Preparatory Studies for Ecodesign Requirements of EuPs (III)

ENER Lot 21 – Central heating products that use hot air to distribute heat
Task 8: Scenario, policy, impact and sensitivity analysis

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Task 8: Scenario, policy, impact and sensitivity analysis

8.1 Introduction

This task summarises the outcomes of all previous tasks and tries to identify a suitable policy, which will allow achieving potential reduction of environmental impacts with consideration to Least Life Cycle Cost (LLCC) and the Best Available Technology (BAT). A scenario is proposed where various minimum energy performance standards are enforced in two different tiers. The scenario tool allows examining and quantifying the improvement potential for the time period of 2010-2030.exist

Although Tasks 1-7 set the foundations for future work to be carried out by the European Commission and stakeholders, Task 8 presents a summary of policies that the authors of the report believe to be of use in order to achieve the desired reduction of the environmental impacts of air-based central heating products. The sensitivity analysis of the key parameters is carried out in order to examine the robustness of the results.

Note that the policy recommendations provided are the opinions of the consultants and do not reflect the views of the European Commission.

8.2 Policy analysis

8.2.1 Subject matter, scope and product definitions

The scope of the proposed policy measures will cover all the products defined below:

- Central (warm) air heaters: devices that generate heated air in a central location and then distribute the air through ductwork to one space or several spaces in a building. The heat is generated in a furnace fuelled by gas, oil, or electricity. Central air heaters are equipped with one or more blowers to circulate air through the duct distribution system.
  Residential and non-residential warm air heaters are included within this group of warm air heaters. The policy options discussed in this task are common for both ranges, since there is no major difference in efficiencies and technologies between these two product categories. As seen in Task 2, the larger warm air heaters for residential applications are around 65 kW of heating capacity. As presented in Task 1, some standards for central warm air heaters have an upper limit of 70 kW of heat input for "domestic" warm air heaters. Therefore, if a distinction between residential and non-residential warm air heaters is to be done, this could be set at 70 kW of heat input.

  The following types of centralised warm air heaters are included:

  - Central gas warm air heaters (heat is generated by combustion)

    - Central oil warm air heaters (heat is generated by combustion)
    - Central electric warm air heaters (heat is generated by the Joule effect in electric resistance heating elements)

- Heat pumps: devices designed to provide heat to an enclosed space by means of a thermodynamic cycle that extracts heat from a medium (air, water or ground) and release it into one or several remote spaces. It may have means for heating, cooling, circulating, cleaning and humidifying the air. Where such equipment is provided in more than one assembly, the separate assemblies are to be used together. The heat pumps above 12 kW nominal cooling capacity of the following types are included:
    - Split heat pumps
    - Air-to-air heat pumps
    - Water-source to air heat pumps
    - Ground-source to air heat pumps
    - Gas engine air-to-air heat pumps

The following equipment is proposed to be excluded from the scope of the proposed policy measures:

- Cogeneration units: appliances designed to provide heat and power as a result of a fuel (solid fuel, oil or gas) combustion process.
- Biomass and solid fuel warm air heaters: appliances that provide heated air by combustion of solid fuels or biomass (already considered in ENER Lot 15).
- Local room heaters /decentralised independent space heaters: appliances designed to heat the indoor space in which they are located. Independent space heaters can be equipped with blowers to distribute the heat into the space, but air is not distributed to remote spaces through ducts. Some independent warm air space heaters can be connected to a duct and thereby become central air heaters. Any policy measures in this case will then be aligned with ENER Lot 20.
- Air handling units: appliances designed to perform one or more of the following functions: circulation, filtration, heating, cooling, heat recovery, humidification, dehumidification and mixing of air. The unit should be capable to be used with ductwork.

The maximum capacity limit proposed for the scope of the recommended measures is 400 kW of nominal heating capacity. This follows the market analysis presented in Task 2 of this preparatory study, which shows that the share of products above 400 kW of heating capacity is negligible. The market shares in Task 2 show that there are no residential warm air heaters above 400 kW of heating capacity. 10% of the market for non-residential applications are above 400 kW heating capacity. Non-residential central warm air heaters are around 53% of the EU stock of central warm air heaters, which means that the share of the products above 400 kW of heating capacity is around 5.3% of the total.

