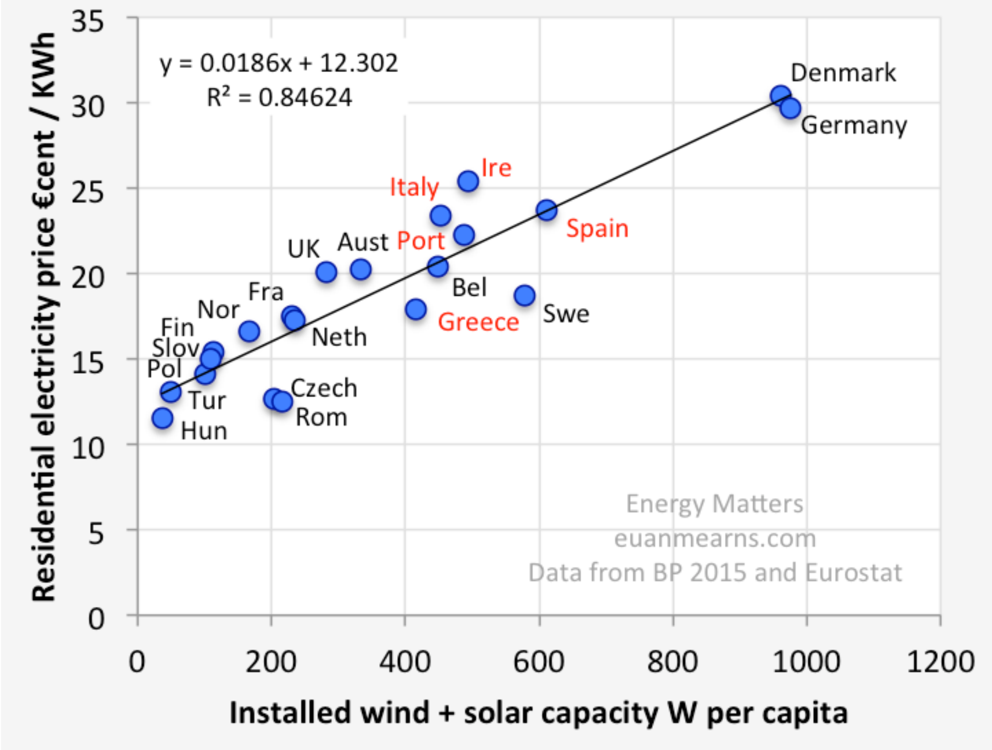


Figure 36: The relationship between the electricity price and the installed wind and solar capacity graph (*ktwop.com, 2014*). Copy of Figure 5.

- Financial supporting refers to the many policy measures that provide **financial resources and grants** to end-users. A difference with the Netherlands is the higher budget that has been allocated to it, and the longer period of time that will be maintained per policy measure. In other words, it is **more predictable** and there is **continuity**. Long-term stable arrangements are needed to increase the effectiveness of policies. Until 2020, Germany expects that most of the savings will be achieved through the 'Energy Savings Regulation for new buildings', combined with the different schemes that provide financial incentives.

- The previously mentioned 'energy-saving regulation for new buildings' falls within the 'normative/regulatory policy'; comparable to the tightened Dutch EPC for new buildings. However, it covers more than just EU initiated policies, for example the introduction of heat and smart meters, and the obligation to label old heating installations in particular, although not all of these are characterised as having a 'high impact'.

Germany one of the leaders, but poor evaluations of policy programmes

According to international literature, Germany is one of the European **leaders** in terms of savings achieved within the existing stock of dwellings (see also chapter 3). At the same time, it has been found that Germany does not correct its policy evaluations for reducing factors such as **free-riders** and the **rebound effect**, which can have a large impact on the amount of savings reported, with **reductions of up to 50%.**

7 Policy in the UK (by R.F. Holdsworth-Morris)

In chapters 5, 6, 7 and 8, the policy portfolio and other relevant aspects of the selected countries will be described. Information from these chapters have fed into chapter 4, where to a certain extent the comparison between the countries has been made. As well, occasionally a comparison is made in the respective country chapters.

The chapters all have the same general structure, after an introduction the policy portfolio and their individual policy measures will be described for the residential sector. This includes all household measures, including those that target the energy consumption of appliances. This relates to some so-called ‘radar graphs’ in Mure, which are quite difficult to understand. The Dutch and German chapters show the graphs, and the Dutch chapter explains it. But in this country chapter only the conclusions are given. Policy measures in Mure have been given a ‘type of policy measure’, as explained in section 4.3. The next section gives an indication of the impact of policy measures that target the energy consumption of space heating of existing dwellings specifically. The table provided comes from a different search query in Mure and includes the relative impact of the policy measure (low, medium or high). Possibly Mure and/or this table is not complete; if found in other sources and/or in other Mure queries, relevant additional policy measures will be discussed.

Then, financial incentives that stimulate the uptake of energy savings actions are looked at. From section 4.9, we know that evaluating the energy savings effect (and their cost-effectivity), is a challenge. Therefore, a section tries to describe the evaluation strategy of the country. Instead of a chapter summary at the beginning, there is a concluding section at the end.

7.1 Country policy introduction

The UK’s Climate Change Act recognises that improvement to household energy efficiency provides one of the main pathways to achieving the nations carbon reduction targets. The UK presents an interesting case for the study of energy efficiency policies as it has one of the oldest existing housing stocks in the EU and the energy used for heating in the residential sector makes up a high proportion of overall consumption (the domestic sector uses around 29% of final energy consumption and 68% of this is used for space heating (theccc.org.uk). Therefore, the UK government has developed a number of policies specifically for the household sector.

The government has a long history with energy efficiency policy and innovative financial mechanisms such as payments for domestic renewable heat generation and the Green Deal on-bill financing mechanism. It was the first country in the EU to introduce an Energy Efficiency Obligation (EEO) in 1994, which is now a principal instrument used by 15 countries in the EU. The UK is considered to have achieved substantial savings using this tool, however less so after 2013 when the rising costs of the scheme became an issue (see section 7.4.1 for detail). Furthermore, it has robust evaluation methods that take into account various reducing effects, and policies designed to overcome barriers within the residential sector and encourage the uptake of efficiency measures (ENSPOL, 2015). Specific targets that are aimed at low income households and reducing energy poverty have been successful. They not only reduce energy consumption and overcome barriers, but lead to other multiple benefits amongst the worst quality housing in the existing stock, such as improved comfort, health and well-being (Ugarte et al., 2016).

National overview of energy consumption in the UK

Household energy consumption for heating in the UK is predominantly from gas (*Figure 37*). Oil is the second most consumed fuel in households for space heating and levels have remained relatively constant with small fluctuations. Electricity consumption (storage heating/resistance) for space heating is relatively high in the UK, considering the average price of electricity is twice that of gas. This is mainly low-income households, with lower efficiency ratings and those that are not connected to the gas supply grid (OFGEM, 2015). Coal has decreased significantly from 1990 levels and is being phased out in the UK.

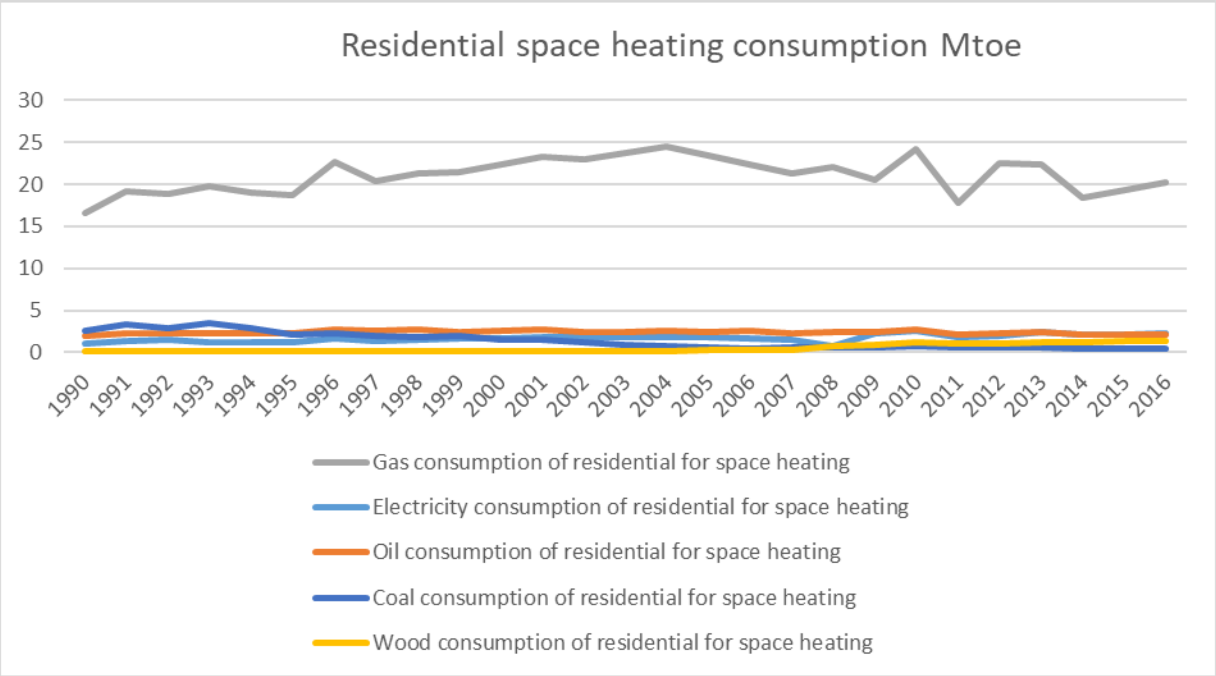


Figure 37 Fuel consumption in the residential sector for space heating by type (source: MURE)

CO_2 emissions from space heating in the UK have decreased since 2000 by the same amount as that of the Netherlands (*Figure 38*). However, the UK's building stock is responsible for the second highest CO_2 emissions in the study in 2016, albeit only marginally behind Germany. This reflects on the fuel types used for space heating. Gas emits the most CO_2 as it supplies the majority of households, but the next largest share is from electricity. Around 19% of the total emissions are from electricity, which is nearly double the emissions produced from oil (see *Figure 19*).

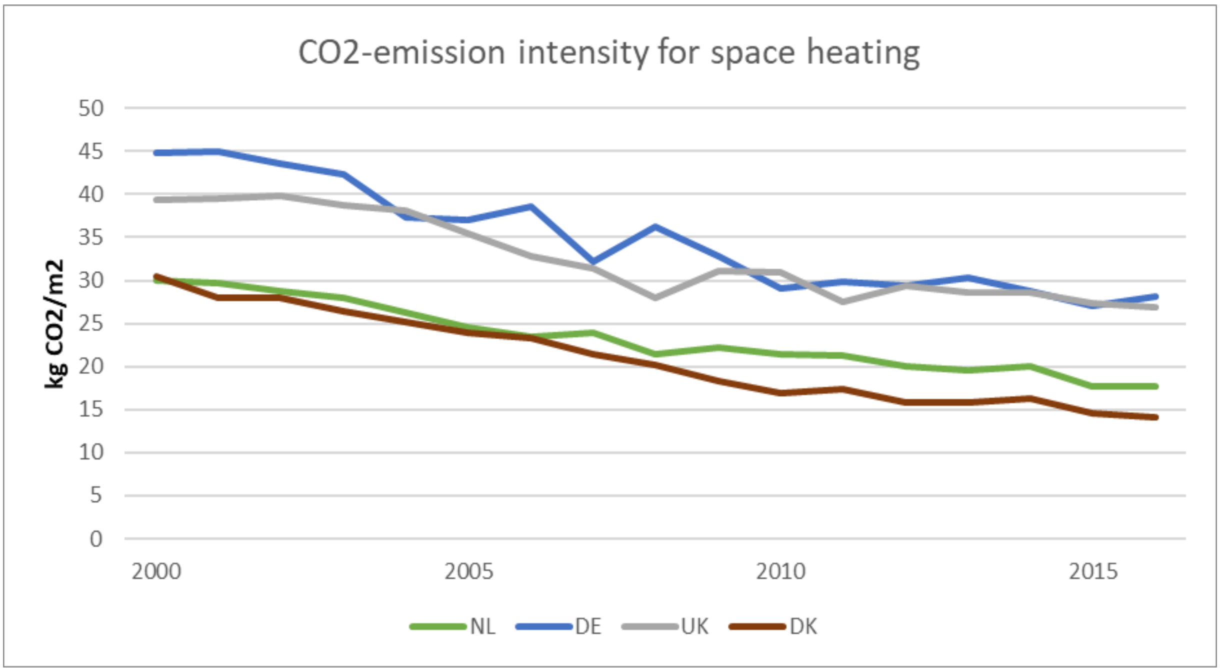


Figure 38 Carbon emissions for space heating in the residential sector by country (source: MURE)

Energy intensity in *Figure 39* below shows that household energy intensity has remained at a relatively constant level from 1970-2004, after which time there is a noticeable decline in the energy consumption per household.

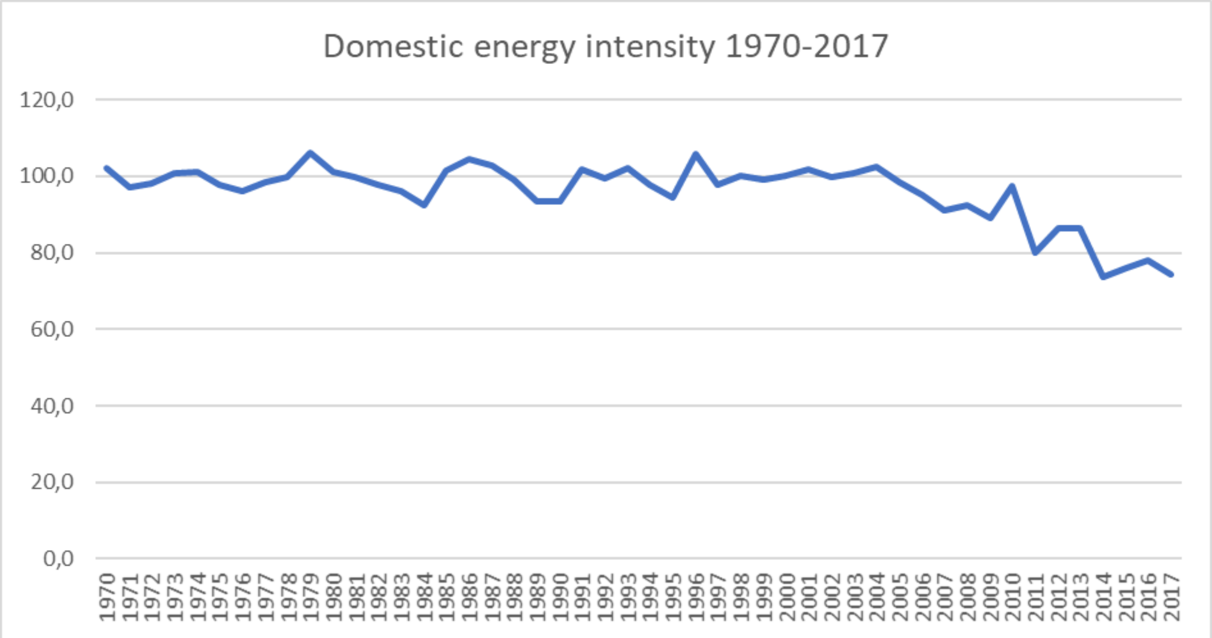


Figure 39 Energy intensity by household energy consumption 1970-2017 (Source: EHS data)

Energy pricing the UK

The UK pays a higher basic price for electricity relative to the other countries in this study. The amount of tax and levies (excl. VAT) is almost twice that of the Netherlands (*Figure 25*), which raises the total price of electricity for the UK (0.19EU/kWh) above the Netherlands (0.16EU/kWh). Around 10% of a consumer's bill is due to climate policies, but it is estimated that the increased price has been more than offset by savings from efficiency gains as a result of these policies. Pricing by energy suppliers is transparent, with the Office of Gas and Electricity Markets (OFGEM) reporting on supplier profits and industry price trends, which results in a high consumer awareness regarding price changes. The Committee of Climate Change was established under the Climate Change Act (2008) and assesses the contribution of various climate policies to household energy bills. *Figure 40* below shows the cost of climate polices on an average dual-fuel household's electricity bill.

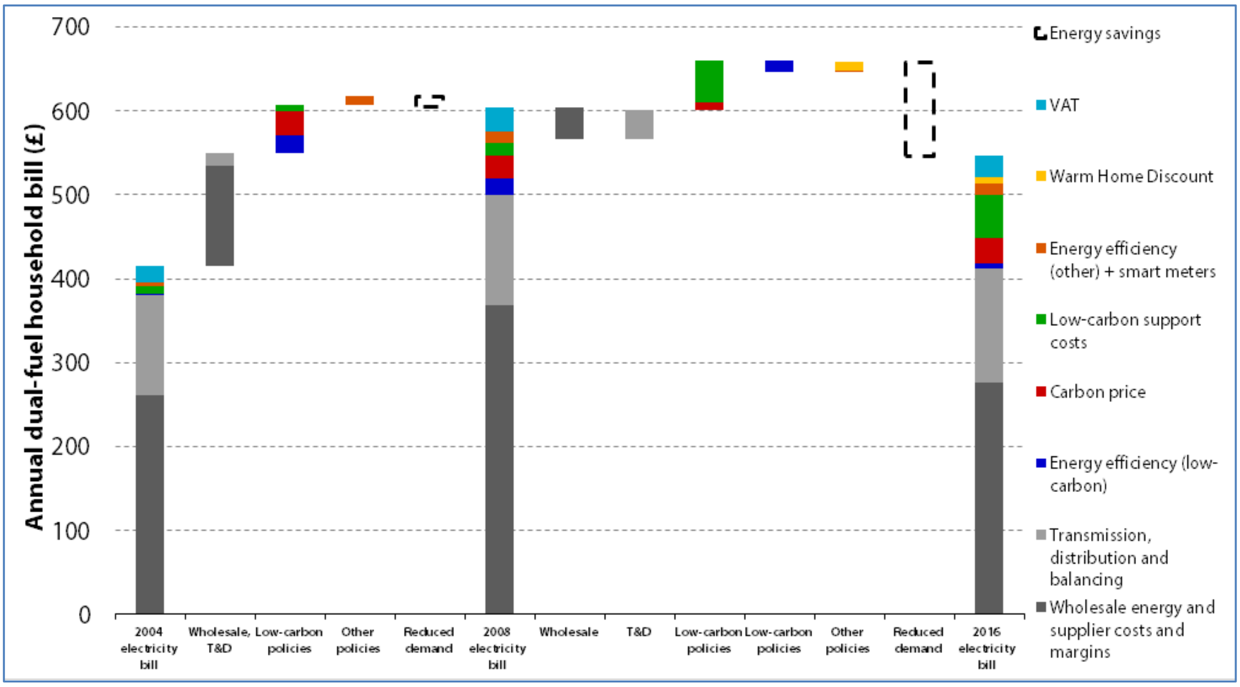


Figure 40 Costs of climate policies in a dual-fuel household electricity bill from 2004-2016 (CCC, 2017)

The basic price of gas in the UK is level with that of Germany, however extra charges such as VAT, taxes and levies are amongst the lowest in Europe. This makes the UK the cheapest country in this study for domestic gas pricing.

7.2 Current policies in the UK, residential sector

National and EU-related

There is a mixture of different policy types used in the UK to manage energy efficiency in the residential sector. *Table 12* shows only policies relating to space heating in existing buildings in the domestic sector and *Table 13* shows cross-cutting policies that impact heating in existing domestic and non-domestic buildings. From the tables, the following main conclusions can be drawn on the type of policies that exist in the UK and the level of impact that these have on energy savings:

- **Dominant policy types:** Legislative/normative is the most abundant policy in the mix and it has a high impact. The next most predominant measures are financial, which have a mixture of medium and low impacts. There are also a large number of measures classed as informative.
- **High impact policy types:** Legislative/normative policies have the highest impact. The "Supplier Obligations" in *Table 13* is a market-based instrument and it has a high impact. One informative measure has a high impact measure (Smart metering and billing, see *Table 12*).

