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Applying the Ecofys Results in the Energy Modelling and the Cost of Heat Savings for the United Kingdom

Work Package 2

Background Report 3b

Co-funded by the Intelligent Energy Europe Programme of the European Union

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4DH
4th Generation District Heating Technologies and Systems

STRATEGO Website: http://stratego-project.eu
Heat Roadmap Europe Website: http://www.heatroadmap.eu
Online Maps: http://maps.heatroadmap.eu

Heat Roadmap Europe 2050

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1 Introduction

Background Report 3a of the STRATEGO project calculated the cost of implementing heat savings for four different STRATEGO countries between now and the year 2050, along with the resulting heating and cooling demand. The four countries included in Background Report 3a are Czech Republic, Croatia, Italy, and Romania. These results are used as inputs for the energy modelling, when developing the heating and cooling strategies in the main STRATEGO report. This report explains how the results from Background Report 3a are interpreted for the energy modelling and afterwards, how they are used in combination with a literature review to estimate the costs of heat savings in the United Kingdom (Section 4), which is the fifth STRATEGO country.

2 Quantifying the Cost of Heat Savings in Buildings for the Czech Republic, Croatia, Italy and Romania

The Background Report 3a of the STRATEGO project presents the total investment costs required in the building envelope to reduce the heat demand between today (i.e. 2014) and the year 2050. Four countries, including Czech Republic, Croatia, Italy, and Romania are all calculated separately, with investments divided between measures 1) existing buildings and new buildings and 2) between investments in the walls/roof and investments in windows. An example for the Czech Republic is provided in Figure 1 and Figure 2 below, which display the heat demand and corresponding investments in heat savings respectively.

These total investment costs were annualised to include these in the energy modelling in the Main Report using a lifetime and an interest rate. It is assumed that the windows have a lifetime of 25 years, the walls/roof/cellar measures have a lifetime of 40 years, and the interest rate is 3%. The investment costs are annualised using equation 1 below, which includes the total investment costs (I), the lifetime (n), and the interest rate (i). The resulting annualised costs are presented for all four countries in Figure 3.

$$I_{Annual} = I\left[\frac{i}{1-(1+i)^{-n}}\right] \quad (1)$$

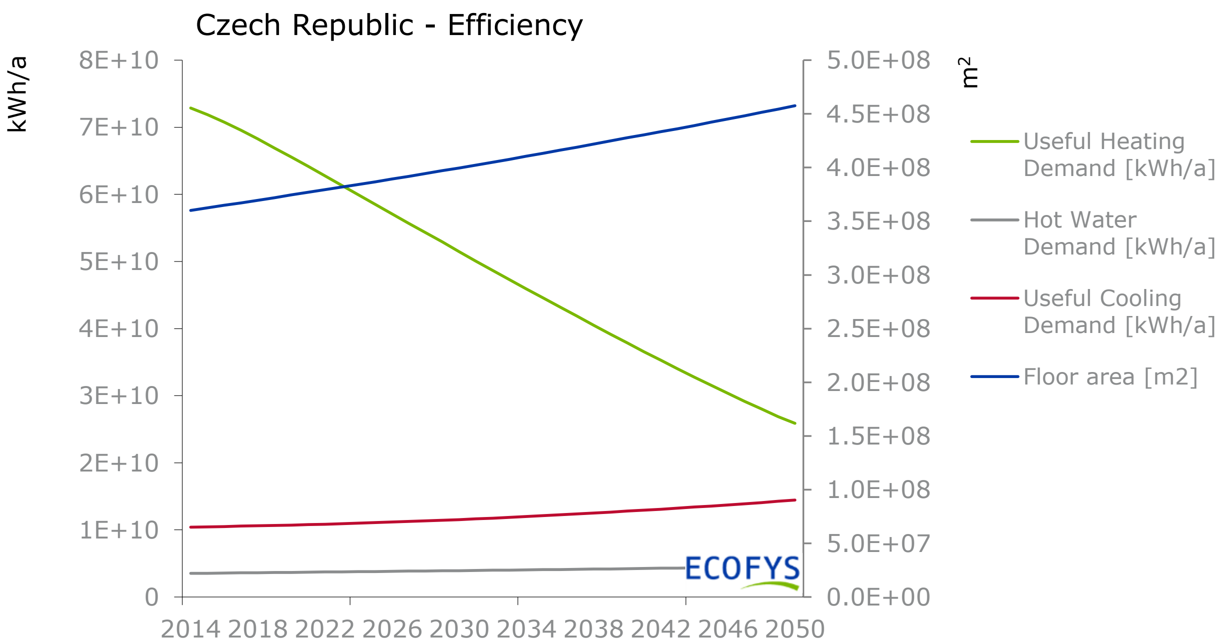

Figure 1: Efficiency pathway in Czech Republic.

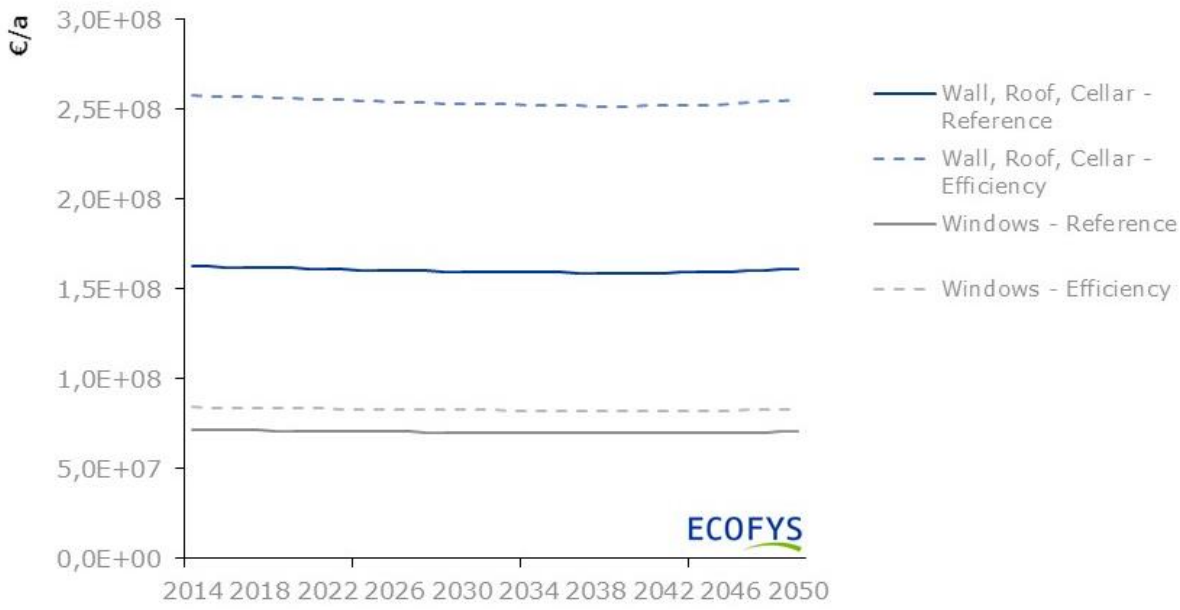

Figure 2: Investments in Czech Republic.