Market shares in Task 2 show that VRF systems over 200 kW are around 2% of the market, and single split above 25 kW is 5% of the market. No gas engine heat pumps above 200 kW have been identified on the market. The limit of 400 kW of heating capacity is also aligned with the other Ecodesign heating lots: ENER Lot 1, ENTR Lot 6 and ENER Lot 20.

Before the finalisation of this preparatory study, the DG Environment of the European Commission requested a discussion on the possibility of extending the scope of the proposed implementing measures to a maximum heating capacity limit of 1 MW. This possibility would undermine air emissions regulations from combustion installations. In such a scenario, the combustion processes for heating would be regulated under the Ecodesign Directive up to 1 MW of heating capacity and larger installations would be covered by a potential revision of the Directive 2001/80/EC (which currently covers plants over 50 MW).

It is feasible to extend the scope of the implementing measures. In that case, all aspects proposed to be regulated in the present document (i.e. energy efficiency, emissions into air, noise power levels, refrigerants, waste/recycling) should be regulated with the same scope limits:

- Central warm air heaters: 4 kW to 1 MW of heating capacity.
- Heat pumps: 12 kW to 1 MW of heating capacity.

As previously mentioned, the market for warm air heaters greater than 400 kW represents around 5% of the total market, and VRF systems over 200 kW represent around 2% of the total market. Therefore, little information is available on these products and their ability to achieve the similar requirements as the smaller products. In the case of heat pumps, high heating capacities are usually reached by combination of several units rather than constructing just one big unit. In that case, the fulfilment of the requirements proposed should not be a problem for these products. The individual products higher than 400 kW are mostly engineered, made under request with very specific characteristics. The feasibility of the proposed requirements should be confirmed once standardised data from the industry will be available.

The standardisation efforts for harmonising energy efficiency, noise power levels, refrigerant charges, and emissions to air should include these high capacity ranges.

The policy measures proposed in this document are closely related to other potential policy measures on space heating and air conditioning, as explained in Task 1 report of this preparatory study. Other products that share the same functionality (i.e. space heating) as the products in the scope of this document are the following:

Table 8—1: Ecodesign preparatory studies with products related to the scope of the products covered in this study

Product	Ecodesign preparatory study
Reversible air conditioners >12 kW cooling capacity	ENTR Lot 6
Air handling units	ENTR Lot 6
Reversible air conditioners <12 kW cooling capacity	ENER Lot 10
Central water-based space heating	ENER lot 1
Local room heating products	ENER Lot 20
Solid fuel combustion installations	ENER Lot 15

Of these product groups, ENTR Lot 6 shares part of the scope of products with the present policy recommendations (i.e. heat pumps). ENER Lot 20 shares also part of the scope of products covered in this document (i.e. warm air heaters).

The policy recommendations presented in this document are aligned with the recommendations for heat pumps/reversible air conditioners in ENTR Lot 6 and warm air heaters in ENER Lot 20.

It is the aim to develop a common Ecodesign measure for central air heating and central cooling products. Such a measure would include reversible air conditioners, chillers and cooling products in ENTR Lot 6 and heat pumps in ENER Lot 21.

Central Warm Air Heaters are proposed to be aligned with any measures issued from ENER Lot 20 on warm air decentralised heating. Although not consistent from the point of view of functionality, this is logical from the point of view of product development. Centralised and decentralised warm air heaters share the same technical principles even if their applications might be different.

Furthermore, the same structure of regulation used for domestic reversible air conditioners and central space heating is followed in the present policy recommendations.

8.2.2 Ecodesign requirements

The Ecodesign requirements discussed hereafter are proposed in a provisional timetable following the common practice in past ecodesign studies and their regulation:

- 1st tier: 2015 or two years after the approval of the proposed implementing measures
- 2nd tier: 2017 or four years after the approval of the proposed implementing measures
- 3rd tier (optional): 2019 or six years after the approval of the proposed implementing measures.

For all the ecodesign requirements recommended in this section, atleast two tier levels are proposed, and for some requirements the third tier is proposed as well.