Table 12 Overview of policy instruments for space heating in existing dwellings (insulation and boilers) in the UK, Including EU related policy[18]. Source: Mure

Code	Measure Title	Types group	Starting year	Qualitative Impact
HOU-UK28	EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Building Regulations 2010	Leg-norm/invest	2010	High
HOU-UK23	Smart Metering and Billing	Leg/norm/use + Info/broad	2007	High
HOU-UK21	EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Performance Certificates	Leg-inform/focus (label)	2007	Medium
HOU-UK5	Warm Front and Fuel Poverty Programmes	Finan-fiscal/invest	2000	Medium
HOU-UK7	Energy Saving Trust	Finan-fiscal/invest + Info	1992	Medium
HOU-UK3	Reduction in VAT rate for energy saving materials	Finan-fiscal/invest	2000	Medium
HOU-UK34	Home Energy Efficient Programmes (Scotland)	Finan-fiscal/invest	2013	Medium
HOU-UK22	EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Code for Sustainable Homes	Leg-norm/invest	2007	Low
HOU-UK37	Private and Social Sector Regulation (Scotland)	Leg-norm/invest	2014	Low
HOU-UK31	Decent Homes Standard - a minimum standard that triggers action to improve social housing	Finan-fiscal/invest	2001	Low
HOU-UK35	Northern Ireland Sustainable Energy Programme (NISEP)	Finan-fiscal/invest	2010	Low
HOU-UK24	Act CO_2 Campaign	Inform/broad (center, etc.)	2007	Low
HOU-UK30	Zero Carbon Buildings (government targets and Zero Carbon Hub)	Inform/broad (center, etc.)	2007	Low

[18] The policy "EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Building Regulations 2006" was removed from the table as it is replaced by the newer Building Regulations 2010

Table 12 shows EU-related and national policies, their impact and starting year. It includes policies that exist in all four countries within the UK, as policy is partly devolved, a certain policy may be implemented with different mechanisms dependent on the individual country (section 7.5 explains briefly the nature of devolution and energy policy within the UK).

The general/cross-cutting policies shown below in *Table 13* are discussed in section 7.4. These include policies influencing renewable technology and space heating in existing buildings.

Table 13 Overview of ongoing cross-cutting policy instruments

Code	Title	Status	Type	Starting Year	Qualitative impact
GEN-UK33	Supplier Obligations - Energy Company Obligation (ECO)	Ongoing	Market-based instrument	2013	High
GEN-UK12	EU-related: Promotion of the Use of Energy from Renewable Sources (Directive 2009/28/EC) - UK12_Renewable Heat Incentive	Ongoing	Financial Measures, General Energy Efficiency / Climate Change / Renewable Programmes	2011	Medium
GEN-UK10	EU-related: Promotion of Electricity from Renewable Sources (Directive 2001/77/EC) - Feed In Tariff	Ongoing	Fiscal Measures/Tariffs	2010	Medium
GEN-UK36	Private and Social Sector Regulation (England and Wales)	Ongoing	General Energy Efficiency / Climate Change / Renewable Programmes	2016	Low
GEN-UK11	Green Deal	Ongoing	Financial Measures, Market-based Instruments	2013	Low

Only EU related policy

The UK has a large proportion of EU-related measures. All EU-related policies are legislative/normative or informative, and all financial measures are national. All EU measures in *Table 12* relate to the EU Energy Performance and Buildings Directive (EPBD), the titles of these measures are: The Building Regulations, Energy Performance Certificates and Code for Sustainable Homes. The Building Regulations have been in place in the UK since 1965, but now include parts relating to EU regulations, therefore they are defined as being EU-related. Of all the EU-related legislative policies, those that are normative have the highest impact in the UK.

Policy trends over time

This section takes a closer look at past policy types in the UK and how they have changed since 1974. The mix of past policy types does not differ drastically from the present mix. Energy efficiency policy has been dominated by legislative/normative and financial measures. Four high impact measures were completed during the period 1989-2003 and one high impact measure in 1974-1988, these were all legislative/normative showing that this policy has long been successful in the UK. Financial measures have also had a high impact in the period 1989-2003 and are still ongoing. More recently, informative measures have had a higher impact and are becoming a larger part of the strategy for improving energy efficiency.

7.3 Impact per policy instrument, space heating only

This section goes into more detail on the individual ongoing policies in *Table 12* and *Table 13*. The policies that have had the highest impact on energy savings are:

- **Supplier Obligations - Energy Company Obligation (ECO):** The current supplier obligation is called the ECO and it has been running since 2013. This measure is classed as a market-based instrument and therefore is (in Mure) not included in *Table 12* for space heating measures. See section 7.4.1 for a detailed description of this measure.

- **Building Regulations (2006 & 2010)**: Part L of the Building Regulations refers to energy savings and efficiency. It requires all new buildings and existing buildings that are to be sold or rented to have an EPC, otherwise a fine may be issued. The label is decided by an accredited energy assessor who carries out the building assessment. The data is then used to generate an EPC using the government approved Standard Assessment Procedure (SAP). For existing buildings the Reduced data Standard Assessment Procedure (RdSAP) is considered the appropriate method to use, however because this method is based on assumptions it is considered less accurate than the SAP (assets.publishing.service.gov.uk).

- **Smart Metering and Billing**: The UK government has set targets for energy suppliers to provide smart meters with in-home displays to every household by 2020. The mass roll-out began in 2016 and 11.3 million smart-meters have so far been installed by energy suppliers (BEIS, 2018a). The aim is to provide information to consumers on real time energy consumption. The observed data from the meters can also be used to improve measurements and post-evaluations, although concerns over data-privacy must be addressed. It works as an informative tool that also provides financial benefits to suppliers and consumers. Smart-metering is a demand-side-management tool which leads to behavioural changes that reduce energy consumption. The requirement for in-home displays differs from the Netherlands smart-meter roll-out where this is not mandatory. Behavioural changes are achieved through raising consumer awareness and providing energy efficiency advice upon installation of the meter. Studies on the impact of smart meters show between a 7-17% decrease in consumption compared to older pre-payment meters (Faruqui, Sergici & Sharif, 2015; Gans, Alberini & Longo, 2013).

When reading the status of certain policies within the *Table 12* and *Table 13*, the reader may wish to consider that some policies listed as 'ongoing' have been significantly scaled-back or have since been incorporated into other policy frameworks:

- EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Code for Sustainable Homes: This was a voluntary national standard for building new homes to promote higher standards in both carbon and energy. It helped to support the Zero Carbon Buildings policy. The newer and stricter Building Regulations are now used as the main policy to set targets for standards of homes (MURE, 2016).
- Warm Front and Fuel Poverty Programmes, this policy which aimed at reducing energy poverty has been revised within the current ECO.
- Zero Carbon Buildings was targeted at the new rather than the existing building stock. All new homes from 2016 would be carbon neutral. It ran from 2008 to 2015 when it was cancelled, failure to provide clear definitions for "zero carbon" and a want to reduce the strict regulations placed on housebuilders were cited as reasons.
- The Green Deal policy was ended in 2015, see section 7.6 for more detail.

Energy Savings Trust
The Energy Savings Trust is classified in MURE as both a financial and an informative policy instrument. It provides funding (grants, loans), endorsement for energy efficiency products and advice for energy efficiency measures to households in the UK. It also conducts research into energy efficiency. It was established in 1992 and has offices in England, Scotland, Wales and Northern Ireland. In England government funding ceased in 2012, but offices continue to be funded by respective governments in Scotland, Wales and Northern Ireland.

Scottish policy
Scotland has devolved powers in relation to energy efficiency (see section 7.5 for an explanation). Due to this fact there are some schemes that are related only to Scotland and have unique aspects:

- Private and social regulations are similar to those in England and Wales. They include 3 measures: Scottish Housing Quality Standard (SHQS), Energy Efficiency Standard for Social Housing (EESSH) and the Regulation of Energy Efficiency in Private Sector Houses (REEPS). The SHQS sets a minimum standard for properties owned by social landlords and includes 5 criteria. The EESSH now replaces the energy efficiency requirement component of the SHQS and is based on energy performance certificates, standards related to property type and fuel type (Scottish Government). The REEPS is a working group aimed at researching energy efficiency measures, behaviours, incentives and regulation within existing buildings.
- Home Energy Efficiency Programmes for Scotland (HEEPS) contains a number of programmes including loans, cashback schemes, advice and area-based schemes. Another part is affordable warmth (funded by the ECO), which provides interest free loans to low income households. Scotland's Energy Efficiency Programme (SEEPS) which runs over 20 year period, is a scheme to find innovative approaches involving community groups and businesses to help reduce costs and improve energy efficiency in households. Local authorities are provided with funding to carry out innovative schemes, these relate to

decarbonisation of the gas grid and new ways to deliver measures to hard-to-treat households at lower costs.

Northern Ireland

Northern Ireland does not have an EEO, instead it uses the alternative scheme the “Northern Ireland Sustainable Energy Programme” (NISEP). It differs from the EEO as it is a voluntary scheme that funds energy efficiency and renewable energy through a price placed on consumers electricity bills. It applies to both domestic and non-domestic buildings, however similar to the EEO it is targeted at low income households.

7.4 Other policies in MURE

All policies of the UK are evaluated in MURE, therefore this section discusses the cross-cutting policies in *Table 13*. Market-based instruments, such as the Supplier Obligations are a central piece of the UK’s energy efficiency policy for targeting the retrofit of existing dwellings in the residential sector. Other general policies that impact both the domestic and non-domestic sectors are discussed in this section, these include the Feed-in-Tariff (FiT) and Renewable Heat Incentive (RHI).

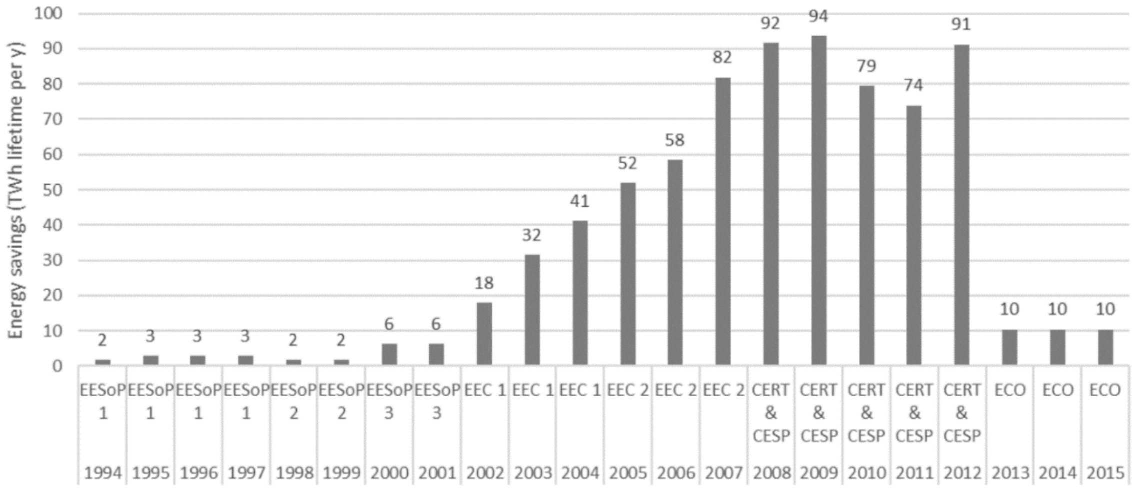
7.4.1 Energy Efficiency Obligations (EEOs)

In the UK, Energy Efficiency Obligations are considered one of the principle instruments for reducing energy consumption and carbon emissions in the residential sector (DECC, 2014; Rosenow, 2012). The UK was the first EU country to introduce EEOs in 1994 under the title “Energy Efficiency Standards of Performance” (EESoP). This was revised in 2002 to become the Energy Efficiency Commitment (EEC), in 2008 the Carbon Emissions Reduction Target (CERT), and most recently in 2013 the Energy Company Obligation (ECO). The UK allows trading between suppliers without the use of White Certificates. The current ECO requires all electricity and gas suppliers with over 250,000 domestic customers to meet a targeted energy savings over the prescribed period. Failure to meet targets will result in penalties from the energy regulator OFGEM.

Energy efficiency measures are funded through household energy bills, it is estimated that this contributed £50 to an annual dual-bill in 2013. The Climate Change Levy (CCL) is a tax that energy suppliers pay and is passed on to consumer bills. Approximately 20% of the funds from the CCL go to government energy efficiency schemes such as the ECO and the remaining 80% goes to renewable energy schemes. In the UK this funding mechanism is criticised as regressive, because it disproportionately affects low-income households. This is because the majority of climate policy costs are added onto electricity bills and the fuel-poor are concentrated in household within EPC bands F and G or use expensive electric heating systems. The ECO attempts to counteract this through ensuring that suppliers must achieve a proportion of their savings targets in low-income households and has focused the target obligation on reducing energy bills.

Figure 41 shows the annual energy savings for efficiency measures under EEO policy in the UK. It is clear that after the new increased targets set by the Energy Efficiency (EEC) the energy savings increase substantially. CERT and CESP are shown to be the policies with the highest impact on energy savings. Different measures that have higher energy saving impacts were favoured during this EEO, such as loft and wall insulation over boiler replacement (see Figure 61 in Appendix B). The new ECO in 2013 substantially reduces savings, bringing levels back to those seen in the early 2000s. The reduction in the total number of measures is in line with the scaling back of the ECO targets and budget due to increasing costs, and reflects the decreased number of measures that were carried out (see Figure 61 and Appendix B).

Figure 41. Energy savings from EEO 1994-2015, accumulated savings from new actions each



Data sources: Lees (2006, 2008), NAO (2016) and Ofgem (2003, 2005, 2006, 2007, 2008, 2013)

year (source: EPATEE, 2018)

EEO in 2008-2013 – CERT & CESP

The EEO was redesigned to align with the targets of the Climate Change Act, with the measured saving target changing from energy consumption to CO_2 emissions. The Carbon Emissions Reduction Target (CERT) in 2008 was aimed at all households and cost-effective measures. The Community Energy Saving Programme (CESP) in 2009 was aimed at low income households and deep renovations. Both are generally considered to be successful schemes and from 2008 to 2012 they delivered 8.5million insulation and heating measures (Hough, 2017). However, because they mainly focused on low impact renovations which would become saturated by 2020, the scheme would not be able to provide funding for deeper, more expensive renovations that were needed within the existing building stock to achieve ambitious climate targets (Rosenow & Eyre, 2014).

EEO 2013 to present – Energy Company Obligation (ECO)

ECO replaced CERT and CESP in 2013, the main difference being the larger budget, which allowed deeper buildings renovations that were more cost effective. The first phase of the scheme contained 3 sub-obligations:

- Carbon Emissions Reduction Obligation (CERO). CO_2 savings by insulating hard to heat properties e.g. those with solid walls or hard to treat cavity walls.
- Carbon Saving Community Obligation (CSCO) focused on low income areas
- Affordable Warmth focused on cost savings tackling fuel poverty

Since 2013 the scheme has been simplified through the removal of CERO and CSCO elements that followed on from CERT and CESP (*Figure 39*). CERO and CSCO measured savings by CO_2 emissions which became an issue because reducing the CO_2 of a household does not always mean energy savings or lower bills.

The majority of measures were supposed to be carried out under the complementary Green Deal, which was introduced in 2013. The Green Deal provided loans for cost-effective efficiency measures. The ECO was intended to provide funding for other higher cost measures and those in harder-to-treat properties that did not meet the Golden Rule (this is further discussed in section 7.6). However, poor uptake and impact of the Green Deal led to it being cancelled in 2015 (section 7.6 explains further the weaknesses of the Green Deal). Since then, the remaining ECO programme has produced significantly lower energy savings compared to the previous CERT and CESP schemes. Targets have been reduced and a 26% cut to the budget was announced in 2016 (NEA, 2015; Thomas et al., 2016).

The current ECO 2018-2022 has been refocused 100% on the Affordable Warmth sub-obligation (*Figure 42*). This shift means the obligation is no longer measured by carbon savings as in the previous schemes, but only bill savings are measured and count towards the final target (CCC, 2017). 70% of funding will be dedicated to eligible low-income households, the number of which are estimated at 6.5m (BEIS, 2018b). 40% of the existing housing stock (around 10.4 million households) is classed as 'hard-to-treat', meaning they have solid walls, no loft space, or are disconnected from the gas grid. Suppliers will often choose to meet targets with the most cost-effective measures, therefore more expensive measures such as solid wall insulation (SWI) may be ignored (Fawcett, Rosenow & Bertoldi, 2018). In order to target these homes a minimum solid wall insulation requirement target is included in the lifetime of the ECO, this is equal to around 60,000 solid wall measures. The SWI requirement target remains throughout the ECO, as this is one of the measures that has the greatest potential to save energy at the household level and also on a national scale, as around 27% of the housing stock is solid wall in the UK (Hall & Caldecote, 2016).

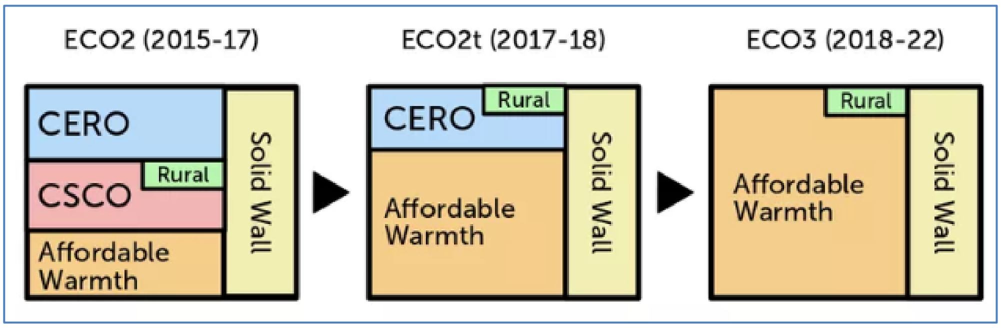


Figure 42 Changes to sub-obligations within the ECO scheme since 2015 (source: BEIS, 2018c)

7.4.2 Renewable energy incentives in the residential sector

The Renewable Heat Incentive (RHI) and the Feed-in-Tariff (FiT) both provide payments to residential producers of energy for up to 7 years. These two instruments are intended to increase the production of renewable heat and incentivise the sale of heat pumps, biomass boilers and solar thermal panels. The FiT is an older scheme that provides payments to producers of electricity from solar, wind, hydroelectricity, CHP and anaerobic digestion technologies. Whilst the impact of the FiT on the number of solar renewable technologies installed in homes has been large, the impact on the CHP market has been limited. It has been mentioned that a similar FiT scheme for energy efficiency could be introduced in the future, but this would require a robust method for calculating energy savings and further funding (EST, 2017).

The RHI aims to increase renewable heat from 2% of total heat demand to 12% by 2020. The scheme initially provided payments to non-domestic users and then extended to include the domestic sector in 2014. Similar schemes to the FiT exist in other countries in Europe, but the UK was one of the first countries in the world to provide long-term payments specifically to heat generating technologies in the domestic sector (DECC, 2011). Under the RHI scheme the largest number of installations have been for air and ground-source heat pump technologies (*Table 14*).

Table 14 Number of domestic RHI installations by technology up to December 2017 (nao.org.uk)

Technology	Number of installations
Heat Pumps	38,997
Biomass boilers	12,523
Solar thermal	8,573
Total	***60,093***

The RHI payment tariffs are based on estimates relating to the EPC of the household. Therefore, all households on the scheme must have an EPC rating, and if stated on the EPC, loft and cavity wall insulation measures must be installed (MURE, 2016). In this way the RHI complements the EPC, so renewable heat incentives are also an incentive to improve energy efficiency.

7.5 Other aspects of the policy

Design of national policy and devolution

Energy regulation for the whole of the UK is the responsibility of Westminster Parliament, however certain policy aspects (for example building regulations, strategies) are decided by the independent governments of Scotland, Wales and Northern Ireland. Northern Ireland differs slightly in its mechanisms, for example it does not have an EEO and uses an alternative scheme. In general, policies share similar scope in terms of target levels and improvements achieved (DECC, 2014).

The Climate Change Act (2008) set ambitious targets to reduce CO_2 emissions by 57% by 2030 and 80% by 2050, against 1990 levels. Slight variations of additional more ambitious targets exist in the different countries within the UK.

The need to improve energy efficiency in the residential sector in the UK can be traced back to the 1970s. Early schemes for energy efficiency in buildings were driven by public concern over fuel poverty levels and the related adverse effects on human health (NEA, 2015). In more recent years, other issues such as climate change and energy security have influenced policy decision making. Reducing fuel poverty continues to be a main priority of many policies and with rising energy prices it is increasingly important that this is incorporated into policy design. This is reflected in obligations to meet targets in low income households, continuous schemes aimed at reducing energy costs, improving warmth in homes and the recent refocusing of the ECO 100% on Affordable Warmth (BEIS, 2018d).

Examples of measures to overcome energy efficiency barriers in the UK

The UK government has a number of measures aimed at overcoming barriers. Split incentives are a barrier to energy efficiency improvements, although efficiency measures provide multiple benefits overtime, the uptake and market growth for energy efficiency remains low. Particular attention is given to overcoming financial barriers, such as being able to pay the upfront costs for efficiency measures or renewable heating technologies. This is of particular concern in the private rented sector (where landlords must pay but tenants benefit), so many UK policies are directed specifically at this sector. The quality of housing is also typically lower in this sector and occupants are likely to have lower incomes. Some specific policy examples to overcome split-incentive barriers measures are:

- The Green Deal attached loans to the property rather than the owner, this allowed for those living in the property to benefit from the improvements for the duration of residence.