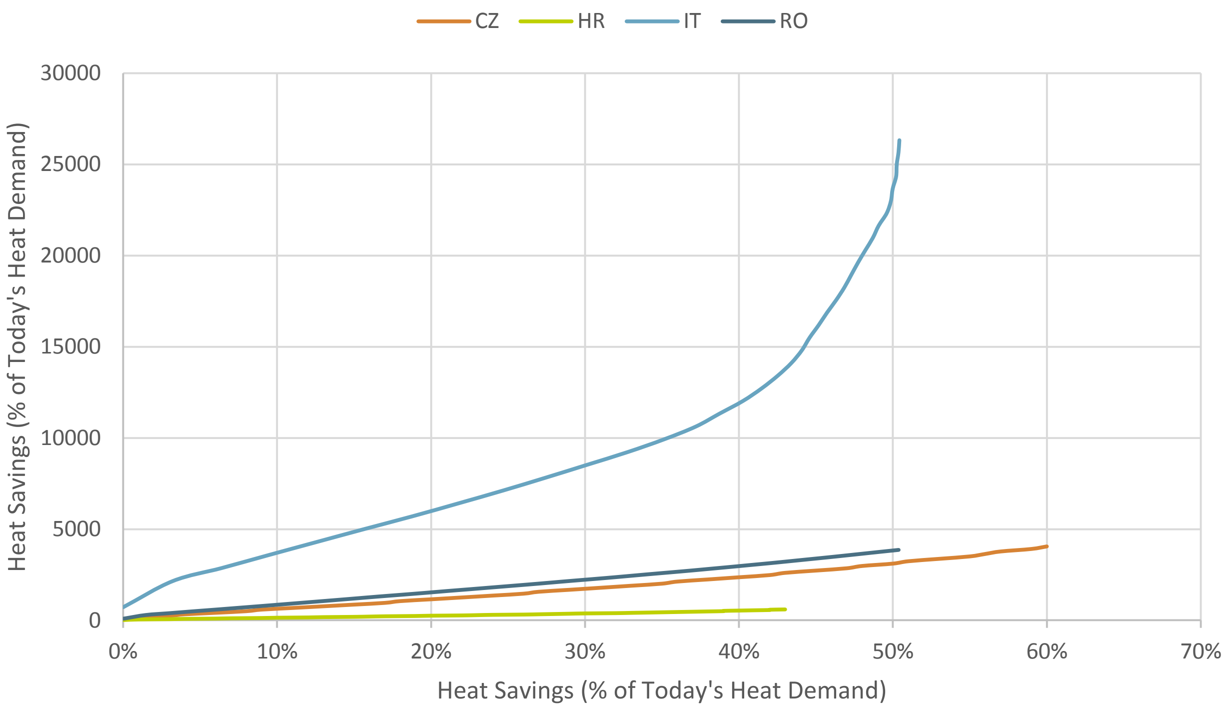

Figure 3: Accumulated Annualised costs for Czech Republic, Croatia, Italy, and Romania. Today's heating demand refers to the year 2014.

After quantifying the total costs for the energy savings, the levelised cost of heat savings (i.e. €/kWh of heat saved) was also calculated so the different countries could be compared with one another. The method used to calculate the cost of heat savings is described below using the Czech Republic efficiency path as an example (see Figure 1 and Figure 2).

1. We calculate the heat demand (space heat and hot water) per floor area (m^2) for every year from 2014 to 2050, by dividing the total square meters of all the buildings by the total heat demand of all the buildings.

For example, in 2015 the total floor space is calculated as being 362,422,144 m^2 (2,428,408 m^2 more than 2014). In 2015 the total space and hot water heat demand is 75.4 TWh (71.9 TWh space heating and 3.5 TWh hot water). Therefore in 2015 the heat demand per floor space is 208 kWh/m^2.

2. We then quantify the 'expected heat demand without savings' by multiplying the total floor area of 2015 (362,422,144 m^2) by the unit heat demand (i.e. kWh/m^2) from the previous year (2014).

For example, in 2014, the previous year, the heat demand was 212 kWh/m^2. This is multiplied by the total floor area of 2015 (362,422,144 m^2). This suggests that if no heat savings were implemented, then the heat demand would have been 76.9 TWh in 2015.

3. We then subtract the actual heat demand of 2015 from the expected heat demand, which is based on the 2015 floor area and the heat demand (kWh/m2) of the previous year (2014).

For example, the actual heat demand in 2015 is 75.4 TWh. The difference between the actual and the expected is 1.5 TWh, which is assumed to be the amount of heat saved in 2015 due to the investments made in heat savings in the year 2015.

4. For each year the total investment costs are also annualised as described earlier in equation 1 and as presented for each country in Figure 3.

In the Czech Republic example, the total investment in heat savings in 2015 is €1080 million (see Table 1). Annualised, this is a total investment cost of M€51/year.

Table 1: Example of total investment costs in renovations measures and the annualised cost for 2014

Component	Building type	Total investment in 2014 (M€)	Annualised cost in 2014 (M€)
Insulation	Wall, Roof, Cellar retrofit	410	32
	Wall, Roof, Cellar new buildings	333	
Windows	Windows retrofit	156	16
	Windows new buildings	123	
Total		1021	48

5. By dividing the annualised costs of the previous year (i.e. 2014) by the total savings in that year (i.e. 2015), it is possible to estimate the unit cost of heat saved (i.e. €/kWh)

For the Czech Republic, the investment in heat savings in 2014 is M€48/year in 2014, while the heat saved in 2015 equates to 1.5 TWh/year, so the levelised cost of heat saved is €0.033/kWh.

6. This process is repeated for all efficiency scenarios for all years in Czech Republic, Croatia, Italy and Romania.

7. Finally, the unit cost of heat saved (i.e. €/kWh) is plotted against the unit heat demand (i.e. kWh/m2) for each year, which is discussed in more detail in section 4.

The results for each country are shown below in Figure 4. The results suggest that heat savings are the most cost effective in the Czech Republic, then Croatia, and finally Italy and Romania have similar costs.

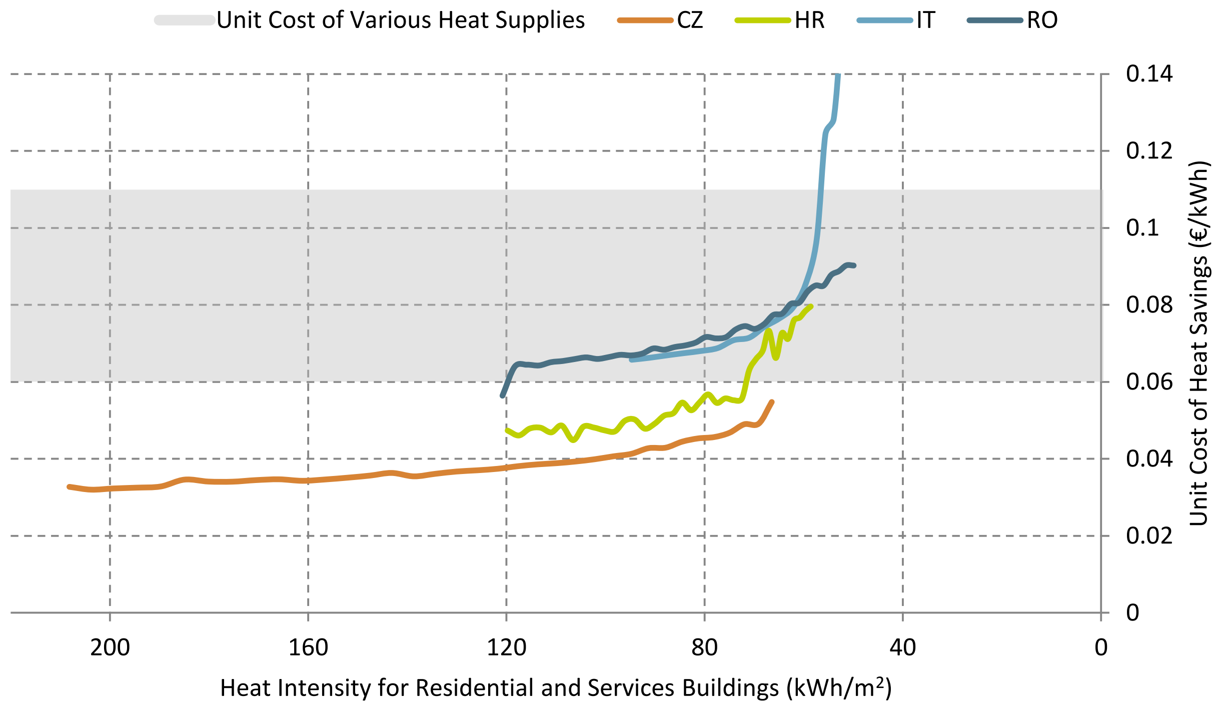

Figure 4: Heat intensity compared to the unit cost of heat savings and various forms of heat supply in the Czech Republic, Croatia, Italy, and Romania. The methodology used to estimate the unit cost of heat supply from various technologies is discussed in section 4.