8.2.2.1 Energy efficiency requirements

It is recommended to set minimum efficiency performance standards (MEPS) for the following products:

- Central gas warm air heaters
- Central oil warm air heaters
- Central electric warm air heaters
- Air-to-air heat pumps
- Water-source to air heat pumps
- Ground-source to air heat pumps
- Gas engine air-to-air heat pumps

Central warm air heaters

For central warm air heaters, two alternatives of energy efficiency requirements are proposed:

- Alternative 1: MEPS in annual energy efficiency in primary energy
- Alternative 2: MEPS in thermal efficiency based on Gross Calorific Value

The annual efficiency in primary energy is calculated[1] as follows:

$$\text{(1)} \qquad \textit{Annual energy efficiency} = \frac{Q}{Eprim}$$

$$\text{(2)} \qquad E_{prim} = \frac{\frac{Q}{\eta_{temp} * \eta_{em}} + \textit{heat losses}}{(\eta_{gen} + \Delta\eta_{ctr})} + Q_{pilot} + Q_{start} + f_{aux} * f_{p,aux}$$

Where,

E_{prim} is the annual primary energy consumption
Q is the reference annual heating demand, expressed in kWh
η_{temp} is the room temperature control efficiency
η_{em} is the efficiency of the heat emission in the room
"heat losses" includes purge losses, jacket losses and losses from the ducts
η_{gen} is the thermal efficiency of the heat generation (provided by manufacturers)
$\Delta\eta_{ctr}$ is the influence of capacity controls in the thermal efficiency
Q_{pilot} and Q_{start} are the heat losses of the pilot flame and the unburnt fuel at start-up
f_{aux} is the auxiliary energy consumed
$f_{p,aux}$ is the primary energy factor for electricity

More details about this calculation method can be found in Task 5 of this preparatory study.

Gas and oil warm air heaters have similar technical characteristics and functioning. Although the combustion process and the burner are different, the combustion efficiency and the annual efficiency are similar for gas and oil warm air heaters. Oil heaters can however present higher auxiliary electricity consumption than gas heaters.

This is not the case for electric warm air heaters. Although the heat generation efficiency in electric heaters is 100%, the annual efficiency in primary energy of these heaters is much lower, due to losses in the electricity grid. Using the same method as for fuel heaters and the formulas (1) and (2), an electric heater with similar characteristics as the Base-Case studied in Task 5 has an annual efficiency of 34%. Even though the market share of electric central warm air heaters in the EU is supposed to be small, in order not to leave any legislative loopholes, it is thus proposed to set MEPS for these products based on the efficiency of the Base-Case.

[1] Following the energy consumption calculations performed in Task 5 of this preparatory study

The proposed MEPS in annual efficiency for centralised warm air heaters are presented in Table 8— 2.These MEPS are based on the analysis of Base-Cases and improvement options performed in Tasks 5, 6 and 7 of this preparatory study.

Table 8— 2: Proposed MEPS for central warm air heaters (alternative 1)

	Annual energy efficiency in primary energy based on GCV	
	Tier 1: 2015	Tier 2: 2017
Gas and oil central warm air heaters	73%	79%
Electric central warm air heaters	34%	34%

However, the annual energy efficiency calculation method presented here is not standardised and there is no equivalent standard at EU level; therefore, as stated in section 8.2.5.2 the development of such a standard is required before the enforcement of the MEPS presented in Table 8— 2.

Alternatively, while an appropriate standard for annual efficiency is developed, the Minimum Energy Performance Standards can be established in terms of net thermal efficiency tested following the standard EN 1020. The MEPS are proposed in two steps following the efficiency values of the Base-Cases selected in Task 5 and the outcomes of the ENER Lot 20 preparatory study.

Table 8— 3: Proposed MEPS for central warm air heaters (alternative 2)

	Minimum thermal efficiency based on GCV [%]	
	Tier 1: 2015	Tier 2: 2017
Gas and oil central warm air heaters	82%	90%
Electric central warm air heaters	100%	100%

As mentioned, it is the aim to have the proposal for Ecodesign measures for warm air heaters that is aligned with independent space heaters in ENER Lot 20.

The analysis of improvement options also showed some potential for room temperature, air distribution and burner controls to reduce the consumption of energy. These parameters affect the energy consumption of the product but are not reflected in the net thermal efficiency. Room temperature controls and air distribution controls are not always part of the product. Instead it should be considered how manufacturers can provide relevant information to encourage efficient use of the central warm air heaters.