- Landlords, from 2016, cannot unreasonably refuse requests for energy efficiency improvements from tenants (Private and social sector regulations, 2015). The tenant must be able to secure funding, for example through the ECO.

- The Landlords Energy Savings Allowance (LSA) was a financial incentive (tax-break scheme) of up to £1500 to encourage landlords to improve the energy efficiency of rented properties. It ran from 2004 to 2015.

7.6 Financial incentives

The Green Deal

This was an innovative government-funded scheme aimed at households and small businesses and was the first on-bill financing mechanism in the EU. It is based on the Pay-As-You-Save (PAYS) mechanism and was outlined in the 2014 NEEAP as a main mechanism for meeting the EU EED targets (Mundaca & Kloke, 2018). The main premise behind the policy was to provide a subsidy-free incentive for the uptake of efficiency measures by removing upfront costs. The loan is valid for up to 25 years and is attached to the electricity or gas meter and repaid through instalments placed on consumer energy bills. In the MURE database it is described as an ongoing policy, however the detailed measure description states it is closed. It ran from 2013-2015 and was intended to work in cooperation alongside the ECO. However, it was cancelled by the government due to a number of failings.

One of these failings relates to the ‘The Golden Rule’ that lay at the centre of the scheme. It stipulates that for a measure to be financed, the energy savings on energy bills must always be higher than the annual cost of the instalments paid back over the measure’s lifetime. For example, in a semi-detached household the average cost for installing solid wall insulation is £9,000. The estimated energy bill savings from the measure are £232 per year. Therefore, Golden Rule would state that maximum annual loan repayments could not exceed £232 (Hall & Caldecote, 2016). The calculation uses the RdSAP and is estimated based on the expected performance of the efficiency measure and the energy consumption of a household. The Golden Rule therefore only funds low-cost measures with the emphasis on bill savings as the main reason for installing measures, whereas a large percentage would choose to install efficiency measures based on other benefits, such as improved comfort (Rosenow & Eyre, 2016).

The loan is attached to the energy meter not the owner, so helps overcome the split-incentive barrier between the difference in length of ownership and payback time of the measure. It also aims to influence the behaviour of energy consumers and reduce the rebound effect, because savings on energy bills are only achieved through reduced energy consumption (Mundaca & Kloke, 2018). However, an unattractive interest rate of around 7-10% (as opposed to Germany's 1% for KfW loans) meant that many consumers chose other financing routes. The ECO at the same time was providing free grants for efficiency measures which proved a better option over the Green Deal. By 2014, the Green Deal had only funded 6,449 measures, as opposed to the ECO which had funded 532,611 measures.

To finance the Green Deal, the government funded Green Deal Finance Company and the Green Investment Bank (GIB) were set up. The GIB was set up by the UK government in 2012 to encourage further private investments in green infrastructure and provide the extra funding needed to meet targets set out in the Climate Change Act (2008). However, it favours larger scale projects and provides little funding to domestic efficiency projects on the household scale (Bergman & Foxon, 2018). A network of approved Green Deal Providers, Assessors and Installers was set up. Green Deal providers managed the loans and provided the upfront costs for the measures themselves, which were often covered by the Green Deal Finance Company or external financiers. The loan was repaid back to energy suppliers in instalments placed on consumer energy bills and then Green Deal providers were reimbursed by the energy supplier. However, the complexity of the scheme and unfamiliar, new networks dissuaded the public and companies from getting involved (Rosenow & Eyre, 2016). The bank became profitable and was bought by the Australian Bank Macquarie for £2.3bn in 2017.

7.7 Evaluation of policy in the UK

All new measures related to Supplier Obligations are subject to an ex-ante evaluation, which is carried out by the Department for Business, Energy & Industrial Strategy (BEIS), or similar government departments in Scotland and Wales. Evaluations are carried out under the policy appraisal guidelines set out in the "Green Book". In addition, the energy regulator OFGEM carries out regular independent evaluations to monitor progress and then compares the results against those of BEIS (EPATTEE, 2018).

Policy evaluations are also commissioned by BEIS and carried out by consultant groups, researchers, academic institutions, and more specifically, the Energy Saving Trust. Furthermore, there have been numerous studies evaluating the impacts of efficiency policies and evaluation methods.

Building and energy databases/ registers

- A recent database, the National Energy Efficiency Data Framework (NEED) brings together multiple databases on housing statistics and energy consumption. One database within NEED is the Homes Energy Efficiency

Database (HEED), which contains retrofits for over 13 million dwellings (Hamilton et al., 2013). The NEED database contains observed data based on energy consumption readings, which when used for ex-ante evaluations will factor in the effect of double-counting and free-riders. It has been used to inform multiple policies and research, including evaluating the ECO (EPATTEE, 2018).

- The English Housing Survey is a national, annual survey that dates back to 1967. It contains publicly accessible statistics. Information on the current and past building stock is widely available.

- Energy Performance of Buildings Data England and Wales (EPC Database) contains 15,623,536 Domestic EPCs. The majority of EPCs for the existing building stock are calculated based on estimates using housing age and other characteristics. The Standard Assessment Procedure (SAP) is a government approved method that was introduced in 1992 to support energy efficiency policies (Appendix C has further detail on the SAP method). It uses energy assessor survey data to assign energy and efficiency performance value on a scale of 100, this is then used to model the EPC label. This is more likely to be carried out for newer, more efficient homes and therefore these are likely to have more accurate label. In 2005, the Reduced data Standard Assessment Procedure was introduced to be used as a lower cost method for assessing existing dwellings energy performance (gov.uk).

7.8 Conclusion

1. **Type of policy:** The UK is relying on regulation such as the 'Building Regulations' and the EPC in addition with market-based instruments such as the 'EEO' to improve energy efficiency. The Netherlands has considered introducing an EEO in the past, however recent experience in the UK suggest there are some pitfalls in the design of the scheme to achieve long-term energy efficiency goals. One lesson to be learnt from the UK experience with the EEO and the Green Deal is that time must be given for the introduction of new schemes and that trusted institutions should be used for delivery to market, thereby increasing consumer and investor confidence. The EEO in its current form, with a reduced budget, is on its own an insufficient instrument to reach efficiency improvement targets in the residential sector and other measures need to be introduced.

   The UK is moving towards increased private sector investments and the involvement of local authorities to stimulate a market for energy efficiency and reduce the increasing costs to suppliers and consumers. In Scotland, the SEEPS are encouraging innovative projects with the involvement of local authorities and businesses to boost activity and find solutions to reduce retrofit costs in hard-to-treat buildings.

2. **Evaluations and monitoring:** The UK includes the impact of reducing effects in the evaluation of policies. Ex-ante evaluations are carried out using NEED, a large database of combined information that factors in free-riders, the rebound effect and removes double-counting. Webber et al. (2015) in an ex-post evaluation presents evidence to suggest that the impacts of reducing effects are over-estimated (see Appendix C: case study Kirklees Warm Zone Scheme). The overall strength of evaluations are supported and increased by:

- Strong institutions such as the regulator OFGEM and the government department BEIS both monitor and evaluate to uphold standards in evaluation and that EEO targets are met by suppliers.
- Smart-metering and billing is a high impact policy measure in the Odyssee-MURE database, if the roll-out is successfully completed it will increase the observed data available for policy evaluations.

3. **Overcoming barriers to energy efficiency:** The UK government has experimented with the Green Deal as a tool to overcome split-incentive barriers and reduce reliance on government subsidy through increased private investment. However, it's failure has demonstrated that the public is reluctant to switch from decades of free subsidies to one that is based on pay-as-you-save loans and higher upfront costs. The German KfW loan scheme with lower interest rates has proved far more successful. Another lesson learnt from the 'Golden Rule' is that the promotion and design of schemes should not be restricted to energy bill savings, but reflect multiple benefits that improvements to energy efficiency can bring such as CO_2 savings, improved comfort and well-being. Targeted policies aimed at low-income households recognise the close link between energy efficiency and society. These policies aim to reduce impacts on the fuel-poor, who are living in the least efficient homes and are subject to higher energy bills.

   Policies which build upon each other such as the RHI and EPC incentivise the production of renewable heat to reduce carbon emissions, and at the same time require insulation improvements under the EPC, reducing the energy demand of a household and improving comfort. The Energy Savings Trust is an example of a trusted central government organisation that combines informative and financial types. It provides research, advice and delivers the financing of various schemes to the public. Providing both advice to consumers and financial benefits at the same time, works to strengthen the impact of policies through influencing consumer behaviour and increasing engagement.

8 Policy in Denmark (by S. Paliouras)

In chapters 5, 6, 7 and 8, the policy portfolio and other relevant aspects of the selected countries will be described. Information from these chapters have fed into chapter 4, where to a certain extent the comparison between the countries has been made. As well, occasionally a comparison is made in the respective country chapters.

The chapters all have the same general structure, after an introduction the policy portfolio and their individual policy measures will be described for the residential sector. This includes all household measures, including those that target the energy consumption of appliances. This relates to some so-called ‘radar graphs’ in Mure, which are quite difficult to understand. The Dutch and German chapters show the graphs, and the Dutch chapter explains it. But in this country chapter only the conclusions are given. Policy measures in Mure have been given a ‘type of policy measure’, as explained in section 4.3. The next section gives an indication of the impact of policy measures that target the energy consumption of space heating of existing dwellings specifically. The table provided comes from a different search query in Mure and includes the relative impact of the policy measure (low, medium or high). Possibly Mure and/or this table is not complete; if found in other sources and/or in other Mure queries, relevant additional policy measures will be discussed.

Then, financial incentives that stimulate the uptake of energy savings actions are looked at. From section 4.9, we know that evaluating the energy savings effect (and their cost-effectivity), is a challenge. Therefore, a section tries to describe the evaluation strategy of the country. Instead of a chapter summary at the beginning, there is a concluding section at the end.

8.1 Country policy introduction

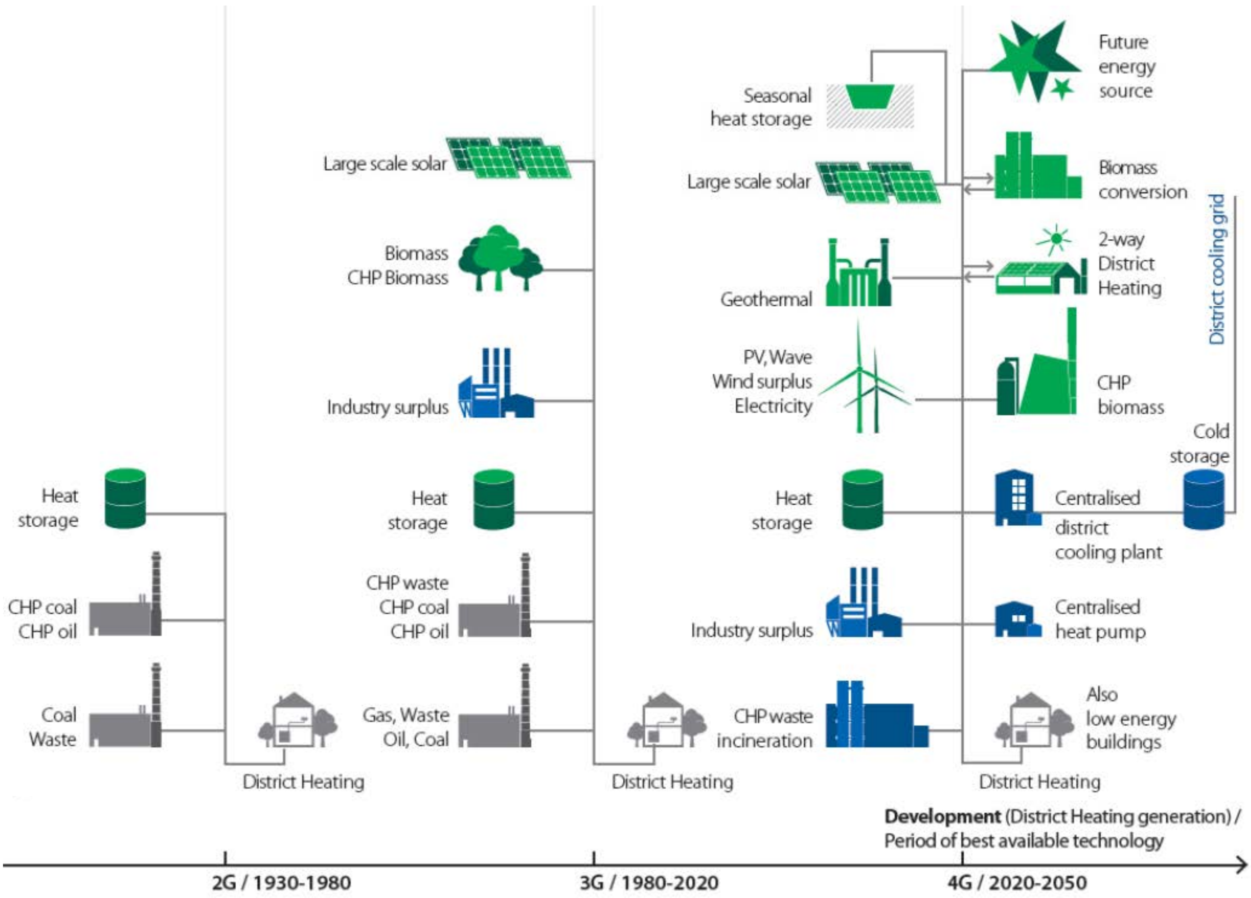
During the Arabic oil embargo of the 1970s when Denmark was faced with the worst energy crisis in recent history, Danish policy-makers recognised that it was crucial to gain expertise in realising energy efficiency (Danish Energy Agency, 2017a). In fact, until 1972, more than 90% of the energy consumed in Denmark was from imported oil. Thereafter, when the oil crisis pushed for further changes, the Danish government invested in the research and extraction of other forms of energy (Danish Energy Agency, 2005). Consequently, in 1984 the North Sea natural gas project began. The “gas and oil” project made Denmark self-efficient by 1997, production peaking in 2005 and decreasing again below sufficient levels in 2013. Furthermore, at an early stage of the oil crisis Danish energy experts realised the importance of decreasing national energy consumption. One option that was identified as having a large energy-saving potential was within buildings.

Hence, the Danish energy experts gained experience and knowledge in planning and implementing District Heating (DH)[19] and Cogenerated Heat and Power (CHP)[20]

[19] As District Heating is defined as a system which distributes heat in forms of water or steam amongst multiple buildings.

[20] Cogenerated Heat and Power is an approach for applied technologies where heat that is normally wasted in conventional power generation is recovered as useful energy, which avoids the losses that would otherwise be incurred from the separate generation of heat and power (ACEEE, 2017).

systems, in order to reduce energy consumption in buildings. In the short time between 1975 and 1995, Denmark reduced approximately 40% of the energy consumption for space heating purposes in buildings (Danish Energy Agency, 2017b). In addition to the sections that follow in this chapter, sections 9.5 and 9.6 contain further detail on Denmark's district heating system. The below graph (a copy of Figure 7) shows the flexibility of the present and future district heating system by combining several technologies and energy sources (northsearegion.eu).



Additionally, special attention has been paid to the development of Renewable Energy Systems (RES) and their integration into the electricity grid. As a result, currently, the proportion of renewable energy in Denmark is one-quarter of the total energy consumption.

Even though a big share of the energy consumed in Denmark has been converted to a clean energy source, it remains a priority for the country to stimulate further energy renovation in the building stock. Today, buildings accounts for 40 percent of national energy consumption. More than 70 percent of the total existing building stock in Denmark was erected before 1979 and consumes a substantially higher amount of energy for space heating in comparison with newer buildings (Danish Government, 2014).

Energy consumption and CO_2 emissions for space heating

In line with the large energy savings realised in the past decades, in the last fifteen years Denmark decreased further the energy consumption for space heating in the residential sector by approximately 20% (*Figure 43*). However, in comparison with the other three countries, the energy demand remains relatively high. More specifically, in 2016 the energy intensity for space heating in Denmark was 500 MJ/m^{2}.

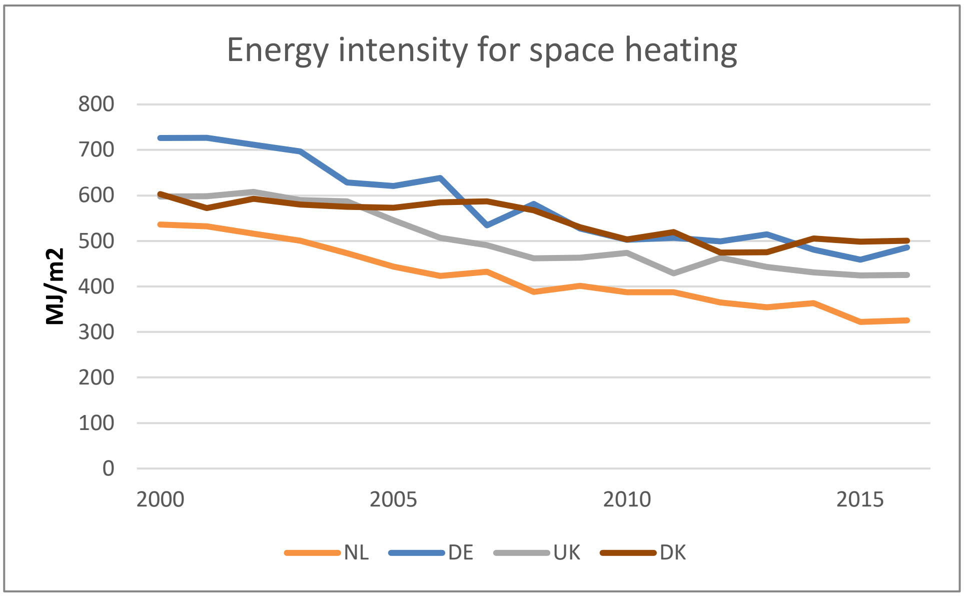


Figure 43. Unit consumption for space-heating (MJ/m^2) (Odyssee-Mure)

In contrast however, the annual CO_2 emissions from the household sector only for space-heating purposes is considerably low (*Figure 44*). This can be attributed to a combination of energy-saving efforts that took place in Denmark during the past years (Dyrelund & Lund, 2008). Firstly, end consumers have reduced the energy demand. Secondly, as seen in Figure 20 the share of district heating in the heat market has increased to 44 percent (corresponding to 64% of dwellings). The expansion of district heating has enabled the implementation of large-scale cogenerated heat and power systems using low carbon energy (Danish Energy Agency, 2017b). Furthermore, the development of RES (renewable energy sources) and mainly the high share of biomass has played a significant role in the reduction of CO_2 emissions. Danish policy-makers are however still aiming even higher to move towards achieving a system that is completely free of fossil fuel emissions.

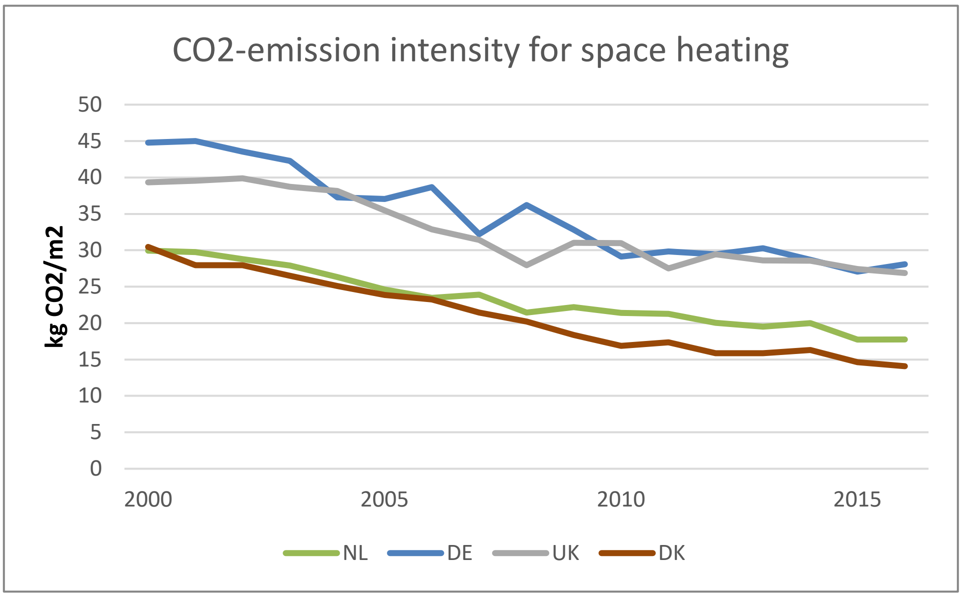


Figure 44 CO_2 emissions space-heating (kg/m[2]) (several sources)

The most important reason for such a low CO_2 intensity in Denmark, is the high share of renewable energy that ends up in the dwelling, as shown in the below graph, due to locally used renewables as wood.