3 Quantifying the Cost of Heat Savings in Buildings for the UK

The UK is not included in Background Report 3a, so a literature review was carried out to establish if the cost of heat savings is already reported for the UK. This led to a study by Element Energy called "*Review of potential for carbon savings from residential energy efficiency*" written for The Committee on Climate Change [1].

This study only considers the residential sector whereas the Ecofys analysis included both residential and services buildings.

According to the main data source used in the Element Energy study, in the United Kingdom the heating energy demand for residential space heating and hot water was approximately 400 TWh in 2010 [2], of which ~80% was supplied by natural gas. Based on 27.4 million dwellings, the average household heat consumption equates to 15,150 kWh of heating each year. The average residential dwelling floor area in the UK in 2010 was around 92 m^2 [3], so the average unit heat consumption was estimated as 161 kWh/m^2.

In the Element Energy study, heat saving potentials were determined for different measures in the UK. Since housing types are varied in the UK and not all measures are relevant for each housing type, the extent of heat savings were quantified for each measure for a range of different UK house types. The UK residential building stock was segmented into groups in order to carry out this study. In total there were 135 different house types. The Standard Assessment Procedure (SAP) was applied for the calculation of the residential heating [1][4].

The SAP methodology calculates the annual heating (space and hot water) and electricity consumption (excluding consumer appliances) demand for each of the different house types before and after the energy saving measure is introduced [1]. The disaggregation and segmentation of the housing stock was determined from the English Housing Survey (EHS), which determined the different types of homes in the UK. The house types vary in terms of size, tenure and fuel.

Element Energy developed a Housing Energy Model (HEM) that was used to calculate the heat savings from each measure. HEM calculates the technical potential for each measure and this is used to determine the potential for heat energy savings associated with each specific measure, which can vary across the house types. The assessment was carried out for each building segment in the stock, but the heat savings were only measured for the housing segments in which they were installed.

The results from the study are used as the basis for the calculations in this report. There are two main components in the calculations, being 1) the additional cost for additional measures and their corresponding heat savings (i.e. €/kWh saved) and 2) the cumulative reduction of the country's domestic residential unit heat demand (i.e. kWh/m^2). This ensures that the results for the UK can be directly compared with those obtained for the other STRATEGO countries in Figure 4.

The weighted average cost from each measure across the total UK stock is presented in Figure 5. The installation cost of the measure is different for different house types. Therefore the cost is determined based on the house type attributes such as wall area, loft area and thickness, glazing area [1], with the results converted into a weighted average. The different house types also affect the annual fuel savings for each measure which are also weighted, which is shown in Figure 6.

After the weighted average cost of each measure is determined, then they are annualised in order to compare each measure with one another, which is also shown in Figure 7. These annualised costs are used in in this study to determine the unit cost of heat savings (i.e. €/kWh). These costs are per measure so they are multiplied by the total number of dwellings to establish the impact at a national level.

To determine the unit cost of heat savings (i.e. €/kWh saved) for each measure, the following steps are carried out:

1. The "number of houses with each measure" was estimated based on the total heat savings for each measure (Figure 8) and the average heat savings for each dwelling (Figure 6).

$$number\ of\ houses\ with\ the\ measure = \frac{total\ heat\ energy\ savings\ by\ the\ measure\ in\ the\ UK}{weighted\ average\ heat\ energy\ savings\ by\ the\ measure} \quad (2)$$

2. The "total annualised cost of the measure in the UK" is determined by multiplying the cost per household for each measure (Figure 7) by the number of houses with the measure (equation 2):

$$total\ annualised\ cost\ of\ the\ measure\ in\ the\ UK = (annualised\ cost\ per\ installation) \cdot (number\ of\ houses\ with\ the\ measure) \quad (3)$$

3. Finally, the unit cost of heat savings is calculated based on the total annualised costs (equation 3) divided by the total annual energy savings due to the measure (Figure 8). As shown in Figure 8, the results are presented in terms of fuel savings, as opposed to heat savings. Since this study focuses on reductions in the heat demand, the fuel savings are converted into heat savings. Different efficiencies are assumed for the different types of heating units, depending on the fuel they consumed. The same efficiencies are used here as in Background Report 4, which are 65% for solid fuel, 85% for natural gas, 80% for oil, and 100% for direct electric heating. The different fuel mix used in the Element Energy study was extracted from the UK Energy Data file [2]. Using this fuel mix and the efficiencies, the average efficiency was calculated as 85%. This efficiency is assumed when converting from fuel savings to heat savings for the individual measures.

$$cost\ per\ kWh\ saved = \frac{total\ annualised\ cost\ of\ the\ measure\ in\ the\ UK}{total\ annual\ heat\ savings\ of\ the\ measure in\ the\ UK} \quad (4)$$

The resulting weighted average heat energy savings per measure, total annual heat energy savings by each measure, the number of houses with each measure, and the corresponding costs are presented in Table 3.

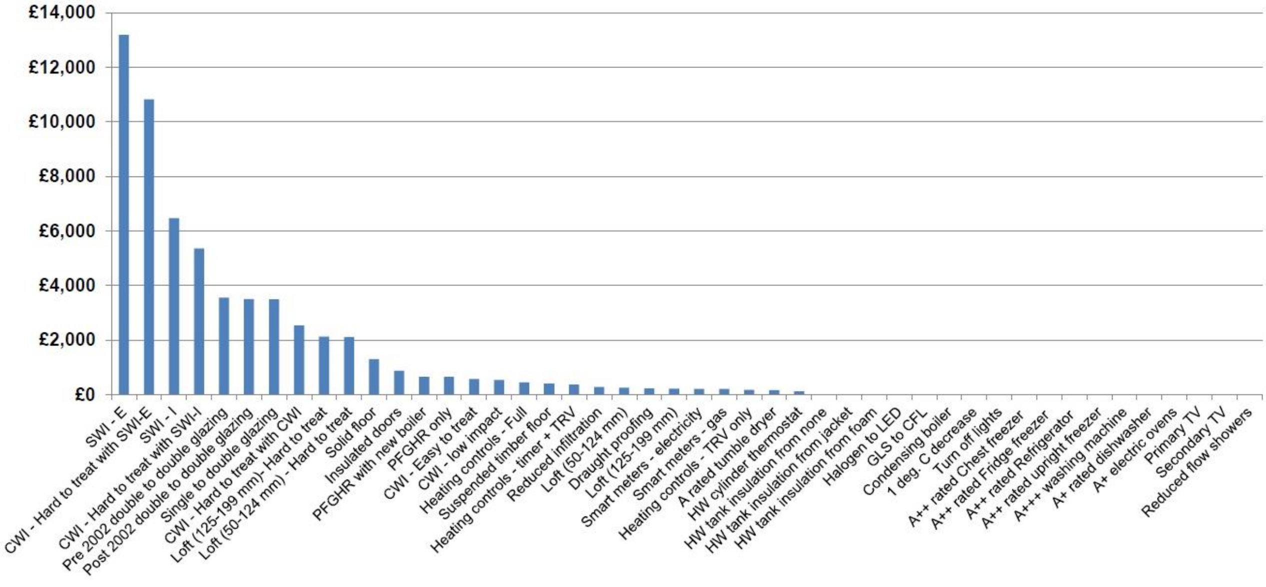

Figure 5: Breakdown of weighted average cost of installation of measures [1]**.**

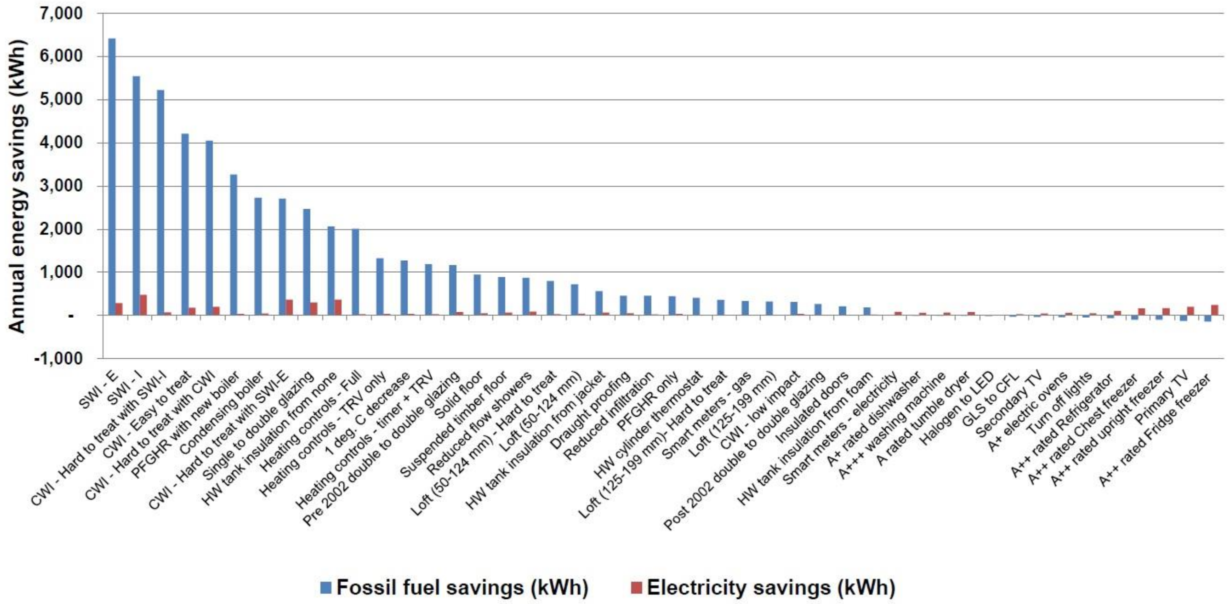

Figure 6: Breakdown of weighted average fossil fuel and electricity savings [1]**.**

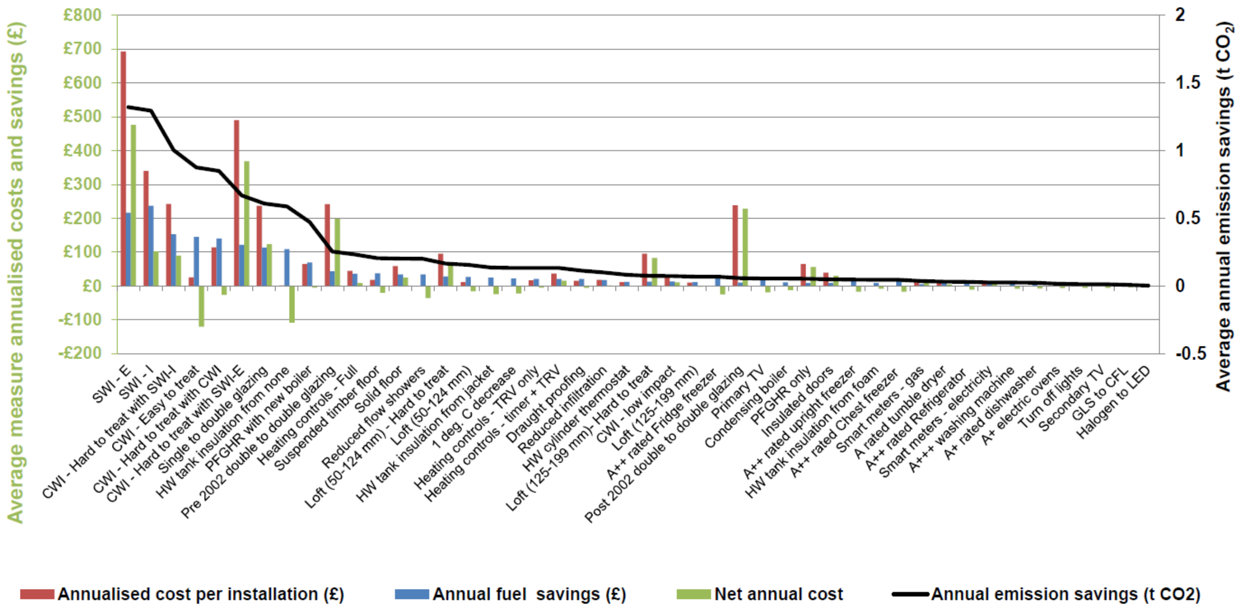

Figure 7: Annualised cost per installation of measure [1].

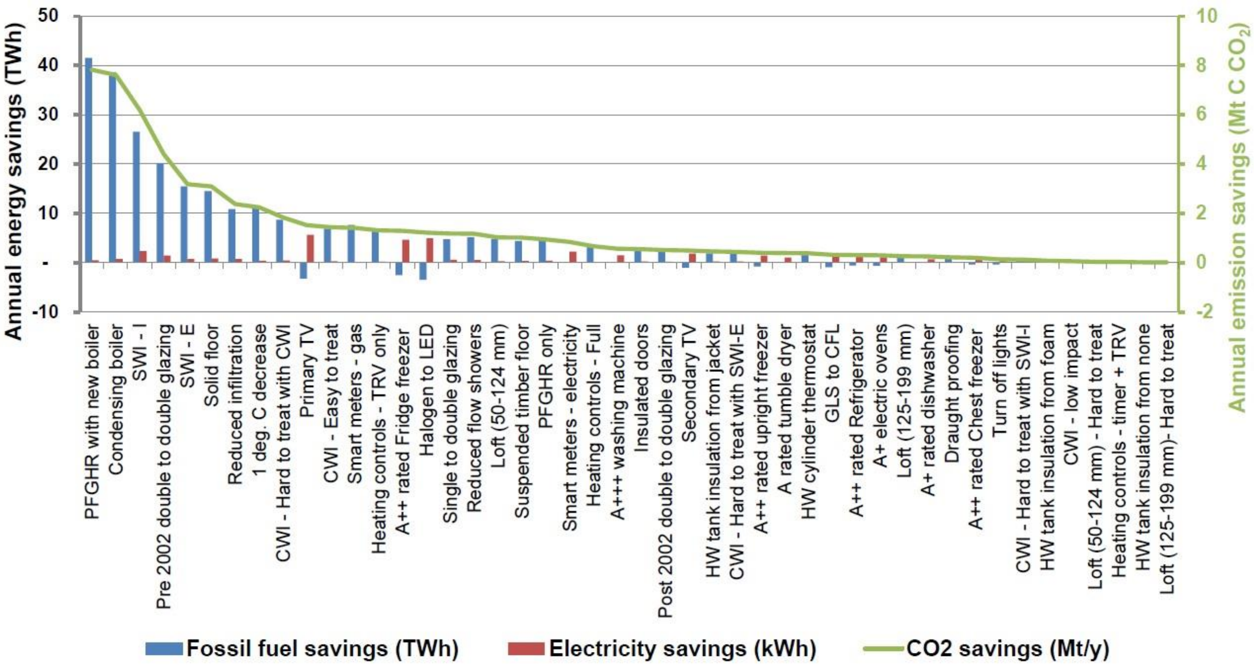

Figure 8: Total potential for annual energy savings across stock [1]