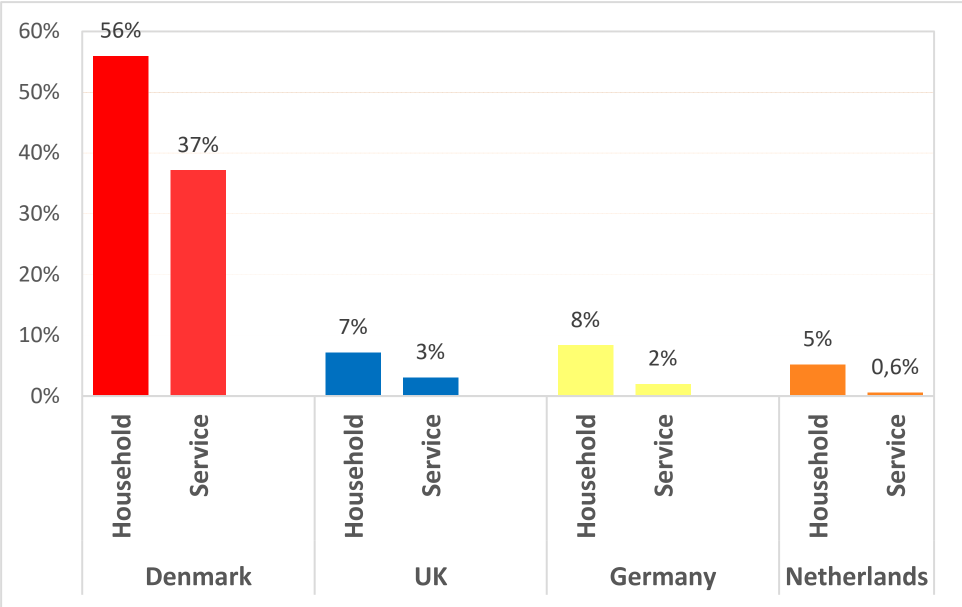


Figure 45 Share of renewable in the household- and services sector only for space heating (2016), by country. Source: Odyssee

Overview of national energy efficiency targets and savings.

The main Danish energy target is to become independent from fossil fuels by 2050. Thus, the Danish energy challenge is twofold. On the one hand is to achieve further energy demand reductions, and on the other hand is to expand and integrate renewable energy systems with space heating technologies in order to utilise their full potential. In other words, the Danish energy strategy has put a particular focus on two different levels; power and heat generation, and energy-savings realised in the end-user phase. District Heating and CHP plants play a primary role in the connection between these two levels, as they provide technological solutions such as short-term heat storage and efficient heat production.

In the strategy document “Our Energy” (*Vores energi, 2011*), the Danish government presented the overall national energy target for 2050 (*Figure 46*). The objective of this target was for the country to use only renewable energy by 2050. In order to meet the final target, short-term targets have been set. Thereby, the country aims towards a 12.6% reduction in primary energy consumption in 2020, compared with 2006. In addition, by 2030 Denmark will have phased out coal of power plants and replaced all the oil-fired boilers in Danish homes with renewable forms of energy. By 2035, all energy supply for electricity and space heating will be entirely covered by renewable sources.

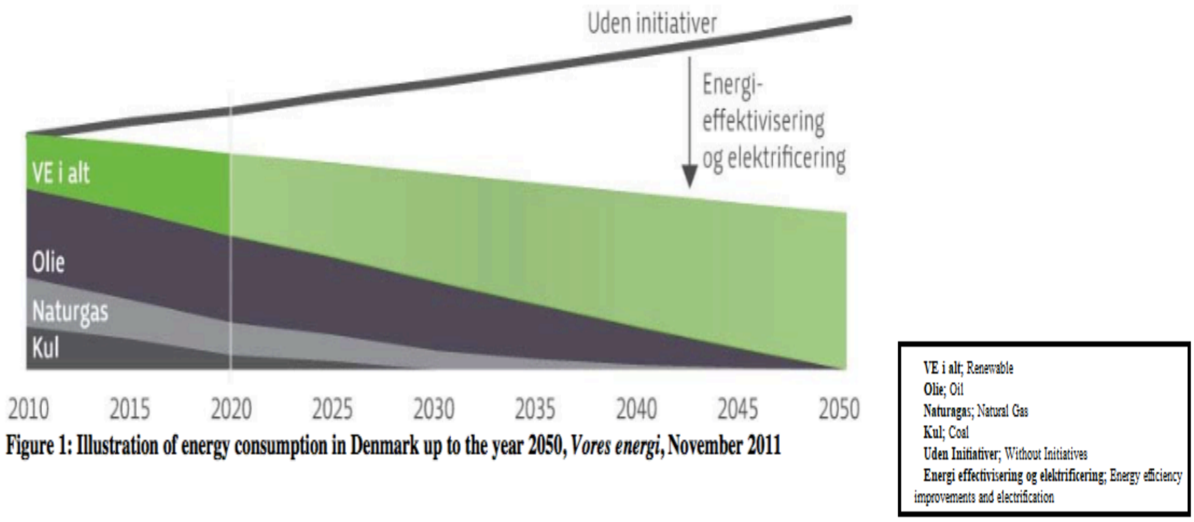


Figure 46. Energy consumption up to 2050 (Centre for Energy Efficiency, 2017).

To make sure the household sector is fossil fuel free by 2035, Denmark has to facilitate some sort of technological transition. This transition is described in *Denmark’s Energy and Climate Outlook* (DEA, 2017d).

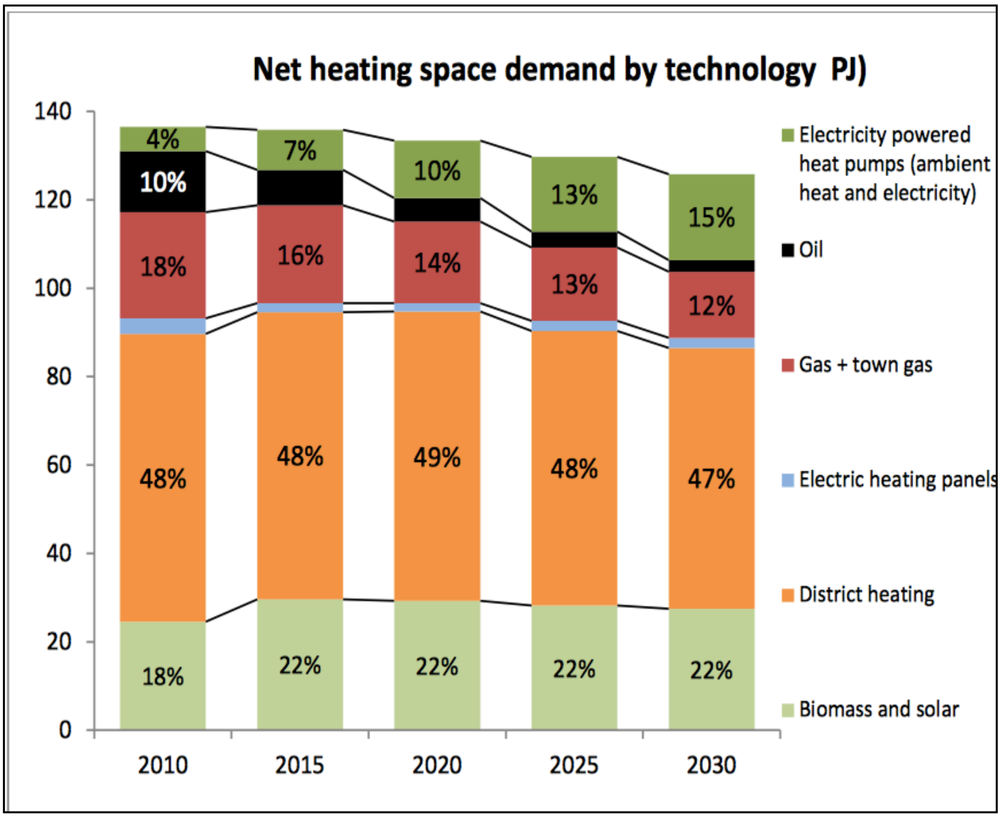


Figure 47. Net heating space demand by technology PJ.

By 2030, the number of electricity powered heat pumps will double in comparison to 2015 (*Figure 47*). The proportion of DH will remain the same, while the share of biomass and solar sources will grow by 4%. In contrast, the share of gas and town gas will be decreased from 16% to 12%.

Overall, by 2030, the net heating space demand is projected to decrease by approximately 10%. The Danish energy policies which stimulate the reduction of the net heating space demand are described in the following sections. All the data for the Danish energy saving policies has been retrieved from the Odyssee-Mure database.

8.2 Current policies in Denmark, residential sector

The energy-saving strategy in the residential sector is based on three key elements;

- The energy requirements in the **Building Regulations** schemes have been tightened up considerably.
- The financial incentives to reduce energy consumption have increased steadily as a result of the **high energy cost**.
- **Advice and information** regarding the energy efficiency strategy has been provided to all stakeholders within the building sector (Danish Government, 2012).

Current National and Eu-Related Measures; Residential Sector.

According to the Odyssee-Mure database (*Table 15*), currently, in Denmark, the most dominant type of measure is Legislation/Normative. Other types of Danish policy measures fall under the categories of *Informational* and *Education* measures. Surprisingly, as is the case in other the countries, neither financial nor fiscal ongoing instruments are indicated in the table.

Table 15 Household sector measures, both national and EU-Related

Code	Title	Status	Type	Starting Year
HOU-DK32	EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU) - Energy Labeling of Buildings	Ongoing	Legislative/Normative	2005
HOU-DK8	EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU) - Building regulations	Ongoing	Legislative/Normative	2006
HOU-DK34	Knowledge centre for energy savings in buildings	Ongoing	Information/Education	2008
HOU-DK35	EU-related: Recast Ecodesign Directive for Energy-related Products (Directive 2009/125/EC) - EU Energy labelling and ecodesign demands of energy-related products	Ongoing	Legislative/Normative	2009
HOU-DK41	Voluntary low-energy building classifications	Ongoing		2010
HOU-DK36	Information effort for energy efficiency regarding end-users (sparenergi.dk)	Ongoing	Information/Education	2012
HOU-DK43	Ban on the use of fossil based fuels for space and domestic water heating in new buildings	Ongoing	Unknown	2013
HOU-DK37	Strategy for energy renovation	Ongoing	Information/Education, Legislative/Normative	2014
HOU-DK40	Better Homes	Ongoing	Information/Education	2014
HOU-DK42	Funding for energy service companies targeting replacement of fossil-based heating with heating based on RES	Ongoing		2016

8.3 Impact per policy instrument

National versus EU-related measures. Household & Cross-cutting sectors.
Denmark has implemented a number of national and EU-related measures in order to realise energy savings. Two out of three EU-related measures (both in the household and in the cross-cutting sectors) are classified as “high-impact” policies. Overall, the Danish energy strategy consists of eight other national measures which contribute to a reduction in energy demand, but only one of them is classified as a high-impact measure (the Strategy for Energy renovation in *Table 15*).

High-Impact measures: Household sector. Space Heating existing buildings
In the Danish Household sector, there are three measures that have been given a high impact. All of the high impact measures are categorised as Legislative/normative. Therefore, it can be assumed that in the household sector the measures which are regulations are more effective than other types of measures.

In the next paragraphs, the three ongoing measures which have been classified as "high impact" are described.

- **EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU)-*Energy Labelling of Buildings*.** The first high impact measure of the table refers to the EU-related policy to provide labels for the building stock. The objective of this measure is to make all the energy specifications of a building visible for owners and renters and to create transparency in the property market. The idea of providing building labels in Denmark is not new, in fact, the country has been trying to label the national building stock since 1978 (Appendix D). However, the EPBD measure which was launched in 2005 and revised in 2010 was directed by the European Union in order to provide a common methodology for calculating the integrated energy performance of buildings across Europe. Some other characteristics of the EPBD measure are; the selection of minimum energy requirements for the existing and new buildings, the provision of independent energy certification systems updated every five years, and regular energy inspections in households.

- **EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU)- *Buildings Regulation*.** The second "high impact" measure of the table, contains all the rules and functional requirements for the construction of buildings in Denmark in all different sectors. The Buildings Regulation measure is also EU-related and reflects on the general EU EPBD measure which has been discussed above. Besides the energy demand regulations for new buildings, this measure introduced two new voluntary low energy classes for existing buildings. In 2015, the Buildings Regulation measure was upgraded with a new version of energy demand requirements.

- **Strategy for Energy Renovation.** The third high-impact measure of the table is a nationally implemented policy which falls under the categories of Leg/norm and Investment. The aim of this national measure is to compose a strategy for the energy renovation of the existing buildings stock, by involving a wide range of stakeholders from tenants and house-owners to building professions and housing associations. In practice, the Strategy for Energy Renovation measure was designed to fill the gaps in the existing energy requirement measures and stimulate building renovation. The buildings of the future are expected to consume far less energy than the old ones (buildings in 2020 will consume 60% less energy than buildings in 2006) as result of the continuous tightening up of energy requirements for new buildings. However, energy saving potential in the new building stock is very limited in comparison with the existing one, and this because of the small rate of demolition in the Danish building sector. The Danish government identified the large energy-saving potential in the existing building stock and implemented the Strategy for Energy Renovation measure.

  Thus, in 2012 the Network for Energy Renovation was established in order to design and implement a number of new initiatives which promote effective methods of energy renovation of buildings. Some of the initiatives that the Strategy for Energy Renovation measure has introduced are;
  - the revision of building regulations and energy requirements that apply to the retrofitting and renovation of existing buildings,
  - the provision of new energy efficiency requirements for windows (to be installed after 2020),

- the revision of the energy certifications systems,
- the establishment of measures to improve professional training to craftsmen or engineers in the building sector,
- information to building owners, construction companies, financial institutions on how to improve energy efficiency,
- and the development and demonstration of new technologies.

Concluding, the Danish Government projected that the Strategy for Energy Renovation measure will bring a reduction of 35% in net energy consumption for space heating by 2050.

8.4 Other policies in MURE

Measures not evaluated in the Household Sector

Some of the measures presented in Table 15 are either not evaluated or not categorised according to their type and their semi-quantitative impact. Therefore, it should be mentioned that these measures are not further described in this report. The three unevaluated measures are;

- ***Voluntary low-energy building certification*.** It is assumed that there is a misconception regarding this measure. The voluntary low-energy building certification is included as an incentive within the EPBD Directive Building Regulations measure.

- ***Ban of the use of fossil-based fuels for space and domestic water heating in the new buildings*;** There is of lack of information regarding this measure. There is no description of the measure in the Odyssee-Mure database or in other governmental reports.

- ***Funding for energy service companies targeting replacement of fossil-based heating with heating based on RES*;** Similar to the previous unevaluated measures, this one lacks a description in the Odyssee-Mure database as well. Denmark's ambition is to be fossil fuel free by 2050, but no measure that addresses this specifically has been found.

General/Cross-cutting measures with an impact on the household sector

Besides the measures that exclusively concern the household sector, there are numerous different measures which stimulate energy-efficiency in multiple sectors. These type of measures in Odyssee-Mure database have been classified as market-based instruments, co-operative measures or general energy efficiency measures. Even though these measures have been designed within general frameworks and are related to all sectors (e.g. services, transportation or industry), they undoubtedly influence buildings as well. Therefore, they are discussed in detail in the next sections.

Table 16. General Cross-cutting Measures (Odyssee-Mure)

Code	Title	Status	Type	Starting Year
GEN-DK9	Denmark's Fund of Innovation	Ongoing	Non-classified Measure Types	
GEN-DK6	EU-related: Energy Efficiency Directive (EED) - Directive 2012/27/EU - The energy efficiency obligation scheme	Ongoing	Co-operative Measures	2006
GEN-DK5	Public funding for energy research, development and demonstration	Ongoing	Market-based Instruments	2007
GEN-DK10	Danish Energy Agreement 2012	Ongoing	General Energy Efficiency / Climate Change / Renewable Programmes	2012

- The first measure which refers to multiple energy sectors, and still affects the household sector is the EU-related scheme ***Energy Efficiency Obligation*** (EEO). The Energy Efficiency Obligation scheme has been characterised as the main policy of Denmark for reaching the targets of Article 7 [21] (NEAAP, 2015). The scheme is based on a voluntary agreement within a legislative framework with distributors of natural gas, district heating, and electricity. The main characteristic of the EEO scheme is the freedom to choose the methods and the sectors in which to realise energy savings, and the introduction of trading savings. Energy companies participate in the voluntary agreement and get involved in energy-saving efforts such as consumer information, energy audits, and subsidies etc. (Morten & Petersen, 2018). Certainly, the efforts of utility companies influence the energy demand of the end-users and have a large impact on the household sector. A detailed explanation of the EEO scheme is provided in the next chapter.

- The measures ***Denmark's Fund of Innovation*** **and** ***the Public funding for energy research development and demonstration*** have similar targets. Both measures aim to financially support and strengthening research, technological development, and innovations on a national level. They are included in this report because ,among others, these two agreements fund projects related to energy-efficiency and renovation for buildings.

- The fourth cross-cutting measure which highly impacts the household sector is the ***Danish Energy Agreement***. This measure contains a wide range of initiatives, bringing Denmark closer to the energy-neutral target of 2050. The Danish Energy Agreement is based on large investments up to 2020 in the areas of energy efficiency and renewable energy and aims in the reduction of the final energy consumption of approximately 8% in comparison to 2010. Some of the initiatives introduced in the agreement are;

[21] Directive 2012/27/EU "known as the Energy Efficiency Directive (hereafter EED) requires Member States (MS) to set up an energy efficiency obligation scheme, or equivalent alternative policy measure/s with the goal of achieving annual energy savings of 1.5% of annual sales to final consumers over the 2014-2020 obligation period". (ENPSOL, 2017)

- o Financial support committed to the development of renewable energy (solar, wind and wave).
- o Reduction of taxes on electricity and restructuring of surplus heat utilisation.
- o Introduction of energy saving targets aiming energy companies (increase utility efforts 100% from 2015 to 2020).
- o Converting big-scale power plants from coal to biomass.
- o Regulation to support sustainable power generation of small-scale plants.
- o Deployment of smart grids.
- o A comprehensive strategy for energy renovation of all Danish buildings.
- o Banning installation of oil-based and natural gas boilers in new buildings.
- o Banning of installation of oil-based boilers in existing buildings in areas where natural gas or district heating is available.

In June 2018, the Danish government updated and resigned the Danish energy agreement including new energy targets for 2030.

The Danish Energy Agreement has been characterized the basic national measure for speed up the phasing-out oil-fired boilers in existing buildings. Therefore, the agreement has a direct impact on the space heating technologies used in the household sector.

8.5 Other aspects of policy

8.5.1 Importance of Energy Efficiency Obligations (EEOs) scheme.

The fact that the EEO scheme has been revised and updated three times since it was initially introduced (2008, 2012, 2016), highlights the importance of the measure for the Danish energy-saving agenda. Denmark is one of only three European countries that have chosen exclusively the route of EEO in order to meet the energy saving target of article 7 of the EE Directive. All other EU countries either choose a combination of alternatives and the EEO scheme or only alternatives (Bertoldi et al., 2015).

The Danish EEO scheme is praised both for its flexibility and for its simplicity of administration (ECOFY, 2018). These two characteristics offer the opportunity to involve a greater number of energy and grid distributors in the agreement. Furthermore, since the scheme gives the freedom to choose across a variety of instruments and policy incentives for realising energy efficiency, the EEO scheme has been used to target several sectors simultaneously. This might be an explanation of why in Denmark the number of introduced measures is relatively low.

Some of the actions that the energy companies can take in order to realise energy efficiency within the EEO scheme are; the provision of audits and energy efficiency information, the implementation of projects for upgrading their grid-infrastructure in order to decrease the energy losses, and the prioritisation of sustainable technologies and energy renovation. Usually, the most common measures in the residential building sector are based on professional advice and subsidies to realise energy savings (ENSPOL, 2015). All the efforts made by energy companies in order to achieve energy saving targets would be financed from consumers via tariffs and taxes. In return, the companies which are directly or indirectly involved in the EEO scheme are rewarded with verifications.

For applying for the verification, the energy distributors are obliged to report annually the energy saving that they have achieved. Even though they don't have to submit an extensive analysis of their methods, they should keep documentation of their energy saving actions in case of random controls by the Danish Energy Agency (Bundgaard et al., 2013).