An important note is that this study excludes all of the behavioural and heating supply measures, such as installing a condensing boiler and decreasing the temperature by 1°C. To be in line with the analysis in Background Report 3a, only measures relating to the building envelope were included such as insulation and improvements to the windows. The resulting measures included are outlined in Table 2. Also, Figure 9 presents the overlapping savings data which corrects the savings when different measures are combined in one dwelling, so they can counteract some of the savings by each other, thus lowering the overall savings. The figure shows that this is only occurs for the boilers, and so all the measures included in this study do not have an overlapping effect. As a result, the overlapping affect is not considered here.

Table 2: Measures included in the study.

Component	Measure
Hot water tank	Hot Water tank insulation from none
	Hot Water tank insulation from jacket
	Hot Water tank insulation from foam
Walls & doors	Cavity Wall Insulation - Easy to treat
	Cavity Wall Insulation - Hard to treat with Cavity Wall Insulation
	Cavity Wall Insulation - Hard to treat with Solid Wall Insulation - Internal
	Solid wall insulation - Internal
	Cavity Wall Insulation - low impact
	Solid wall insulation - External
	Cavity Wall Insulation - Hard to treat with Solid Wall Insulation - External
	Insulated doors
Ceiling	Loft (50-124mm)
	Loft (125-199mm)
	Loft (50-124mm) - Hard to treat
	Loft (125-199mm) - Hard to treat
Floors	Suspended timber floor
	Solid floor
Windows	Single to double glazing
	Pre 2002 double to double glazing
	Post 2002 double to double glazing
Building air tightness	Draught proofing
	Reduced infiltration

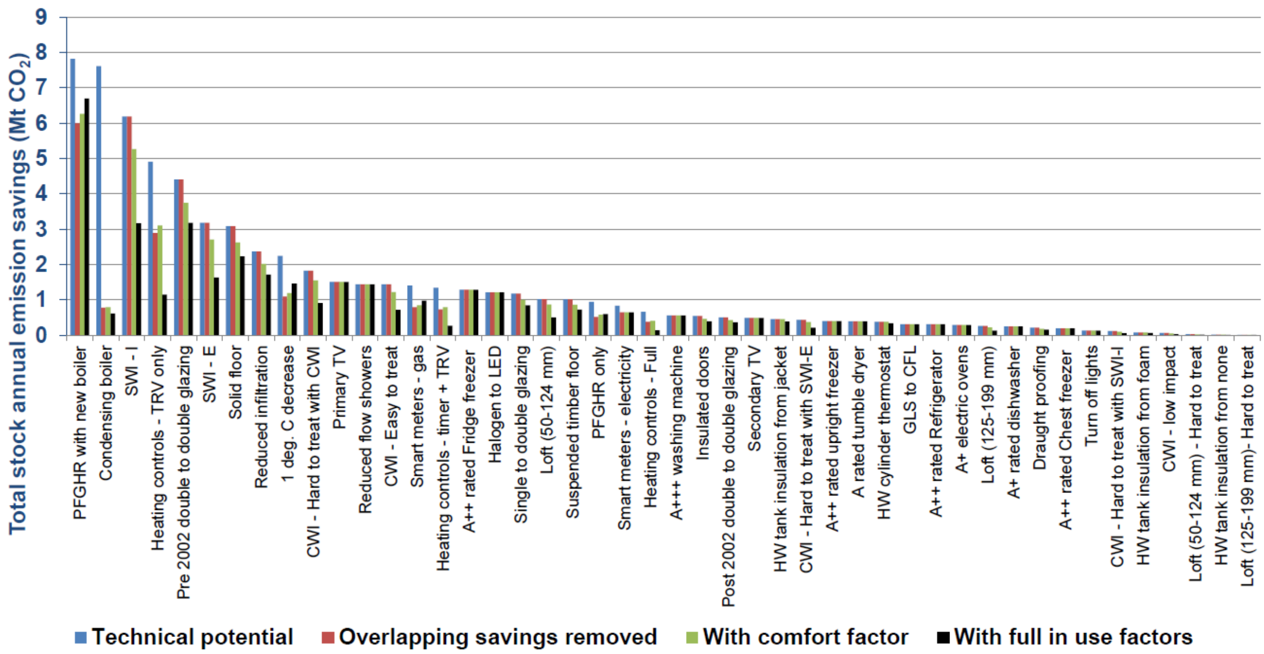

Figure 9: Comparison of technical potential savings versus overlapping savings removed [1].

Table 3: Heat savings per measure in the UK, including number of dwellings receiving each measure along with the corresponding cost for each measure, including unit cost of heat savings.

Component	Measure	Weighted average annual heat savings per measure (kWh)	Annual heat savings in UK (TWh)	Number of dwellings receiving measure in UK	Total annualised cost for the UK (€ Million)	Unit cost (€/kWh saved)
Hot water tank	Hot Water tank insulation from none	2067	0.09	41,152	0.06	0.0007
	Hot Water tank insulation from jacket	519	1.3	2,459,016	3.4	0.003
	Hot Water tank insulation from foam	162	0.3	1,578,947	2.2	0.008
Walls & doors	Cavity Wall Insulation - Easy to treat	3726	6.4	1,712,329	58.7	0.009
	Cavity Wall Insulation - Hard to treat with Cavity Wall Insulation	3573	8.1	2,261,905	77.5	0.01
	Cavity Wall Insulation - Hard to treat with Solid Wall Insulation - Internal	4475	0.3	76,046	23.9	0.07
	Solid wall insulation - Internal	5062	24.3	4,789,916	2,165.5	0.09
	Cavity Wall Insulation - low impact	281	0.2	606,061	24.9	0.15
	Solid wall insulation - External	5657	13.2	2,330,827	2203.3	0.17
	Cavity Wall Insulation - Hard to treat with Solid Wall Insulation - External	2637	1.3	483,871	324.8	0.25
	Insulated doors	179	1.7	9,523,810	391.4	0.23
Ceiling	Loft (50-124mm)	676	4.3	6,289,308	86.2	0.02
	Loft (125-199mm)	272	0.1	312,500	4.3	0.05
	Loft (50-124mm) - Hard to treat	736	0.1	115,607	15.8	0.19
	Loft (125-199mm) - Hard to treat	349	0.04	121,951	16.7	0.39
Floors	Suspended timber floor	817	3.8	4,687,500	96.3	0.025
	Solid floor	851	12.8	15,000,000	1130.3	0.089
Windows	Single to double glazing	2340	4.7	2,000,000	630.2	0.13
	Pre 2002 double to double glazing	1038	17.9	17,213,115	5541.8	0.31
	Post 2002 double to double glazing	230	1.7	7,407,407	2334.1	1.37
Building air tightness	Draught proofing	451	0.4	943,396	19.4	0.046
	Reduced infiltration	434	9.4	21,568,627	443.2	0.05
TOTAL		N/A	112	N/A	N/A	N/A

Overall by implementing these measures the UK could save around 112 TWh (or 28%) of heat demand per year out of 400 TWh based on the 2010 demand, assuming that the floor area remains the same, at a total annualised cost of around €16 billion/year.

All the measures are ranked from cheapest to the most expensive. The results shown in Table 4 and Figure 10 show the cheapest measures first up to the most expensive. Table 4 provides the new heat density (kWh/m^2) after each measure is installed in the UK. Before any of the measures are installed the heat density is 161 kWh/m^2. Figure 10 shows the measures being installed one after the other in this order. On the x-axis the reduction in heat energy of the total UK heat demand is calculated as each measure is implemented. Each measure is added to the previous measure and the cumulative energy savings for the UK housing stock are determined until all the measures have been implemented. When plotting each measure on the chart, the measures are added to each other as if they are installed sequentially in the UK building stock and thus the energy savings keep accumulating. Although the energy savings accumulate along the x-axis, the unit cost of each measure is not accumulated on the y-axis. Instead, it reflects the cost of the measure individually.

Table 4: Unit heat demand (kWh/ m^2) as each measure is installed, starting with hot water tank insulation to post 2002 double to double glazing.

Hot Water tank insulation from none	**Hot Water tank insulation from jacket**	**Hot Water tank insulation from foam**	**Cavity Wall Insulation - Easy to treat**	**Cavity Wall Insulation - Hard to treat with Cavity Wall Insulation**	**Loft (50-124mm)**	**Suspended timber floor**	**Draught proofing**	**Reduced infiltration**	**Loft (125-199mm)**	**Cavity Wall Insulation - Hard to treat with Solid Wall Insulation - Internal**
161	161	160	158	155	153	151	151	148	147	147
Solid floor	Solid wall insulation - Internal	Single to double glazing	Cavity Wall Insulation - low impact	Solid wall insulation - External	Loft (50-124mm) - Hard to treat	Insulated doors	Cavity Wall Insulation - Hard to treat with Solid Wall Insulation - External	Pre 2002 double to double glazing	Loft (125-199mm) - Hard to treat	Post 2002 double to double glazing
142	133	131	131	125	125	125	124	117	117	116

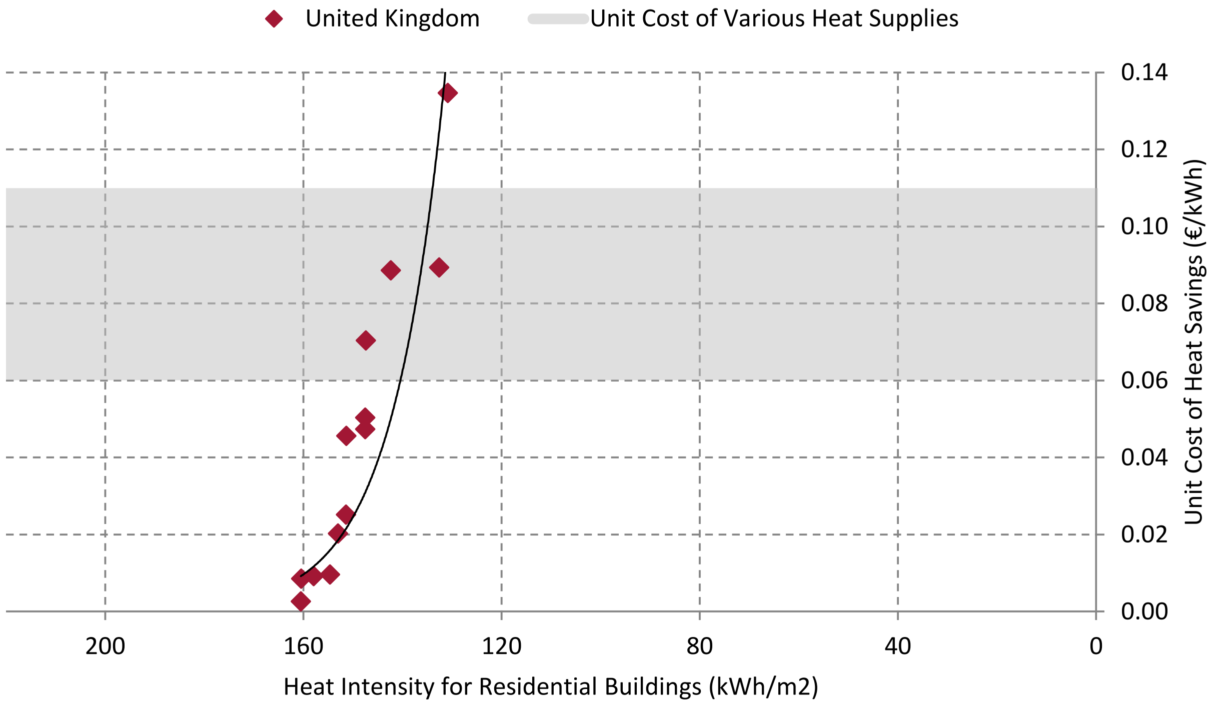

Figure 10: Heat demand per square metre against cost for marginal savings. Note that this does not include all of the savings presented in Table 3 since the scale on the axes is the same as in Figure 4.

4 Comparing the Cost of Heat Savings and Heat Supply for Each STRATEGO Country

The building envelope is usually much more efficient in newer buildings than in older buildings, due to improved building regulations over time. Therefore, when heat savings are implemented in older buildings, there is usually a shorter payback than when buildings are implemented in newer buildings. As a result, heat savings are usually implemented in older buildings first, so in the beginning heat savings are extremely cost effective from a private and socio-economic perspective. However, over time the number of older buildings that need renovating becomes less and less, so the payback of heat savings reduces, with previous studies concluding that the cost of further heat savings will eventually surpass the cost of supply [5]. On the broader energy system level it is at this point that it is more cost-effective to consume heat within the building rather than to add a new heat saving measure. The key question remaining is at what point does the cost of heat savings exceed the cost of heat supply?

Here, the balance between the cost of heat savings and the cost of heat supply is compared for the STRATEGO countries. This comparison is based on the unit cost of heat savings obtained in sections 2 and 3, with the unit cost of heat supply. Therefore, the unit cost of heat supply has to be calculated. The levelised cost was determined for 1 kWh of heat for oil boilers, natural gas boilers, biomass boilers, air source heat pumps, ground source heat pumps, electric heating, and district heating. The assumptions used to estimate the levelised costs of heating are provided in Table 5, while the resulting levelised costs for heat are displayed in Figure 11.