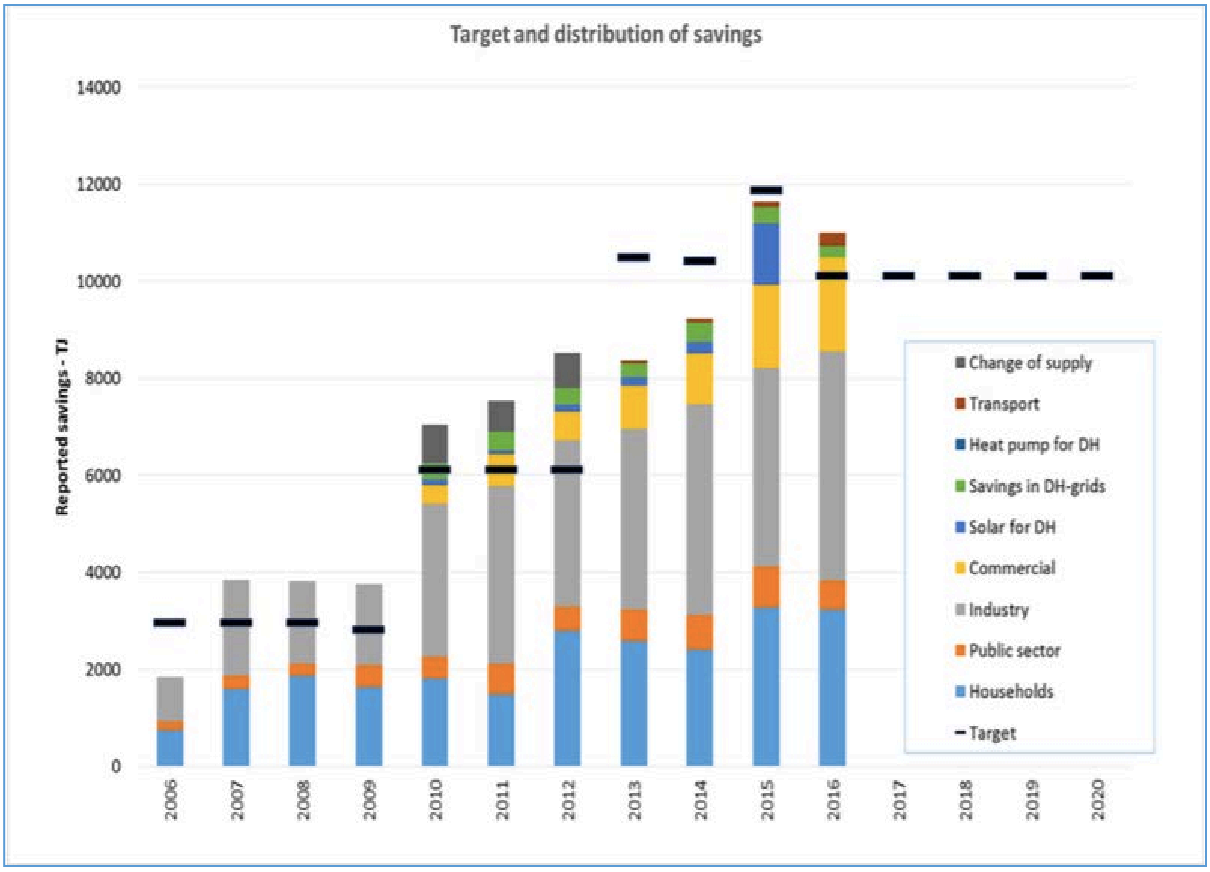


Figure 48. EEOs Target and Distribution of Savings (Bundgaard et al., 2013).

In total, 480 companies are involved in the EEO (NEAAP 2017);

- Around 70 electricity grid companies.
- Three natural gas distributors.
- Around 400 heating grid companies.
- The oil sector, which takes care of the activities on behalf of six oil companies.

In April of 2018, a new version of the scheme was presented and proposed to be implemented between the period 2021-2030 (Morten & Petersen, 2018). However, a few months later the Danish government announced that the scheme would not be updated after 2020.

8.5.2 The combination of different space heating methods in Denmark.

As mentioned previously, Denmark is a unique study case, due to the combination of technologies that are used for the production of heat which results in relatively low CO_2 emissions. Overall, more than 64% of all Danish private households are connected to the district heating system, while about 36% percent use individual space heating methods (Odyssee-Mure, 2018). It is assumed that most of the private houses which are not connected with the DH are located in rural areas[22].

Approximately two-thirds of district heat is supplied by co-generated heat and power (CHP) plants, whilst the other one-third is supplied by heat only boilers (HOB). The proportion of HOB technologies tend to have reduced in the last years, since CHP is considered as a significantly more efficient solution. Usually, HOB plants are used as additional supply sources to the CHP in small DH areas, they are also referred to as "peak and reserve boilers". Although they can produce heat using a variety of renewable and non-renewable fuels, they are mainly based on gas and oil (DEA, 2017).

District Heating.

Since this research is focused on the energy efficiency strategies for the household sector and particularly policies for space heating, the fact that Denmark has gained considerable expertise in space heating methods should be highlighted. Denmark has been characterised as a forward-thinking country due to the installation of advanced space heating technologies (Danish Energy Agency, 2005). Hence, a short explanation of the district heating system will be provided in the next paragraph. At this point it should be mentioned, that it is not the intention of this paper to analyse further technical characteristics of the district heating systems, but rather to provide an understanding of the system and its effects on the energy-saving policies.

Denmark's first district heating network was installed in the 1930s in Copenhagen, where the heated water from the power plant was distributed amongst households over a small area. Some decades later, the Danish policy-makers decided to expand the network, because on one hand they recognised the economic and energy potential, and on the other hand they had already gained experience with the DH technologies. By 1990, the share of private household connected with the DH networked was double in comparison to 20 years before (UNEP, 2017).

Simultaneously with the expansion of the DH network in Denmark, the share of renewable sources used for the production of district heat increased as well. More specifically, *Figure 49* indicates that the percentage of fossil-fuels has declined considerably in the last decades. Oil, natural gas and coal account for approximately 40% of the total fuels used for district heat. Furthermore, the percentage of non-renewable waste used as fuel has grown recently too. On the other hand, the composition of renewables that are used for producing district heat has increased by 34% since 1994. One of the main reasons is because some CHP plants in large district heating areas have switched from fossil fuels to renewable sources, mainly biomass (in forms of straw, wood chips, etc).

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[22] District heating technologies are only efficient in high heat demand density areas such as urban and suburban districts (Averfalk, H. 2017),

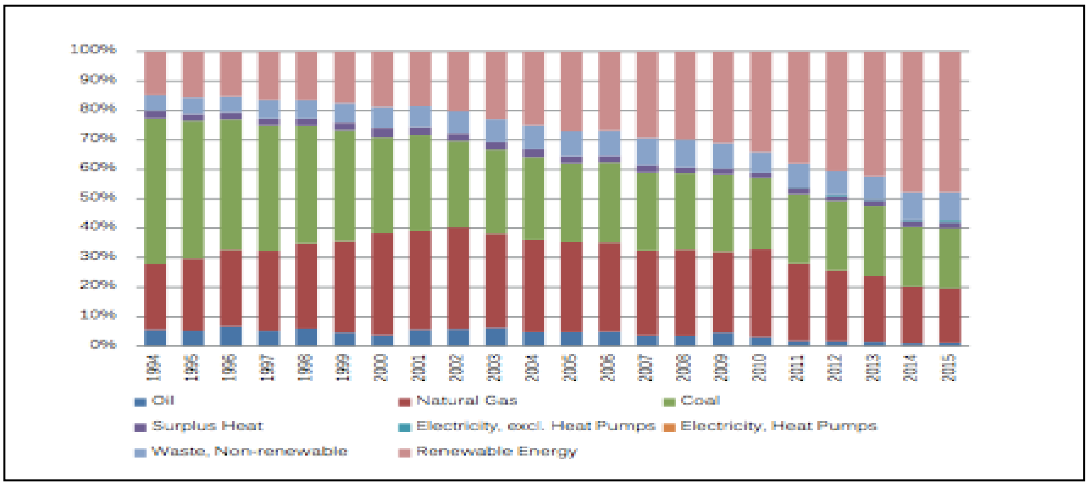

Figure 49 Fuel Composition for District Heating. source DEA, 2017

To conclude, the biggest advantage of the DH systems and the CHP plants is that they provide technological solutions for the integration of RES into the energy grid by the next two functions;

- Firstly, they can be used as Demand Side Management tools, as the pipe-network can offer short-term heat storage (energy) solutions and help Denmark to match the demand and the supply of energy during the day.
- Secondly, the CHP give the possibility to use a combination of different heat production sources in one plant. Thus, the CHP can guarantee reliable energy and heat supply regardless of the renewable energy generation. Thus, the share of renewables within the DH can be increased without increasing the risk of energy supply cuts.

8.6 Financial incentives.

The Danish government realise energy savings without providing any particular funding for the implementation of the abovementioned initiatives. In general, all the efforts which contribute to improving national energy efficiency are to be financed by the end-consumers via tariffs on energy distribution (Centre for Energy Efficiency, 2017). For instance, initiatives for expanding renewable energy that is supplied both to the electricity and gas grid is supposed to be financed via a PSO (Public Service Obligation)[23] (Danish Energy Agreement, 2017).

For the national high-impact measure; Strategy for Energy Renovation measure.

Regarding the national measure Strategy for Energy Renovation, there is no specific financial support or subsidy scheme mentioned. In general, there is a framework that offers some options for financing energy renovation, such as mortgage lenders or

[23] Public Service Obligation Service (PSO) is an energy tariff paid by the consumers via its electricity bill.

bank loans. However, it is more often the case that building-owners will self-finance a renovation since in long-term they benefit from reductions in the energy bills or add value to their own property making it more financially attractive on resale (Danish Government, 2014).

8.7 Evaluation of policy in Denmark

The first part of this report is based on data and graphs retrieved from the Odyssee-Mure database. For the case of Denmark, the input data for the Odyssee-Mure database has been provided by the Danish Energy Agency (DEA). Furthermore, the DEA is responsible for the evaluation of all the energy policies for all sectors. Often energy efficiency evaluations are carried out in collaboration with independent parties such as the EA Energy Analyses, NIRAS, and Viegand & Maagøe and others.

Overall, the DEA is considered to produce accurate evaluation results which have helped to improve the existing policy-measures. However, after a literature research, it is clear that there is a particular disagreement between the EEO evaluations conducted by independent parties and the DEA's evaluations. Therefore, this chapter provide a detailed analysis on the evaluation method of the Danish EEO scheme.

Evaluation of the EEOs.

More specifically, on the one hand independent evaluations have indicated that the EEO scheme has a positive economic impact on the commercial, industrial and public sector, and a negative economic impact on the household sector. On the other hand, in the last socioeconomic evaluation conducted by the Danish Energy Agency, a positive impact of the EEO across all the economic sectors was identified (Morten & Petersen, 2018).

The energy savings in the household sector resulted from the Danish EEO scheme have been claimed to be inaccurate by some scholars or third-party consultants (Bundgaard et al., 2013 & Moser, 2017). These claims are based on uncertainties that occur due to the methodology of the evaluations and on the reliability of the documented savings.

More specifically, Danish energy companies are required to document only the fact that savings have been properly calculated and fulfil the requirements. Thus, the results are not required to be provided, unless a random sample control will occur. Furthermore, the biggest proportion of evaluations conducted in the household sector are based on deemed savings and not in surveyed or scaled savings (*Figure 50*). This can cause uncertainties such as;

- Errors in the calculation and reporting methods (tackled by random checks).
- Uncertainties related to engineering calculation or deemed savings differences between the estimated and observed energy consumption (usually due to rebound and pre-bound effects) (Energispareindsats, 2017).

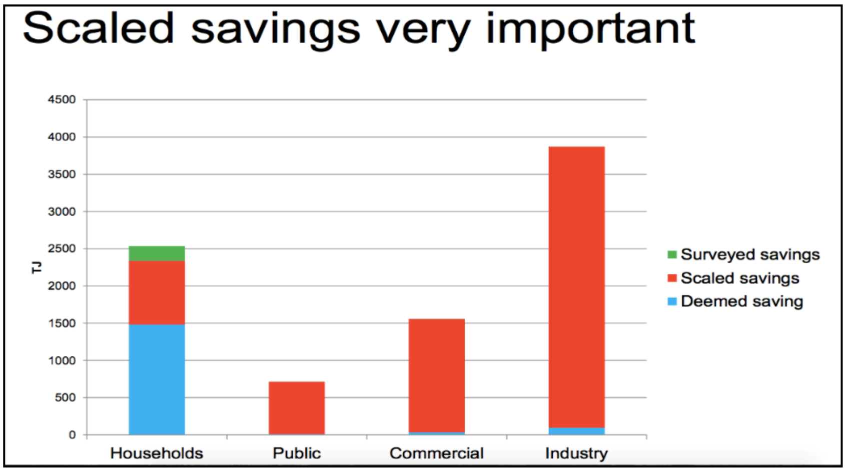

Figure 50 Energy Savings Evaluation. source: **Morten & Petersen, 2018**.

To conclude, the fact that evaluation of the EEO in the household sector is based on deemed rather than measured results, in combination with the fact that data is provided by energy companies themselves, can have a significant influence on the reliability of the evaluation results (Moser, 2017).

8.8 Conclusions

In comparison with the other three countries, Denmark has a relatively small number of energy-saving measures targeting the household sector (only 10 according to the Odyssee-Mure database). This definitely does not reflect upon the strong experience and knowledge that the country has gained in implementing energy efficiency policies. During the past decades, Denmark has significantly reduced the CO_2 emissions in this sector, by using advanced district heating technologies and decreasing the energy demand in the household sector.

Type of policy.

In Denmark, all three high-impact energy efficiency policy measures are classified as legislative/normative, and only one of them is designed at a national level. More specifically, similar to all European countries, Denmark has implemented the *Building Regulations* and *Energy Labelling of Buildings* EPBD measures, which have proved to have a high-impact in the national energy strategy. Furthermore, the national legislative measure *Strategy for Energy Renovation* has a high-impact on the energy renovation of the existing building stock. Besides these, there are several low-impact ongoing measures which aim to provide information (information/education) both to the consumers and to the energy distributors.

Apart from the measures targeting exclusively the household sector, the Danish energy agenda contains several cross-cutting/general measures which highly effect the energy-efficiency and related CO_2 emissions of dwellings as well. For instance, the Energy Efficiency Obligation scheme, is an EU-related measure which is used to realise the targets of article 7 of the EED. The EEO has shifted the responsibility for realising energy savings towards the energy companies. These companies have been given the freedom the choose themselves the sectors and technical measures that are, according to them, most cost-effective. Note that in the UK, the EEO focuses on the residential sector only, and so-far mainly was aiming at poor households, often living in poor-quality dwellings.

The *Danish Energy Agreement*, is a relatively recent cross-cutting measure which contains a broad range of initiatives aiming at the expansion of renewable heat in the household sector.

Evaluation & Financial support of the measures.

The Danish Energy Agency is the main responsible authority for the evaluation of the energy saving measures in Denmark. Additionally, independent parties participate in the evaluation as well. Overall the evaluations conducted by DEA have not been characterised as inaccurate, except in the case of the EEO. The energy savings in the household sector resulting from the Danish EEO scheme have been claimed to be inaccurate due to uncertainties in the methodology used by the energy companies that evaluate their own projects. Savings are over-estimated since they have been calculated, based on 'deemed data' (assumptions in an ideal situation), instead of using real measurements.

Some initiatives for realising energy-efficiency have been introduced through the cross-cutting/general type of measures. Hence, responsibilities for realising energy efficiency are shared amongst energy companies.

Even though the Danish energy agenda does not contain fiscal or financial type measures, the Danish government has increased the financial incentives included in the general measures by increasing the energy cost. Thus, Denmark has the highest electricity prices among the 28 European countries, and the highest share of taxes and charges paid by households. Although the gas price is not the highest, is still belongs to the top-6 in Europe, with again the highest share of taxes and charges paid by households (figures for 2016).

Highlighted energy efficiency findings

A combination of different policies, methods and technologies are used by the country in order to achieve a relatively low CO_2 emission, although the energy efficiency in the household sector is relatively low. The extensively rolled out (decentralised) heat district, the use of combined heat and power (CHP) integrated within this, and the high share of (centralised and decentralised/local use of) renewables are reasons for the decline in CO_2 emissions in general, and in the household sector, over the last decade.

In the past, Danish policymakers have recognised the weaknesses of their previous policies and strengthened them through revisions or the introduction of new measures, as in the case of the Strategy for Energy Renovation policy.

Main Findings

- Similar to most of the other countries, the most impactful measures belong to the "Legislative" category.
- Denmark has managed through the EEO scheme to give freedom to energy distributors to choose in which energy form and in which sector they will realise energy efficiency.
- Two of the most important (high impact) policies in Denmark have given much responsibility to the energy distributor-companies. (Danish Energy Agreement & the EEO).

- The efforts of these energy companies to implement energy savings measures are financed by tariffs and taxes. As a result, Denmark has the highest prices of electricity in Europe.
- Denmark has managed to connect policies from both the energy generation and the energy demand level, thereby they achieved great results in meeting the country's energy targets (CHP and District Heating) and reducing the CO_2 emissions for space heating purposes.

9 General themes in the Dutch discussion about making dwellings more sustainable (by R.F. Holdsworth-Morris, S. Paliouras)

9.1 Introduction

In the Netherlands, a few general themes can be identified in the search for a strategy to reduce the energy consumption within the residential sector. Themes such as these are inevitably a part of the negotiations for the national climate agreement in the Netherlands. In these negotiations, most attention goes to existing buildings. New buildings must comply strong building codes and will not be connected to the natural gas grid. The challenge is how we can reduce the CO_2 emissions of existing buildings. In the Extensive Summary at the beginning of this report, a free translation of the Dutch ‘Design of the Climate agreement’ is given, taken from the introduction to the chapter that relates to the built environment.

With the country information we have gathered so far, in this chapter we have tried to reflect on some themes that are part of the Dutch debate and the Design of the Climate agreement:

- Policies to stimulate insulation
- Building-related finance and other financing structures abroad
- Experiences with switching to district heating
- Connecting existing dwelling to district heating
- Increasing the share of renewables locally and in district heating
- Lowering the retrofit costs.

Since we have added this chapter at the last stage of this study, some questions will need further research in order to deliver a satisfying answer.

9.2 Policies to stimulate insulation

Background and question

In the Design of the Climate agreement, the importance of reducing the heat demand of dwellings has been mentioned. What kind of policies have other countries used to stimulate insulation of existing dwellings by private home owners (like a subsidy or an obligation, energy tax or other fiscal measures? Is insulation of existing houses a measure stimulated by energy saving obligations for energy suppliers?

Referring to the relevant sections

The short answer to this question from the perspective of the examined countries in this study can be found in section 4.6 and 4.7. Within the country chapters more details can be found in the third section, titled ‘Impact per policy instrument, space heating only’.

Denmark contradicts the statement

The Danish EEO, among others, contain subsidy schemes for energy renovation in the existing building stock. However, since energy companies have the freedom to choose the sector and the policy related practical actions for reaching energy targets, they usually prefer more cost-efficient initiatives. In other words, in the household sector, most of the EEO actions are based on information provision and upgrades to the overall infrastructure which is considered more cost-efficient than insulation improvements in each household. As we have seen in section 2.14, therefore the Danish residential sector did not lower their energy intensity as much as the other countries did over the last 16 years, although the CO_2 emission reduction was the largest. Currently, the Strategy for Energy Renovation is the main policy for stimulating energy-saving in buildings, see section 8.3.

9.3 Building-related finance

Background and question

To switch an existing dwelling to all-electric heating a large investment is needed, e.g. for an electric heat pump, insulation and transformation of the heating system such as the radiators. In the Netherlands we think about building-related financing. The loan is linked to the dwelling and will be transferred to the next owner when the dwelling is sold. What are the experiences with building-related finance in other countries?

Lessons from building-related finance experiences in the UK: The Green Deal

The Green Deal was the first of its kind for the residential sector in Europe and at the centre of the UK's NEEAP 2014 plan to meet EU Energy Efficiency Directive targets. The main premise of the scheme, which was based on the 'Pay-As-You-Save' and on the 'On-Bill Financing' mechanisms was viewed positively for its ability to overcome split-incentive barriers. It aimed to reduce reliance on government subsidies and increase private investment to develop a market for energy efficiency. However, after two years the scheme was cancelled, its failings related to the complex design of the scheme, high loan interest rates, low consumer engagement, and the restrictive 'Golden Rule' (see Table 17 for a summary). Experience in the UK shows that it is important to ensure such a scheme is well-designed to secure sufficient demand and engagement; to be able to attract investment and develop a market for energy efficiency (Bergman & Foxon, 2018).