Table 5: Cost assumptions to estimate the levelised cost from various individual heating technologies. These are the costs of single-family heating units for new buildings based on the year 2020 [6][7]**.**

Heating System	Oil Boiler	Natural gas Boiler	Biomass Boiler	Heat Pump Air Source	Heat Pump Ground Source	Electric Heating	District Heating
Specific investment (1000€/unit)	6.6	5	6.75	12	16	8	2.5
Technical lifetime (years)	20	22	20	20	20	30	20
Annual Investment* (€/year)	444	251	454	672	874	408	202
Fixed O&M (€/unit/year)	270	46	25	135	135	80	150
Efficiency	100%	102%	87%	330%	350%	100%	98%
Annual Fuel Consumption# (MWh/year)	15	15	17	4.5	4.3	15	15
2010 Fuel Cost+ (€/MWh)	32	36	32	65”	65”	65”	36”
2050 Fuel Cost+ (€/MWh)	65	54	41	83”	83”	83”	51”
Annual District Heating Pipe Costs (€/MWh)^							4

**Using equation 1 and assuming an interest rate of 3%*

#Annual a heat demand of 15 MWh/year

+Based on the cost from the Euroepan Commission [8]*, with the addition of fuel handling costs* [6]*. Carbon dioxide costs are not included here.*

^Based on the cost of conventional district heating networks in existing areas [7]*.*

”Assuming the electricity/heat is produced from a combined cycle gas turbine and based on the cost assumptions in the EnergyPLAN Cost Database [6]*.*

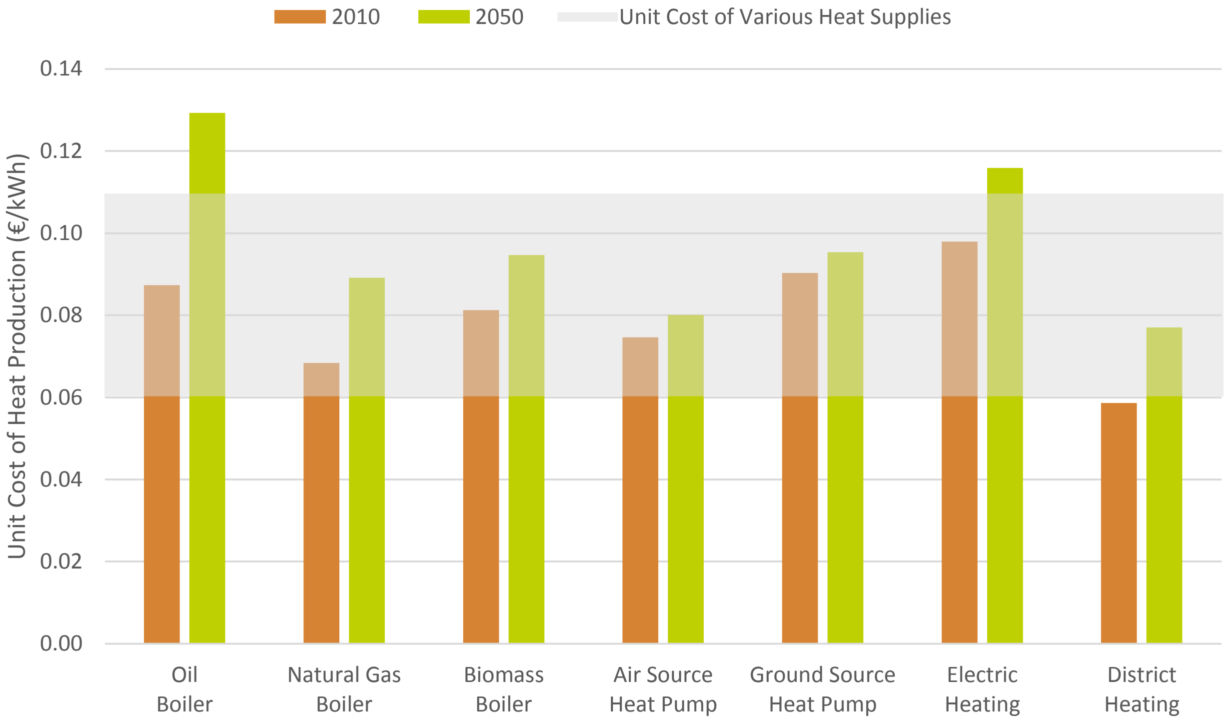

Figure 11: Unit cost for different years and costs for different heat sources.

The result suggest that the unit cost of heat supply is in the region of €0.06-0.11/kWh depending on the type of technology and the fuel price. These levelized costs are good for approximations, but they should only be seen as a guide since they do not account for the synergies that can be utilised in the energy system. For example, the electricity price for heat pumps and electric heating could vary significantly depending on the mix of technologies for electricity production. Here these unit prices are used as guide and compared with the unit cost of heat savings to establish an initial estimate for the level of heat savings feasible in each country.

Figure 12 displays these unit costs of heat supply against the unit costs of heat savings identified in sections 2 and 3. The results indicate the level of heat savings can vary dramatically depending on the specific cut-off point that is defined and the country that is being considered. For example, if the lowest estimated cost of heat supply is chosen, then the level of heat savings is 0-60% depending on the country chosen, while if it is the highest cost of heat supply, then the level is 20-60%. This illustrates the dangers of using a unit cost approach when defining a specific level. However, on the contrary, the unit costs approach also provides some valuable insights.

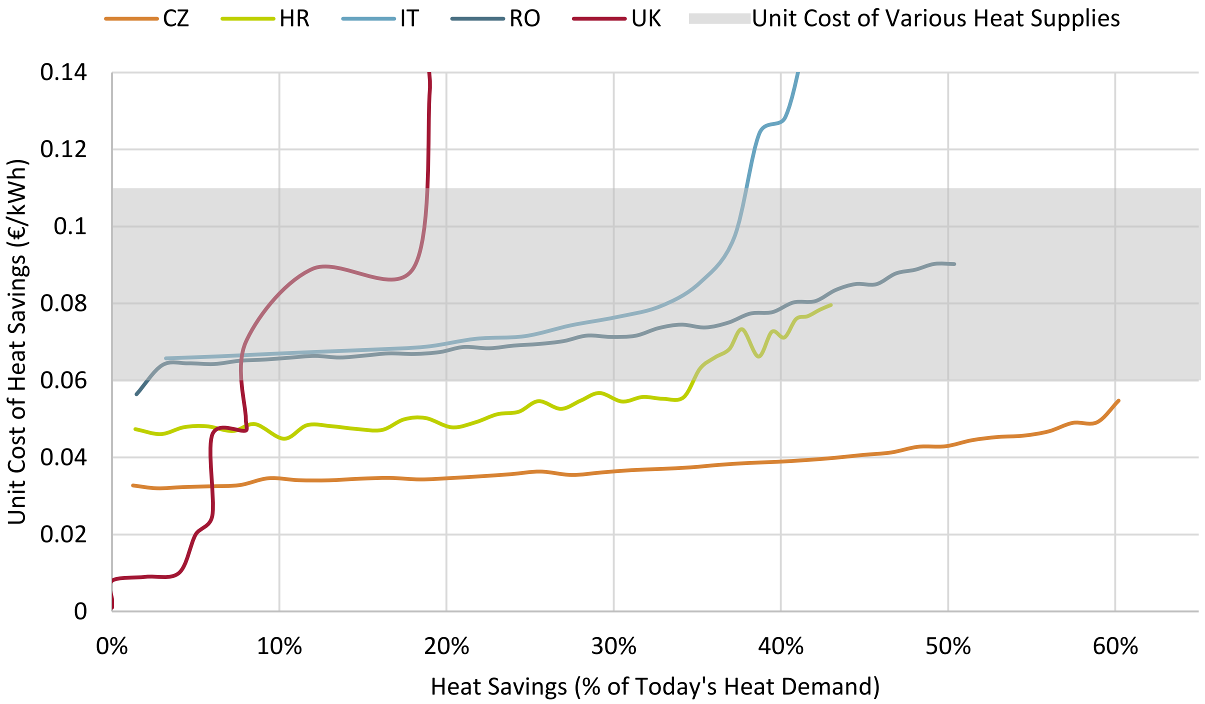

Figure 12: Comparison between the unit cost of heat supply and the unit cost of heat savings, along with the corresponding level of heat savings for each STRATEGO country. Note: today's heat demand refers to the year 2014 for Czech Republic, Croatia, Italy and Romania, but to the year 2010 for the UK.