Table 17 Summary of the successes and failings of the Green Deal scheme

Positives	Negatives
Overcomes split-incentive of owner-benefits	High interest rates and upfront administration fees
Reduces reliance on subsidies, increasing private investment	Low consumer engagement
Support for PAYS mechanism	Unfamiliar delivery networks
Lowers risk of debt, energy supplier responsible for repayment so increases investor confidence	Limited number of efficiency measures eligible due to restrictive Golden Rule
	High number of free-riders
	Lack of government involvement
	Narrow focus on financial benefits, failing to consider multiple benefits
	Scheme was overly complex with too many actors
	Credit checks were carried out on owners
	Potential devaluation of property

The loan can be valid for up to 25 years and is attached to the electricity or gas meter and repaid through instalments placed on consumer energy bills, thus termed as ‘On-Bill financing’. It is attached to the property rather than the owner with the idea that whomever is living in the property at the time will be benefitting from the energy savings at the same time as repaying back the loan at an attractive rate. To be eligible for a loan the ‘Golden Rule’ must be met. This states that the modelled energy savings on energy bills must always be higher than the annual cost of the instalments paid back over the measure’s lifetime. Modelled savings are calculated with the Reduced Standard Assessment Procedure, which is based on database values and estimates such as building age and climate. Therefore, it is important that a scheme has a strong assessment procedure in place to be able to accurately calculate energy savings. An inaccurate calculation can lead to rejection of the Golden Rule and therefore limited success of the scheme (Ingram & Jenkins, 2013). Note that this, as an ex-ante calculation, has similarities with evaluation methods used to determine the ex-post impact of policy measures (see section 4.9).

The upfront cost of many measures meant they were too expensive to be eligible for funding hindering the effectiveness of the scheme. Many householders were also unwilling to pay the high interest rates and evidence suggests that incentives in the form of a grant or subsidy provided in co-ordinance with the loan could help overcome this barrier. In **Germany**, the central bank KfW provides finance to reduce interest loan rates, thus making them more attractive to consumers.

The Green Deal Finance Company could potentially secure funding from the Green Investment Bank (GIB). However, the GIB has shown to favour larger scale projects as opposed to individual household scale retrofits which are not financially attractive. This is one example of the barrier to financing energy efficiency using the private sector. The heterogeneity of the housing stock in the UK makes it difficult for larger scale area-based schemes to be carried out that attract higher investor returns. Success has been shown in the UK with the Kirklees Warm Zone scheme, with local authorities coordinating retrofit schemes. A study into the possibilities of upscaling to attract private sector finance or alternative methods is not included within the scope of this study, but could provide useful insights.

“Energiesprong” is a Dutch scheme that is now being implemented in the UK and France. It is similar to an on-bill financing mechanism as it is paid for by savings to energy bills with no additional net costs to tenants. The aim is to retrofit homes on a large scale in co-operation with housing associations to net-zero energy and increase the market for delivering energy efficiency measures. The work is carried out in one week to minimise disruption (EC, 2018). This works well in areas where the social housing stock is more homogenous and similar measures can be mass applied. The Energiesprong scheme recognises multiple benefits and barriers to improving energy efficiency through retrofits and includes them within the design of the scheme (EC, 2018).

The experience of the Green Deal highlights the complexity of the market for energy efficiency and the importance of incorporating appropriate tools to overcome multiple barriers. After the withdrawal of government support for the scheme, the Green Deal

Finance Company was privatised. The future of the Green Deal and whether it will eventually prove to be successful in the UK remains uncertain. The scheme had some promising aspects and support was shown for the PAYS mechanism as a policy tool. However, a solid policy tool can easily fail if the implementation is insufficient (Galvin & Sunikka-Blank, 2017).

9.4 Other financing structures abroad

Background and question

What other kind of financing structures are available in other countries to finance the energy transition in existing dwellings of private home owners?

UK funding provided by the Energy Company Obligation (ECO)

UK funding for improving the energy efficiency of privately-owned households is mainly provided by the Energy Company Obligation (ECO) and targets low-income households/vulnerable groups. The ECO fund can also be fed into other schemes such as the HEEPS (see below for further detail). The responsibility for improving household efficiency therefore rests largely on suppliers, who then identify households in which the ECO target can be met most cost-effectively. Householders may apply directly to a supplier for ECO funding if they meet eligibility criteria, although ultimately it is the supplier's decision whether to provide funding.

Financial incentives combined with informative measures: targeted delivery in Scotland's HEEPS overcoming multiple barriers

The Energy Savings Trust (EST) engages with private home owners through offering advice services and administering financial support schemes throughout the UK. The Home Energy Efficiency Programmes Scheme (HEEPS) delivered by the EST exists in Scotland. There are a greater number of financial incentives available to stimulate insulation in private households due to this scheme. Information is provided online and over the phone by the EST, then an energy audit is carried out to identify the most cost effective measures. The government then provides financial support along with the offer of a loan for more expensive measures (Ordonez et al., 2017). Finance from the ECO scheme is mixed with HEEPS to create larger funds and increase delivery. HEEPS includes different schemes:

- Government funded interest-free loans (of up to GBP 15000, up to 12 years) are provided to homeowners for efficiency improvements, renewables and district heating connections.
- Area-Based Schemes involve local authorities and communities delivering retrofits to areas of low-income and fuel poverty.
- Scotland's Energy Efficiency Programme (SEEPS)- Plans to run over 20 year period and includes schemes for innovative approaches involving local community groups and businesses to help reduce costs and improve energy efficiency in households. Local authorities are provided with funding to carry out innovative schemes, these relate to decarbonisation of the gas grid and new ways to deliver measures to hard-to-treat households at lower costs.

Recommendation: whether other financing methods (such as revolving funds) could be more effective requires further research.

9.5 Experiences with switching to district heating

Background and question

Districts with dwellings could be shut off from the gas grid in order to change the classical Dutch way of using (natural) gas for heating purposes. The municipality must give direction to this process. The whole district could switch to district heating or electric heat pumps. There is a discussion to give the municipality the right to shut off people from the gas grid. Is there experience in other countries with a district approach or with a switch over to other energy infrastructure for heating in existing buildings?

International initiatives and guidance on district heating

Besides Denmark, district heating (DH) systems have been widespread in numerous European countries such as Finland, Germany, Sweden, the Baltic countries and Eastern Europe. For some countries such as Denmark and Sweden, DH systems have been a long-time tradition, while in some other countries, such as the UK, relatively new energy transition strategies have been designed and begin to be implemented in order to move from conventional heating systems towards innovative DH networks.

Generally speaking, a change towards a new DH network-method can be considered a system transition. Thereby, as in any other system transition, different actors and organisations are required to collaborate in order to set up stakeholder groups who eventually facilitate a change.

Although decisions and measures associated with District Heating systems are usually developed on a local level, the last years a transition to DH methods has attracted national and EU attention. It is noteworthy, that in 2016, the first EU District Heat & Cooling (DHC) strategy was proposed by the European Commission, recognising the importance of DHC systems. Additionally, one year before the UN-Habitant published the District Energy in Cities report, where they analysed the development and the potential of district energy systems. Moreover, this report refers to a policy and investment roadmap which comprises 10 steps to facilitate the development and modern scale-up of DHC in cities. Namely, the 10 steps are (simpla-project.eu);

1. Assess existing energy and climate policy objectives, strategies and targets, and identify catalysts.
2. Strengthen or develop the institutional multi-stakeholder coordination framework.
3. Integrate district energy into national and/or local energy strategy and planning.
4. Map local energy demand and evaluate local energy resources.
5. Determine relevant policy design considerations.
6. Carry out project pre-feasibility and viability.
7. Develop a business plan.
8. Analyse procurement options.
9. Facilitate finance.
10. Set measurable, reportable and verifiable project indicators.

In the same report, a DHC policy framework is designed with a distinction for locally and nationally organised heat districts, shown in Figure 51 and Figure 52.

Country examples: UK, local level

The United Kingdom is an example of a country using a differently designed heat system than the DH systems. Traditionally, the country was based on centralised energy systems, liberalised energy markets and a dependency on gas fuels for space heating in buildings. However, even this small transition is a result of recognition of the potential of the DH system. The primary responsibility of facilitating the transition towards DH in the case of UK was put on a local level, as the municipalities retain the ownership of networks and offering strategic coordination for development (they owned energy service companies). On a national level, the Heat Network Delivery Unit (HNDU) was formed to overcome the barriers faced by local authorities by offering guidance, support, and funding to commission studies. There was no regulation which obliged house owners to participate in this transition. The connection, and acceptance of the DH systems is based on a voluntary scheme and on the fact that DH can potentially offer financial benefits both for the consumers and for the local authorities (Bush, 2017).

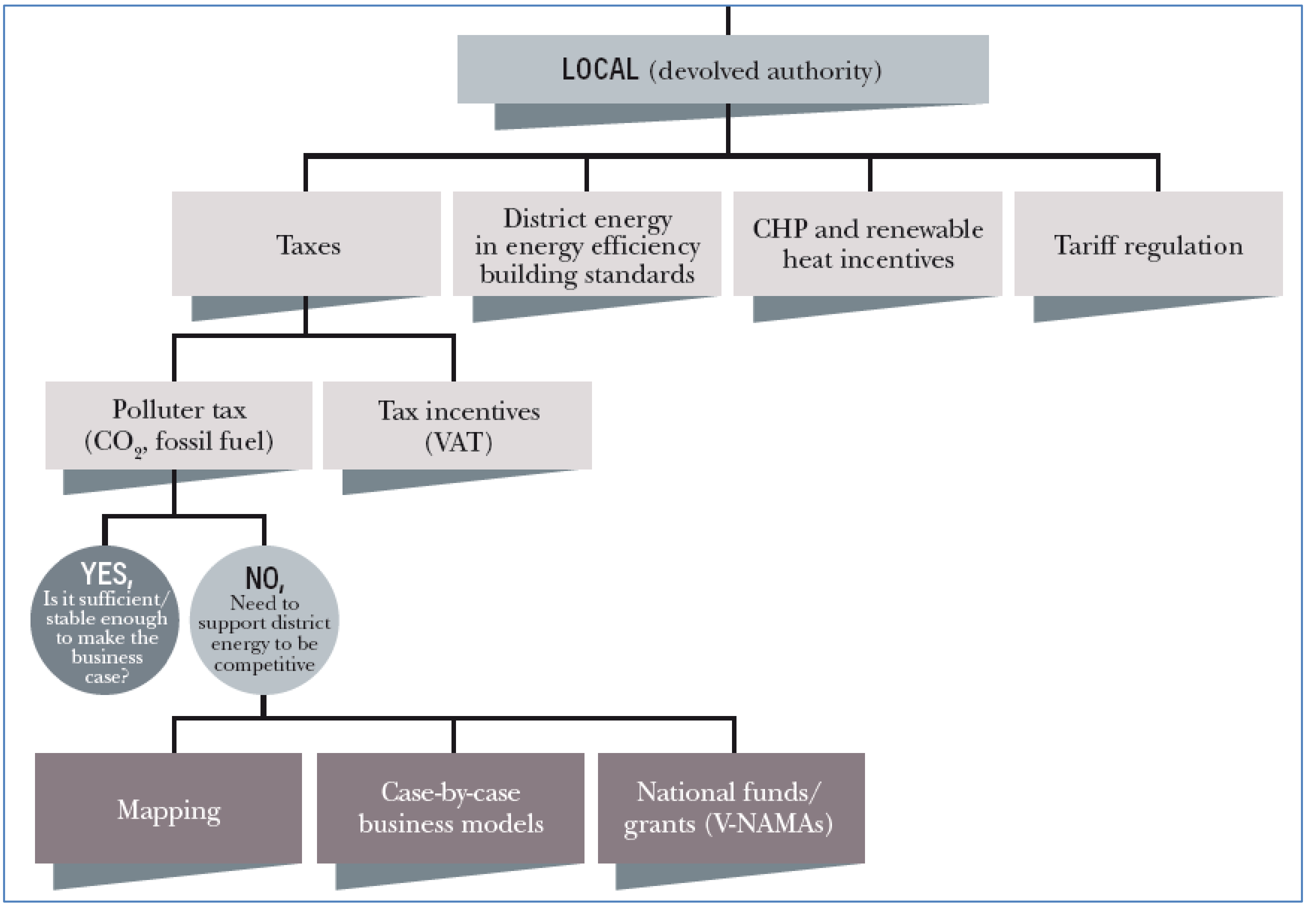

Figure 51 Assessing options in expansion cities to develop district energy based on the local regulatory framework (*simpla-project.eu*)

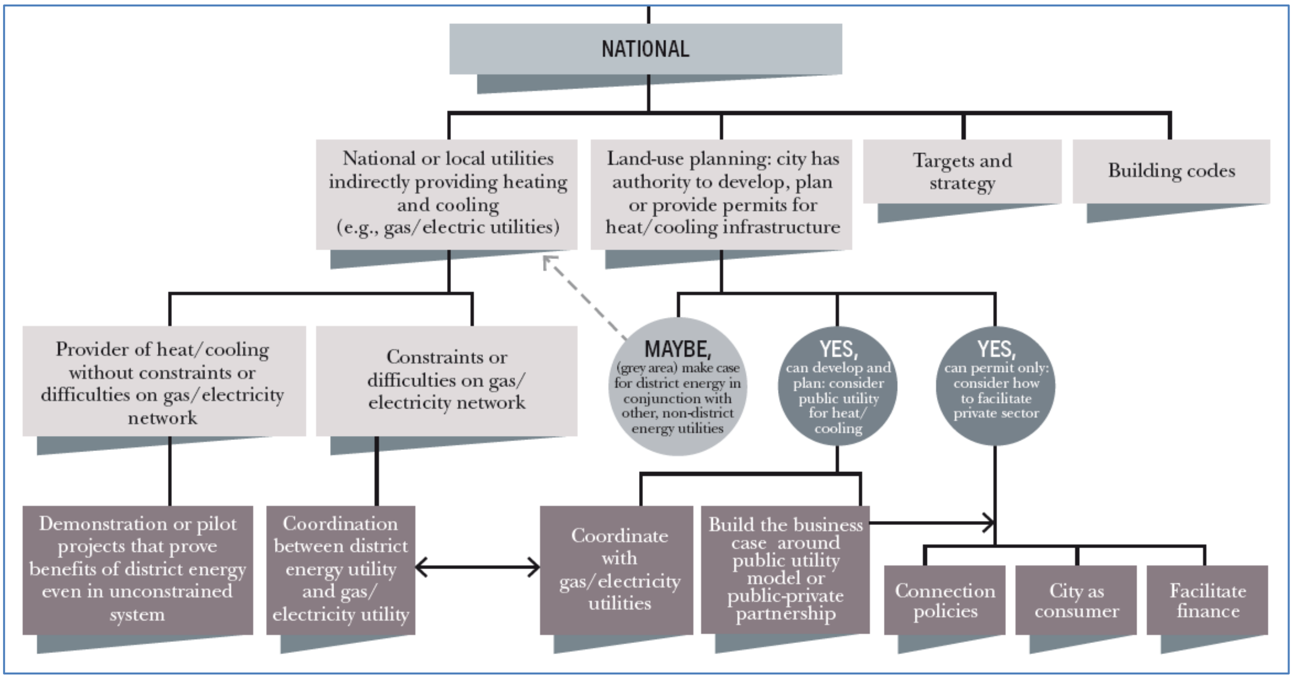

Figure 52 Assessing expansion options in cities to develop district energy based on the national regulatory framework (*simpla-project.eu*)

Country examples: Sweden, local and national level

The case of Sweden differs from the one of UK, as Sweden has a long tradition and a significant percentage of households that get heat supplied through a DH network (approximately 60 percent). The development of the Swedish DH systems has been based strongly on institutional factors including municipalities and national policies and regulations. More specifically, the initiative to build DH networks was initially taken by the municipalities back in the late '50s, with the aim to enable efficient electricity production in CHP plants. Later on, this initiative was supported by the Swedish Heat Utility Association (currently named District Heating Association) to promote the development of DH systems nationally. Another factor which stimulated the transition towards district energy systems in Sweden was the lack of alternative forms of energy (such as natural gas). It must be noted, that nowadays a big share of the district heat production is based on biomass. This is a result of constant reductions in the price of biomass which is a consequence of technological innovation and favorable national public policies and regulations, for instance, carbon taxes. Thus it is clear that Sweden has followed a comprehensive heat strategy, supported by both municipal and national authorities (Di Lucia, L., & Ericsson, K. 2014).

Country examples: Finland, local and national level

Finland has installed district heating networks since the second half of the 19th century, and today district heating accounts for approximately 50% of the total heating market. Recently, national requirements and building guidelines, have stimulated the expansion of DH systems. For example, in Finland, building codes set primary energy efficiency standards for new buildings, where district heating scores relatively high in the calculation (Riahi, L. 2015). Furthermore, local level municipalities have played a vital role in the establishment of public enterprises that have been responsible for heating public and private buildings since the 1990s (market instrument) (Okkonen, L. 2010).

Country examples: Denmark, local level, supported nationally

To date, more than 64% of the private Danish households use not only heat but also hot water produced from the district heating network. Thereby, the last four decades, Denmark has gained valuable experience and knowledge in designing and expanding the national district heating energy systems. The first heat supply law passed in 1979, and since then, the Heat Supply Act provides the municipalities with the power to engage in planning and decision-making regarding the development of district energy. At a national level, legislation and guidelines were developed by the Danish Energy Agency (established 1976-1979), with respect to the local authorities who have the main responsibility for designing local heating systems. Later on, the Danish government established a number of planning directives concerning the system's fuel choice and the development of CHP plants. In line with these directives, many subsidy schemes were introduced to develop a district heating market with particular focus on CHP systems and renewables. See the Denmark country chapter for more detail.

Country examples: concluding

Concluding, it should be mentioned that the dynamics which affect a transition towards District Heating differ in each case. Each country implements a different package of policy measures according to the national population, topographical, market and behaviour characteristics. However, from the above country examples, there are some common steps that have been followed:

- the empowerment of local authorities,
- the establishment of an association/authority responsible for the expansion of the DH network,
- the privatisation of the heat market,
- the design of building codes and regulation that include DH,
- and lastly and maybe most importantly the taxation of heat supply.

The use of polluter taxes is a key policy in Nordic countries, where extensive infrastructures of district energy have already been achieved.

9.6 Connecting existing dwelling to district heating

Background and question

The switch to district heating in existing dwellings is in most cases unprofitable for commercial heat suppliers. Is there experience in other countries with connecting existing dwelling to district heating. Are there subsidy schemes for district heating from the government? Or is district heating done by non-commercial suppliers?

Recommendation: search for countries experienced with connecting existing dwellings to district heating.

Nordic countries

Since the expansion of district heating systems in Norway, Sweden and Denmark started more than three decades ago, dwellings that have been constructed after this period have always been connected to the grid. For other countries we have not searched for additional information on connecting existing dwellings to a heat district system. Possibly the mentioned literature resources of the previous section can give some answers.

Currently, the Danish Energy Agency does not aim to further expand the district heating network. This because already a large percentage of private households in urban and suburban areas are supplied by district heat. For instance, in the capital city of Copenhagen 98% of private households are connected to the DH network (C40, 2011). Thereby, most of the current subsidy schemes are stimulating the development of Cogenerated Heat and Power plants which will make the generation of district heat more energy efficient. Research with a main focus on the financial schemes which have stimulated the development of the district heating network in the past is recommended as further research.

In the past, and especially during the oil crisis, the Danish policymakers identified the socioeconomic potential of DH systems. Thereafter, many non-commercial authorities collaborated to set up a common district heating system in Denmark (Danish Government, 2014). In addition, many subsidy (mainly for the construction of CHP plants) and taxation schemes were introduced by the Danish government to financially support and stimulate the increase of district heating share in the heat market (Danish Government, 2014).

9.7 Increasing the share of renewables locally and in district heating

Background and question

District heating can only reduce CO_2 emissions, when the heat is produced from renewable heat sources like biomass, geothermal heat, solar heat or waste heat. Is a switch to renewable heat also ongoing in other countries? What policies stimulate this?

In general, according to literature

District heating systems are one of the most effective ways of integrating renewable energy sources into urban space-heating methods for two main reasons (C40, 2016 & UNEP, 2016):

- The first reason is that district heating is based on the flexibility of the DH system, which in practice can use a variety of sources (renewable, non-renewable, or a mixture of them) at the same period.
- The second reason is that district heating networks can provide the opportunity for short-term heat storage. Heat storage remains one of the biggest challenges and barriers associated with the integration of renewable heat.

These Demand Side Management strategies have been discussed in relation to Denmark in section 2.13.

In line with the 2030 Climate and Energy Framework targets, all member states of EU are expecting to contribute to the reduction of greenhouse gases and increase the share of renewables. The development of state-of-the-art and affordable district heating systems is one of the most energy-efficient and least-cost solutions for reducing primary energy demand and greenhouse gas emissions in urban areas (UNEP, 2016). Therefore, DH systems have already enabled cities such as Copenhagen, Goteborg, and Vilnius to integrate renewable energy sources into heat production. In some of these cities, geothermal resources are used within district heating networks, while in others with poor geothermal resources, bioenergy is used for the production of district heat.

Heat Network Strategy / District Heating in the UK

The UK government is working to develop a district heating network to facilitate the low carbon transition. Biomethane, hydrogen gas and heat pumps are the main cost-effective options for decarbonising the UK's domestic heating network (CCC, 2018). In the UK, there is presently hardly any district heating available (see Figure 20). Current targets are to increase the share of district heating to 17% of residential energy use for heating by 2050. The focus is to create a market which can operate without government subsidy. A Heat Networks Investment Project (HNIP), will invest £320m of capital funding in heat network projects, which is anticipated to leverage further funding from the private sector. The HNIP's pilot phase awarded 9 local authorities with £24m for projects to provide an example and stimulate investment in the heat network market. Triple Point Heat Networks Investment Management is the delivery partner of investment project, which manages a range of government and private sector funds. From April 2009, grants and loans will be available for heat network projects. Local authorities operate at a scale which is appropriate to coordinate these schemes and success has been shown in these projects in social housing with the help of low-cost loans (Liddell, Morris & Lagdon, 2011).

The Renewable Heat Incentive (RHI) of the UK

Locally-used renewables are however financially stimulated. The RHI is the key policy to achieve the government's target of 12% renewable heat by 2020. It provides payments to domestic producers for a range of technologies for up to 7 years. The RHI works alongside the EPC, because to qualify for the incentive payments an EPC must have been carried out and loft and cavity wall insulation must be installed if needed (MURE, 2016). Creating synergy between the RHI and EPC strengthens the overall impact of policies, as heat pumps are shown to perform better in well-insulated households (British Gas, 2016, data.parliament.uk).

9.8 Lowering the retrofit costs

Background and question

The energy transition can be more profitable when we can lower the costs of electric heat pumps and insulation. There is a need to scale up the numbers of dwellings that will be insulates so an industrialisation process can take place with lower costs. What do other countries do to lower the costs to insulate existing dwellings?

Recommendation: investigate what other countries do to lower the cost of their (scaled-up) insulation programme for the existing dwelling stock.

Recommendation for further research

It is true that the retrofit rate is relatively slow. Figure 15 in section 2.9 shows the 'major renovation rate' per country. It can be seen that Norway and France have the highest rates (2,4% and 2,0%), followed by Slovakia and Austria. Germany (1.5%) is in fifth position, the Netherlands is lagging behind (1.0%). For the UK, Sandberg et al. (2016) states the renovation rate at 1,6%. The retrofitting rate generally is low, but still 10 times higher than the demolition rate. During this study, we have not looked into this specific question and therefore recommend to do so during additional research. A good start might be the 'Existing Building Energy Efficiency Renovations; an international review of regulatory Policies (EIPEEC, 2017):

Table 18 Major Policy instruments for improving the energy performance of existing buildings (EIPEEC, 2017):

Type of Policy	Benefits	Challenges
Targets: Performance based renovation targets and requirements	Very broad driver that sets high ambitions and goals	Complex to administer generally and challenging to determine and impose penalties for non-compliance
Energy Codes: Building energy codes/standards applied to existing buildings	Relatively simple to develop and administer	Applies only at time of substantial renovation, so does not drive widespread market change rapidly
Disclosure/Improvement: Mandatory energy performance disclosure, sometimes linked to upgrade requirements	Simple rating and disclosure of performance is not controversial, and allows market forces to operate	Without mandatory upgrade requirements, may not result in significant performance improvement
Financing/Incentives: Voluntary standards that become mandatory with financing from certain sources	Can be most creative and ambitious, as these initiatives are voluntary and therefore require less political consensus	Cost for implementation—needs to come from some source, either government funds, or energy price surcharges

"Energy consumption from buildings that have been constructed prior to the implementation of recent improved energy performance regulations will continue to consume significant amounts of energy long into the future. Determining the most effective set of policies to significantly improve the existing building stock is a key challenge for energy policy makers around the world. A variety of regulatory policy instruments have been used worldwide to drive energy performance improvements in existing buildings. The major policy instruments can be broken into the four categories mentioned in Table 18.*'*

10 What about the services sector? (by J.M. Sipma)

10.1 Introduction

According to Eurostat, more than half of the population, living in these four countries, have a job, as shown in Table 19. According to OECD, three quarters of the work force, works in the 'services sector', also called the tertiary sector.

Table 19: The population, employees and share of employees each sector; by country. Source: *Eurostat*, and *OECD*

				% employment in sector		
2017	**Population**	**Employees**	**% employees of total population**	**Services sector**	**Industry**	**Agriculture, hunting and forestry**
Germany	82.775.000	44.559.000	54%	71%	27%	1,3%
UK	66.253.000	32.231.000	49%	81%	18%	1,2%
Netherlands	17.176.000	9.052.000	53%	83%	15%	2,0%
Denmark	5.781.000	2.907.000	50%	79%	19%	2,2%
Total	171.985.000	88.749.000	52%	76%	22%	1,3%

There are of dozens of buildings types that belong to the services sector, such as offices, warehouses, schools, swimming pools, sports accommodations, hotels, nursery homes, car garages, shops, supermarkets, museums, theatres, etc. This is a matter of definition and system boundaries as well, you could e.g. split-up shops further into types of shops. All these buildings consume energy as well. As a reference; in the Netherlands, the services sector uses one-and-a-half times more electricity compared to the residential sector, and almost half of the gas consumption (Schoots, 2017).

There are a few systems to divide the services sector into smaller sub-sectors, where the former buildings can be found. The dividing system can differ from country to country. In the OECD statistics, country statistics have been made comparable by placing the data within the system of the so called 'International Standard Industrial Classification of all economic activities' (ISIC) (UN, 2008). In Table 20 the share of employees over the 15 identified sub-sectors is shown for the total of the four countries in this study. More than half of the employees work in 'Wholesale and trade', 'Healthcare', 'Education' and 'Public administration'.

The last three subsectors, form part of the 'Public Sector' which is a sub-domain within the services sector and to which 'Arts, entertainment and recreation' partly could be added. The public sector is usually composed of organisations that are owned and operated by the government. This includes federal, provincial, state, or municipal governments. Opposite this sub-domain could be found the 'Private Sector' consisting out of the majority of the remaining subsectors. The private sector is usually composed of organisations that are privately owned and not part of the government. These usually includes corporations (both profit and non-profit) and partnerships (privacysense.net).

Table 20: Share of employees in each residential sub-sector; based on the total of the four countries examined in this study. Source: stats.oecd.org

Services sector sub-sectors	**% employment**
Wholesale and retail trade, repair of motor vehicles (G)	18,3%
Human health and social work activities (Q)	17,8%
Education (P)	10,7%
Public administration and defence, social security (O)	8,6%
Professional, scientific and technical activities (M)	8,6%
Administrative and support service activities (N)	6,6%
Transportation and storage (H)	6,5%
Accommodation and food service activities (I)	6,0%
Information and communication (J)	4,6%
Financial and insurance activities (K)	4,4%
Other service activities (S)	3,7%
Arts, entertainment and recreation (R)	2,6%
Real estate activities (L)	1,0%
Activities of households as employers (T)[24]	0,5%
Activities of extraterritorial organisations and bodies (U)	0,1%
Total	**100%**

The relative importance of the services sector (as an average for the four countries) grew from the year 2000 onwards. In 2000, 69% of the working force had a job within this sector, in 2017 this had grown to the earlier mentioned 76%. As can be seen from Figure 53, this share is the highest in the Netherlands, followed by the UK, Denmark and finally Germany. The share of employees within the industrial sector follows the reverse order.

One clearly sees the effect of the financial crises that started round 2007. As a consequence of the economic downturn, employees lost their jobs during these years. Often companies will downsize their office space a few years later. Both will affect the energy consumption of the services sector. During the better economic years, the opposite will happen. These cyclical fluctuations are sometimes described as the ‘Pork cycle’.

[24] Sub-sector T are actually often companies / offices that are part of the residential sector. Therefore, the number of employees working here are removed from the analysis in the reports to which this section refers to later. Germany has with 0,8% the largest share of employees within this sub-sector, the Netherlands the least (0,07%),

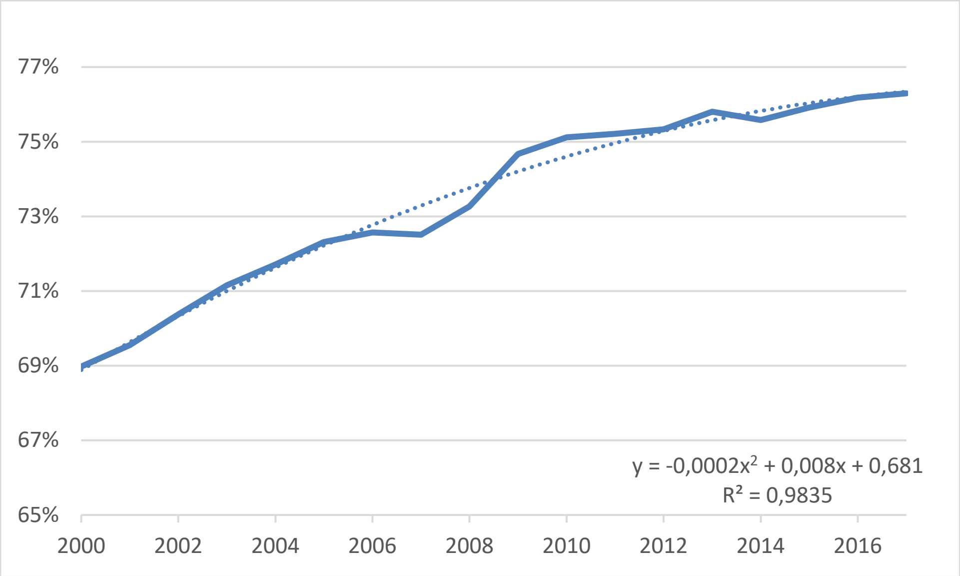

Figure 53 The share of employees in the total workforce working in the services sector between 2000 and 2017, average for the four examined countries.

10.2 Two additional internship reports

In an additional, though smaller study, we have compared the energy policy portfolio of the four countries to bring down the energy consumption of the services sector. For Denmark, this will fall under the same EEO umbrella as applies to the residential sector; for the other countries policies will be completely different. The results can be found in two internship reports. The first report (Holdsworth-Morris, 2019) deals with the services sector of the UK, with a short description of the services sector of the Netherlands added as an attachment. The second report deals with the services sector of Denmark and Germany (Paliouras, 2019).

Policy measures that that have been designed to reduce the energy consumption in a building and/or within an organisation or an enterprise, do not always make the same distinction in terms of sectors. Although we try to focus as much as possible on the services sector; it might even be easier to speak about measures that target non-residential buildings. This could even include the agricultural, forestry and fishing sectors.

Some measures are designed to target a commercial enterprise or a public organisation. That enterprise or organisation could have several individual buildings in use. Other measures could (at the same time) target individual buildings. Some measures are designed to target enterprises with a certain size. A size could relate to the number of employees working at the organisation, and/or to the yearly turnover it makes. Besides the large organisations, often small and medium size enterprises are involved (SME's):

Company category	Staff headcount	Turnover	Balance sheet total
Medium-sized	< 250	≤ €50 million	≤ €43 million
Small	< 50	≤ €10 million	≤ €10 million
Micro	< 10	≤ €2 million	≤ €2 million

Although the services sector occupies in the Netherlands 35% of the total building stock floor area, it is responsible for almost 40% of the total energy consumption, making this an important sector to consider. This is shown in Figure 54.

The figure shows that the UK is performing relatively best; because amongst the countries the surface area of the UK services sector occupies the largest share (38%) of the total built environment (residential + services), but the related energy consumption is relatively low (just over 30%).

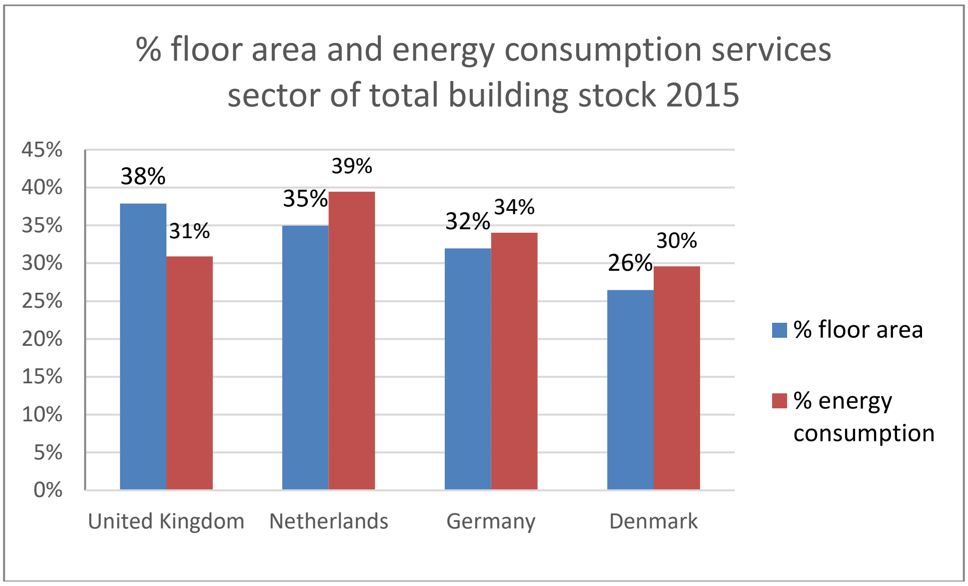

Figure 54 Floor area occupied by the services sector and related total energy consumption, as a percentage of total building stock (dwelling plus services). Source: several, calculated

Just as with the residential sector, we see that the CO_2 emission intensity for Denmark is the lowest, in recent years, although the energy intensity (expressed as each employee or m^2 of floor area) is somewhere in the middle of the other countries. The most important reason for both sectors, is the high share of renewable energy that ends up in the buildings, as shown in graph Figure 55. Note that we have decided to allocate electricity-consumption related CO_2 emissions to the building. This share is highest for the residential sector in Denmark, due to locally used renewables as wood. In the services sector this is not used.

Please see the two internship reports for more information and results.

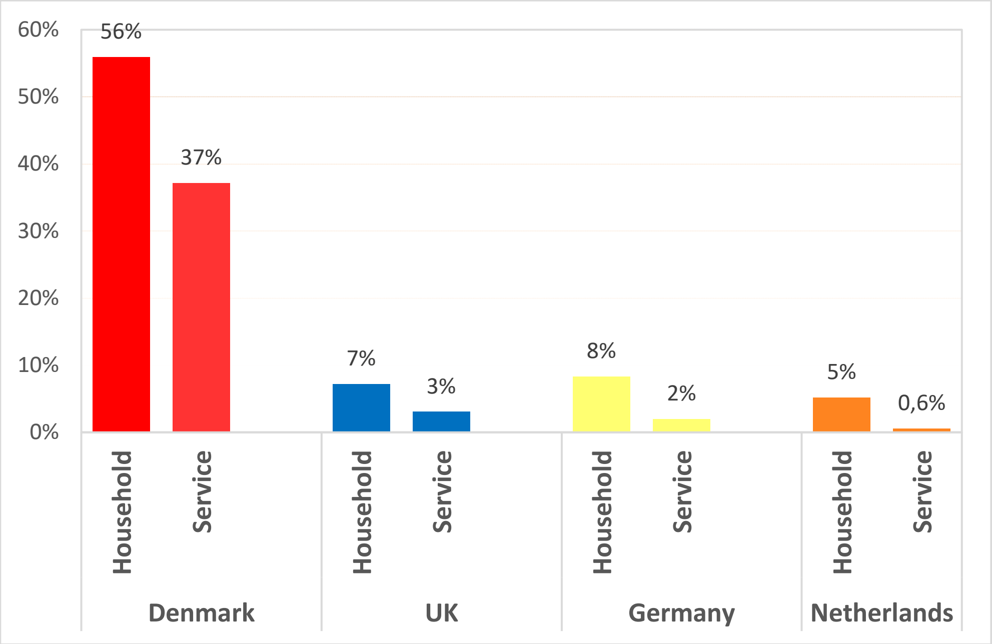

Figure 55 Share of renewable in the household- and services sector by country, for space heating only (2016). Copy of Figure 45. Source: Odysee-Mure;

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Pictures used for the cover sheet are taken from:
https://www.backroads.com/trips/BDSI/sweden-denmark-bike-tours
https://indietravelpodcast.com/europe/netherlands/
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APPENDICES

A A demand for new dwellings due to non-policy factors, the details

In this appendix we have made a general analysis of non-policy factors that have increased the demand for new dwellings. The data is mainly taken from database (ADEMA, 2017) or otherwise mentioned sources). The main observations of this appendix have been used in section 2.7.

A.1 The effect of population growth

Population growth will create demand for more new buildings. All countries except Denmark have a growing population since the year 2000. Since 2010, the population of the UK grows fastest at around 0,5%. Denmark's population is declining since 2005 at a present rate of -0,16%.

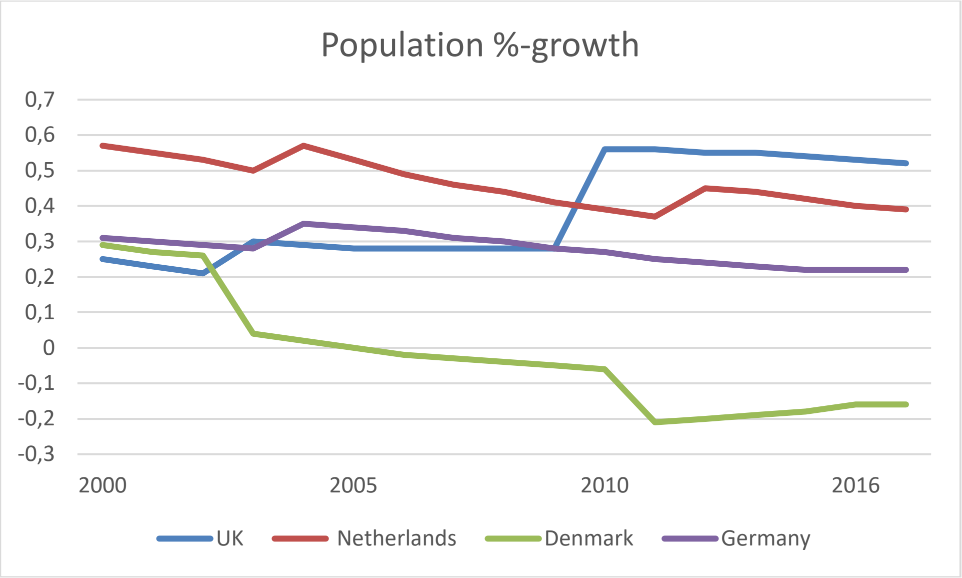

Figure 56: Percentage growth of dwelling floor area since 1990. Source: *indexmundi.com*

A.2 The effect of average dwelling size

Another parameter that could increase the dwelling stock is the **average dwelling size**. As a physical law, larger buildings have a lower energy intensity compared to smaller buildings, although they have the same energetic quality. This has to do with the ratio of inside space that needs to be heated (m^3) versus outside area of walls, floors and the roof, that leaks heat to the outside (m^2). This mean that this factor even influences the energy intensity.

In the Netherlands and Denmark, dwellings tend to be larger compared to those in the UK and Germany, as shown in the below graph. In all countries the average dwelling size has increased between 1990 and 2016. The average for the four countries lies around 14%.

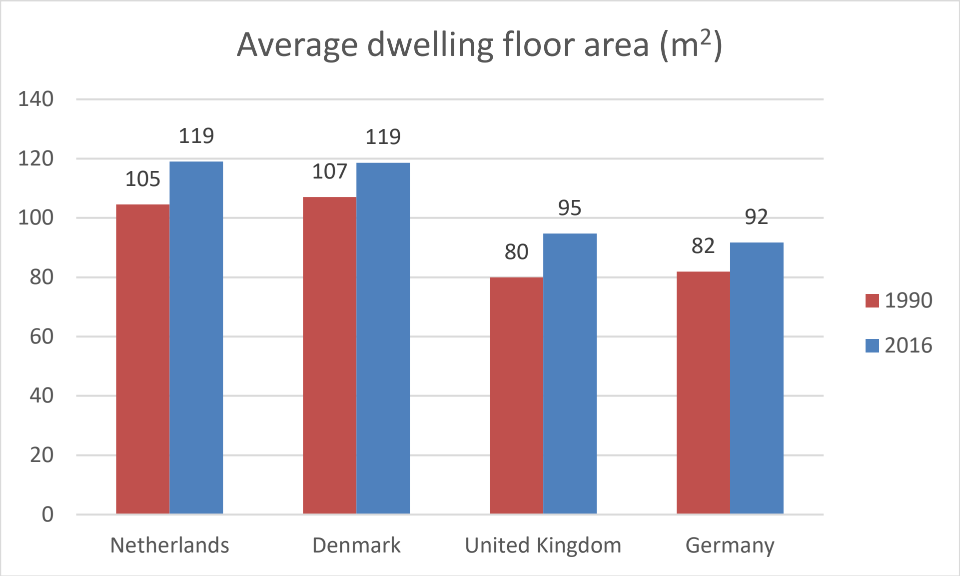

Figure 57: Average dwelling size 1990 versus 2016. Source: Odyssee

A.3 The effect of average household size

At the same time, the average household size has decreased by 10% from 2.4 persons each household to 2.2 now. Combined, this means that each resident has received 24% more square meters of floor area between 1990 and 2016. In Germany and the Netherlands this percentage is highest with 33% and 31%.