Table 6: Heat Savings feasible in each country at based on the levelized cost of heat savings compared to the levelized cost of heat supply.

Heat Savings Feasible (% of Today's	Cost of Heat Supply €0.06/kWh	Heat Intensity (kWh/m²)	Cost of Heat Supply €0.11/kWh	Heat Intensity (kWh/m²)
CZ	60%	66	60%	66
HR	35%	70	45%	60
IT	0%	100	40%	55
RO	3%	120	50%	50
UK	10%	150	20%	130

**This is the maximum level of heat savings that is technically feasible even with very strong policy support between today and 2050 (see Background Report 3a).*

The results show that for four countries (UK, Croatia, Italy, Romania) the cost of renovations reaches a point in which it can be argued that it is cheaper to supply heat rather than install more heat saving measures. However, as shown in Figure 12, the Czech Republic is able to reduce its heat demand significantly at a relatively cheap cost, and it never crosses the threshold for the cost of supplying heat. There is a slight upward trend at the end of the modelled data, so if more heat saving measures are installed, then it is likely that the cost of heat savings would eventually surpass the cost of the heat supply for the Czech Republic, but this point is currently unknown,

For the four countries in the Ecofys analysis (see Background Report 3a), which are the Czech Republic, Croatia, Italy, and Romania, it is assumed as a starting point in the analysis that the level of heat savings is approximately 40-50%. Afterwards, the heat savings will be increased and decreased using an whole energy systems analysis approach with the EnergyPLAN tool, to establish the cheapest level of savings from an energy systems perspective.

The UK profile in Figure 12 is different to the other countries, since the cost of renovating the dwellings increases much faster, and overall less savings can be achieved with similar renovations measures (insulation and windows). The point at which the cost of heat savings surpasses the cheapest heat supply is at around 10% heat savings, which is at a heat intensity of 150 kWh/m^2, while it crosses the most expensive heat supply threshold at 20% heat savings, which is at a heat intensity of 130 kWh/m^2 (see Table 6). This is very different to the other countries, which is most likely related to the methodology. For example, some key considerations between the two methodologies are:

- The UK study does not consider new buildings or demolition of old buildings. The building stock remains the same in the study. In comparison, the Ecofys method increases the floor area every year since it considers demolition and new building rates, whereas the floor area in the UK remains the same
- The Ecofys method includes residential and service buildings, whereas the UK study includes only residential dwellings
- The Ecofys method calculates heat demand per year based on installation of insulation and windows every year, whereas the UK study calculates the savings from different measures as a total for the UK stock, and this does not consider the time horizon in which that occurs.
- The Ecofys study is based on a modelling tool that uses some key parameters, such as demolition rate, new build rate etc. Whereas the UK study is based on detailed analysis of the buildings stock and real-life potential for renovations and associated costs.

It is very unlikely that the UK varies this much from the other countries. In other words, it is unlikely that all other countries can potentially reach a heat intensity as low as 50-65 kWh/m^2, but the UK can only reach 130 kWh/m^2 (see Table 6). Due to these differences, the cost of heat savings in the UK is not based on the costs identified here in section 3. Instead, it will be assumed that the heat intensity in the UK can be reduced to a similar level as the other STRATEGO countries, which is conservatively assumed here to be 70 kWh/m^2, and that the cost of these savings measures in the UK is the average of the costs in the other four STRATEGO countries. Assuming a 70 kWh/m^2 corresponds to a total heat demand reduction in the UK of ~40%, while the average cost for the other four STRATEGO countries will only be available after the cheapest level of heat savings is identified in the energy system analysis in the main study for the other four countries. The level of UK savings will be varied at different levels in the same way as the other countries to see if this 40% level is a reasonable assumption from an energy system perspective, but again the corresponding costs will be the average of the other four countries and not the costs identified here in section 3.

5 Discussion and Conclusion

Identifying a balance between the cost of heat supply and heat savings is a very difficult task. When comparing unit costs, small changes in the assumptions can have a large impact of the level of heat savings defined as optimal. In addition, these numbers could potentially hide many of the challenges relating to the implementation. An extreme example could be an historical building where it is technically possible and economically viable to renovate from an energy perspective, but due to the cultural value of the building's façade, it is not possible to implement these measures. As a result, it is often important to go beyond the numbers when analysing the realistic level of heat savings that can be implemented in the future. Below are some reflections on the context of the numbers developed in this report.

Firstly, the numbers in Figure 12 and Table 6 are average numbers for the entire building stock, so there will be differences between the buildings in each country. For example, new buildings typically have a higher unit cost per heat saved than an existing building. For example, if you install a triple-glazing window with a very low insulation level in a new building, then it will be an improvement on the standard double-glazing window that usually goes into new buildings. However, if you put the same triple-glazed window into an existing building, then the window will cost the same price, but it will now most likely replace a single-glazed window in the exiting house rather than the double-glazed window that is typically in new houses. Therefore, for the same investment, you have obtained higher savings.

Furthermore, it is likely that more heat savings can be achieved in the rural areas than in urban areas, since the passive solar heat gain is usually higher for rural dwellings. For example, in the urban areas many buildings are located close together and the buildings can be four, five or more stories high, so the passive solar heat gain can be relatively low. Also, in rural areas it is easier to develop individual renewable heat sources such as solar thermal and solar PV, since there is more roof area per person available. This means that in the urban areas, there will likely be less heat savings on average, while in rural areas, there will likely be more heat savings on average.

Also, even if a lot of heat savings are implemented, it is still unlikely that the 'dispatchable' heat production unit can be removed completely (i.e. the boiler or heat pump). For example, to become a Net Zero Energy Building (NZEB) is not only a matter of heat savings, but it also typically requires some form heat supply. The main heat supply in a NZEB is often solar thermal or solar photovoltaic panels, but since their production is intermittent, some form of 'dispatchable' or 'controllable' heat supply is still necessary, since the space heating and/or hot water demands cannot rely solely on solar in the winter for example. For this, some typical options could be heat pumps, electric heating, boilers, or district heating. It is very unlikely that the 'backup' unit will ever be completely removed since there is a risk that the solar cannot supply the hot water when necessary. This is an important consideration since once the 'backup' unit is in place, the cost of supplying heat from the unit is much lower than if you also include the original investment cost.

Finally, it is important to appreciate that savings are usually an extremely economic solution for the energy system, since they eliminate the need for the rest of the supply chain, such as the fuel production, transportation, and maintenance. However, in some cases the heat supply available will take place with or without heat savings. For example, even if there is no heat demand in the buildings, there will still be excess heat available from the thermal power plants which could be used to heat the buildings. These synergies are only visible when the energy system is analysed from a holistic perspective in the main report.

In conclusion, the results in this study demonstrate that the cost of heat savings is likely to surpass the cost of heat supply as more heat savings are implemented. However, this economic balance between heat savings and heat supply is still unclear after comparing the unit cost of heat supply and the unit cost of heat savings. The balance varies significantly depending on the country and on the cut-off point defined for the cost of heat supply. Therefore, instead of defining an exact level here, the unit costs are used as a starting point when analysing different levels of heat savings in each of the STRATEGO countries.

Although a literature review was carried out to identify specific costs for the UK, these results were significantly different to those reported in Background Report 3a for the other four STRATEGO countries. Therefore, the scale and cost of heat savings in the UK is based on the average cost of heat savings from the other four countries.

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