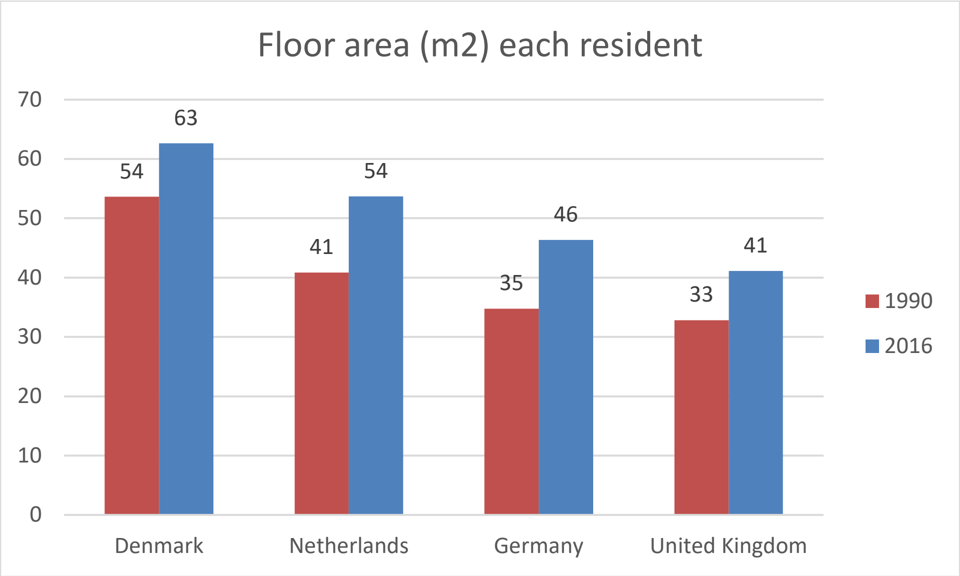

Figure 58: Average floor area per resident 1990 versus 2016. Source: Odyssee

A.4 The combined effect

A combination of these factors has led to an increased number of dwellings built in all countries since 1990. *Figure 59* shows the percentage of new dwellings being built yearly, as a percentage of the total dwelling stock at that moment. For a long time, the Netherlands had the highest new construction rate, Denmark the lowest. The previous discussed factors partly explain the observed development.

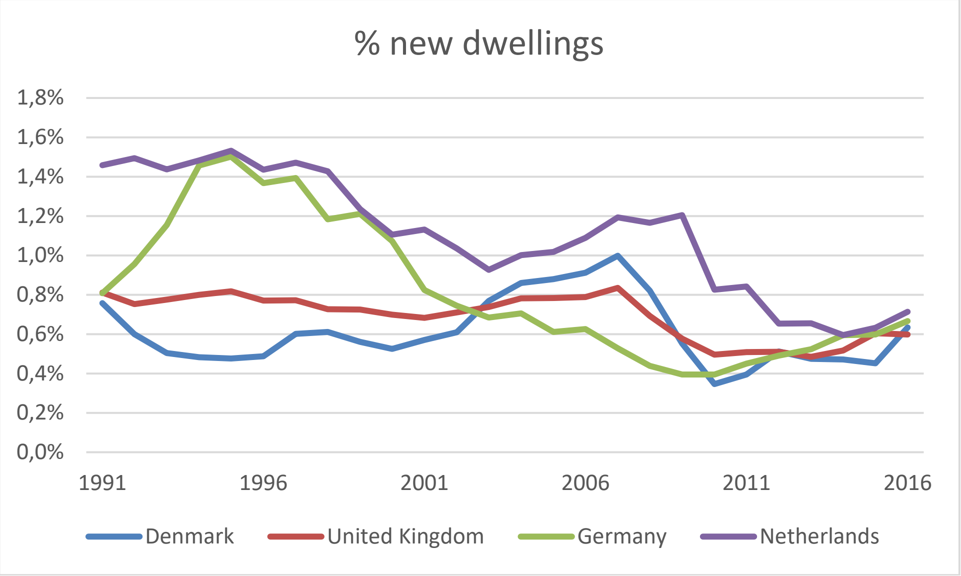

Figure 59: The percentage of new dwellings being built yearly as a percentage of the total dwelling stock at that moment.

The percentages look small, but when added up, we can calculate that in 2016, 25 years later, 19% of the total stock consists of dwellings that have been built after 1990. In the Netherlands this percentage is even more than 25%. Due to the fact that new dwellings became larger at the same time, this share expressed in new dwelling floor area went even faster with an average of 40%, as shown in *Figure 60*.

The growth was the highest in the Netherlands, due to the highest population growth and increased floor area each resident. The growth for Denmark was the lowest, probably dominated by the decreasing population. One could say that from the perspective of the need for new buildings, the Netherlands had the best opportunity to increase the quality of the total dwelling stock, while the opportunity in Denmark was the lowest.

The 'big' question now is with what **building code** the dwellings have been constructed, a typical policy measure, that has made the new dwellings over time more energy efficient. Section 2.8 gives the answer to this question.

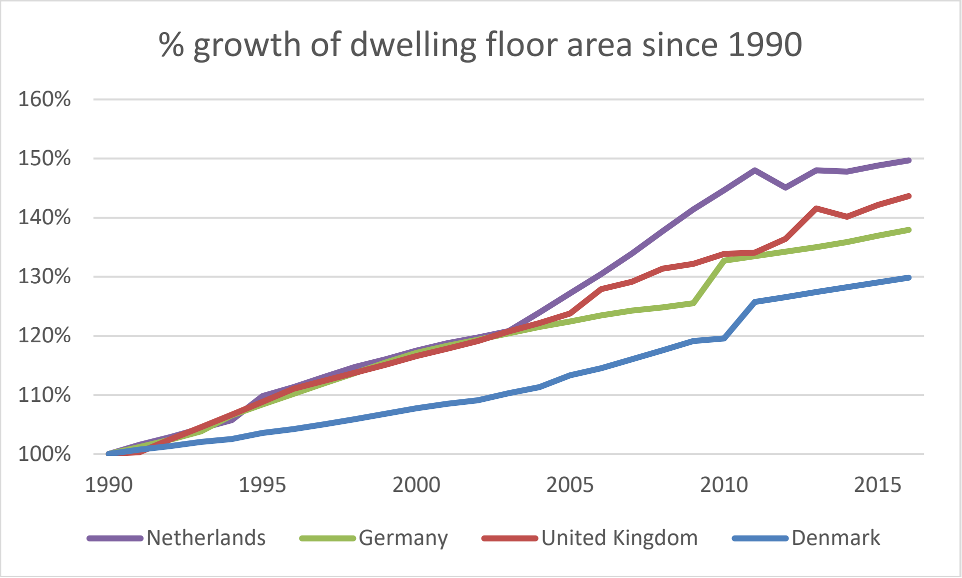

Figure 60: Percentage growth of dwelling floor area since 1990 (copy of Figure 13)

B UK: Supplier obligation evaluations

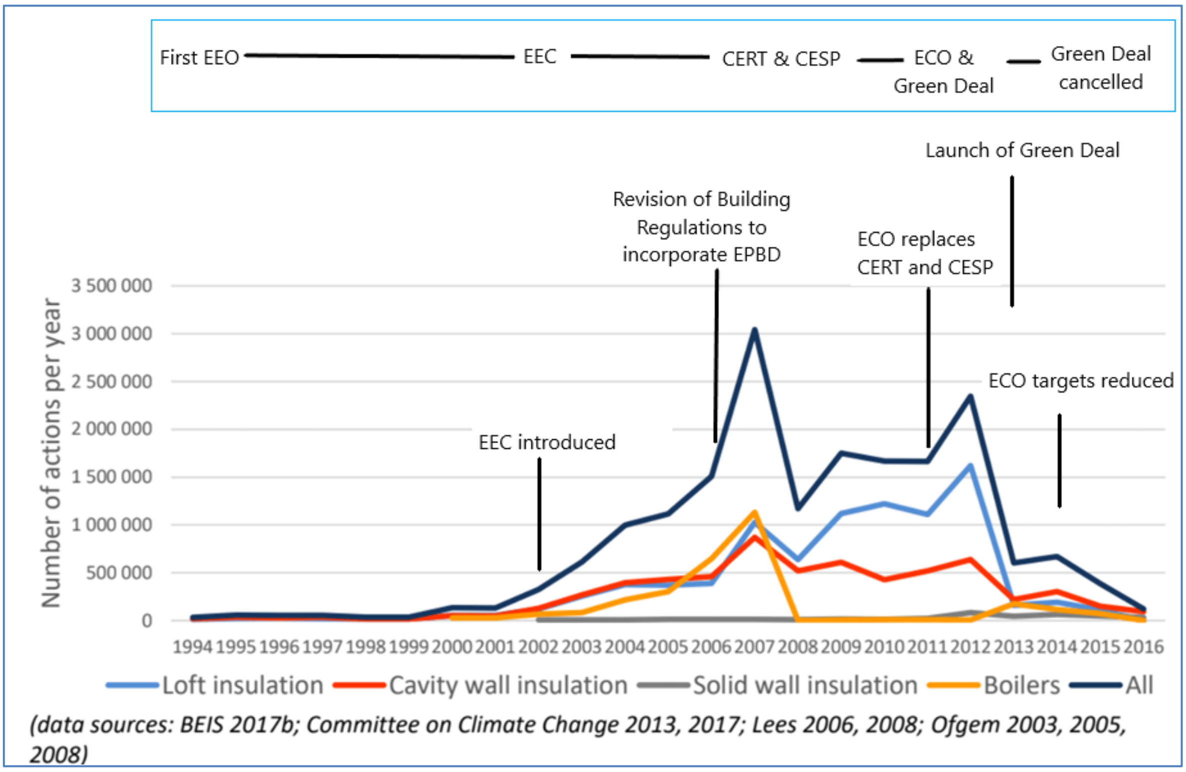

Figure 61. Number and type of measures installed and major policy changes along the timeline of the EEO

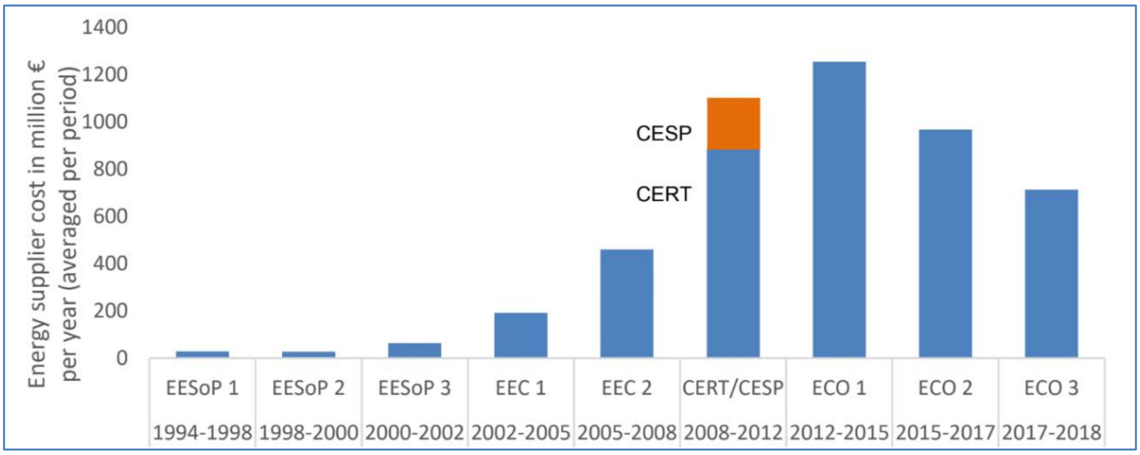

Figure 62. Annual costs of the EEO schemes

C UK: Evaluation methods of policy

Example case: EEO scheme

The UK has in the past received praise for its strong evaluation methods that include multiplying effects, such as free-riders and the rebound effect (Rosenow & Galvin, 2013; IEA, 2006). *Figure 63* shows the methods that the UK includes in evaluating the EEO scheme such as ex-ante validations and audits. The strength of policy evaluations is in part related to the use of the comprehensive NEED framework, which is used in ex-ante evaluations for EEO schemes. The NEED framework is an assembly of observed consumption data from energy meters and the HEED database, which contains efficiency measures carried out under major government programmes such as the EEO. During the EEC schemes free rider effects were considered during the design stage and revised several times to finally be estimated at below 20% (Rosenow & Galvin, 2013). However, the actual energy savings for different EEO schemes cannot be compared as the evaluation method has changed over time, as has the unit of measurement for targeted savings (Rosenow, 2011).

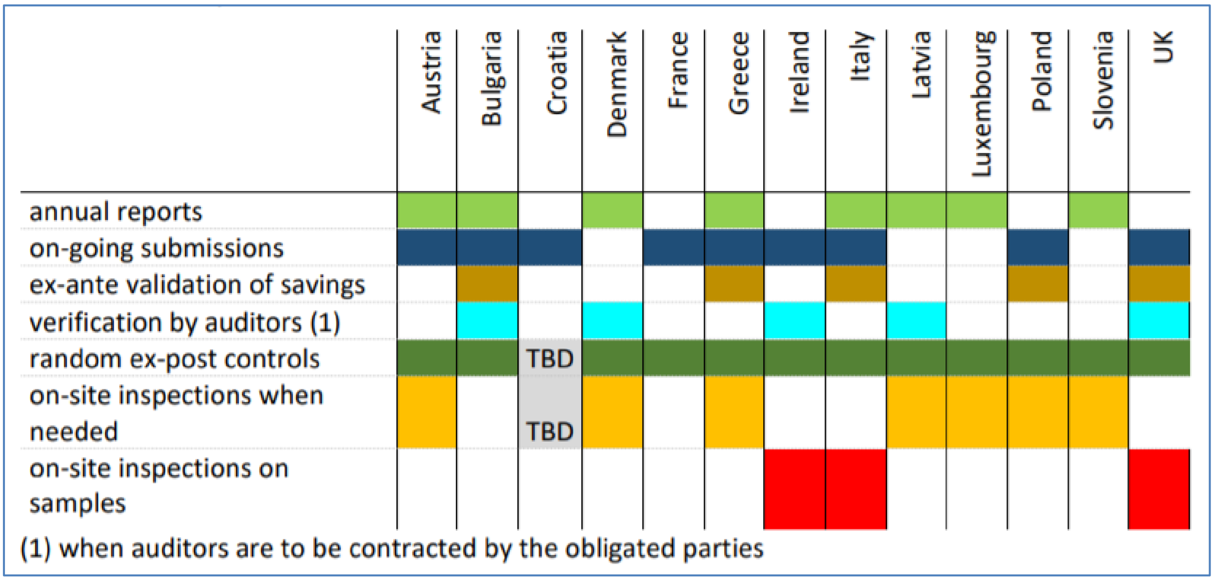

Figure 63 Monitoring and evaluation of EEO scheme across EU member states (*atee.fr*)

Example case: Kirklees Warm Zone scheme

A study by Webber et al. (2015) conducts an ex-post evaluation of the successful Kirklees Warm Zone scheme that retrofitted over 51,000 homes from 2007-2010. The study compares energy use, carbon emissions, energy bills and comfort factors in households before and after the scheme using measured energy data rather than those based on modelled predictions. Impacts of the scheme were higher than predicted. In middle- and higher-income households the performance gap and rebound effects were lower than in ex-ante calculations. The research’s quantitative focus could not identify reasons for limited uptake of the scheme and highlights that a more qualitative approach is required to understand this barrier. Detailed data on energy use in homes is needed to understand the factors that influence background trends in energy use and to perform ex-post evaluation of policies.

Energy Performance Certificates

The EPC is based on the SAP (for new buildings) and the RdSAP (for existing buildings). The SAP is a government model that includes a score of 1-100 which is converted into a corresponding EPC, *Table 21* includes the conversions. The SAP and RdSAP are regularly reviewed by the governmental body BEIS (formerly DECC) and have been updated several times to improve its accuracy related to policy programmes.

Table 21 SAP score and equivalent EPC rating

SAP score	EPC rating
92+	A
81-91	B
69-80	C
68-55	D
54-39	E
38-21	F
1-20	G

D Denmark: policy story line

The idea of providing building-labels in Denmark is not new, in fact, the country has been trying to label the national building stock since 1978. The next figure contains all the policy instruments that have promoted energy efficiency in buildings in a chronological order. As it is indicated in the timeline figure, the building regulation and energy labelling measures started in the 70s and 80s respectively. It is obvious therefore, that Denmark was implementing energy efficiency policies before the introduction of the current EU-related measures.

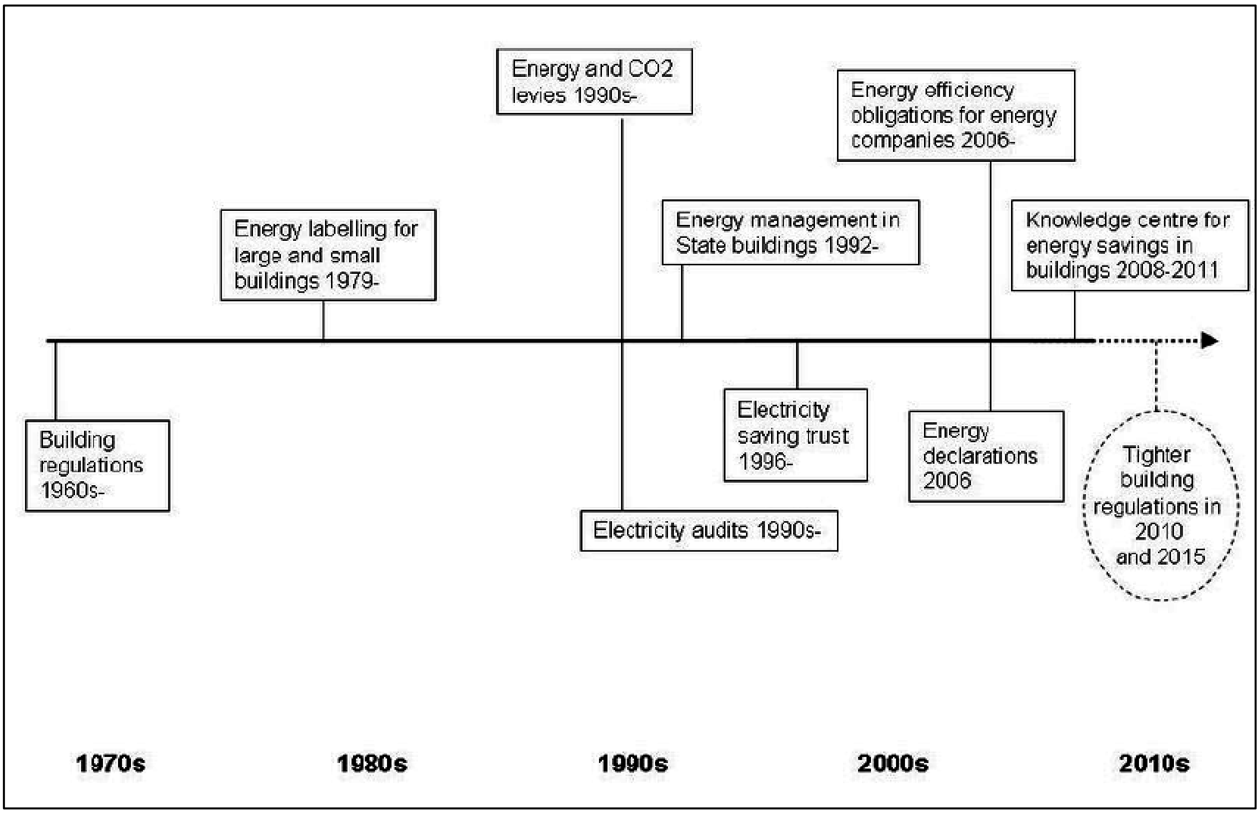

Figure 64 Timeline of key policy instruments in Denmark (source: Kiss, B. 2010)