One of the key factors to ensure energy efficient warm air heating is the correct dimensioning, design and installation of the specific heating system in a building. It is therefore recommended to set requirements of minimum information that the manufacturers should provide to designers/installers.

Heat pumps

For heat pumps, the energy efficiency parameter is the SCOP (Seasonal Coefficient of Performance) as defined in the standard prEN14825. The standard prEN14825 includes the method for calculation of SCOP, which is explained and used in Task 5 of this preparatory study:

(1) $$SCOP = \frac{reference\ annual\ heating\ demand}{annual\ electricity\ consumption}$$

(2) $$AEC = \frac{Q_e}{SCOP_{on}} + H_{to} * P_{to} + H_{sb} * P_{sb} + H_{ck} * P_{ck} + H_{off} * P_{off}$$

(3) $$Q_e = P_{design} * H_e$$

(4) $$SCOP_{on} = \frac{\sum_{j=1\,j}^{n} \cdot P(T_j)}{\sum_{j=1\,j}^{n} \cdot \left(\frac{P(T_j) - elbu(T_j)}{COP(T_j)} + elbu(T_j)\right)}$$

Where,

Q_{he} is the reference annual heating demand, expressed in kWh

AEC is the annual electricity consumption

H_{to}, H_{sb}, H_{ck} and H_{off} are the number of working hours in thermostat off mode, standby mode, crankcase heater mode and off mode, respectively

P_{to}, P_{sb}, P_{ck} and P_{off} are the electricity consumption during thermostat off mode, standby mode, crankcase heater mode and off mode, respectively

$SCOP_{on}$ is the seasonal efficiency of a unit in active mode

P_{design} is the full load capacity in heating mode

H_{he} is the number of equivalent hours per year in heating mode

T_j is the bin temperature

J is the bin number

n is the amount of bins

$P_h(T_j)$ is the heating demand of the building in kW for the corresponding temperature T_j

h_j is the number of bin hours occurring at the corresponding temperature T_j

$COP(T_j)$ is the COP value of the unit for the corresponding temperature T_j

elbu is the capacity in kW of an electric backup heater with a COP of 1

More details about this calculation method can be found in Task 5 of this preparatory study.

The proposed MEPS for heat pumps are presented in Table 8— 4. These MEPS are based on the analysis of Base-Cases and improvement options performed in Tasks 5, 6 and 7 of this preparatory study. As mentioned, it is the aim to have a proposal for Ecodesign measures for heat pumps that is aligned with ENTR Lot 6.

The MEPS are proposed for air-to-air heat pumps, water-source to air heat pumps, and ground-source to air heat pumps. According to the results of the study, the market of water-source and ground source in the EU is not significant compared to air-to-air heat pumps. Johnson Controls manufactures and commercialises ground-source and water-source air heat pumps in the US between 2 kW and 23 kW of heating capacity. Mitsubishi Electric commercialises water-to-air heat pumps certified within the Enhanced Capital Allowance Scheme from the UK. Therefore, in order not to let any legislative loopholes, these types of heat pumps are also included within the scope of the implementing measures. The efficiency of these heat pumps is similar and can even be higher than air-to-air heat pumps, but the installation and maintenance costs can be higher. The requirements of the Enhanced Capital Allowance Scheme in the UK for water-source heat pumps are more ambitious than those for air-to-air heat pumps. (COP of 3.70 against COP of 3.60).

Little information exists on the efficiency of gas-engine heat pumps. Nevertheless, they could be included in the scope of implementing measures proposed in this document, in order not to leave any loopholes in the legislation. Using the Primary Energy Factor of electricity (i.e. currently 2.5), the same MEPS proposed for electric heat pumps have been applied to calculate the MEPS for gas-engine heat pumps. A similar testing and calculation method as for electric heat pumps can be used, but the development of an official standard is of pertinent (see section 8.2.5.2).

Together with seasonal energy efficiency requirements, it is recommended to establish as well requirements on full load efficiency. This requirement would prevent drawbacks of the design optimisation for part load efficiency and also assures that heat pumps that mostly work at full capacity also are energy efficient. The recommendation of MEPS at full load is based on the current standard EN 14511, which establishes testing conditions of heat pumps at full load. The minimum energy performance standard at full load proposed for 2015 are the same as the Base-Cases analysed in Task 5 of this preparatory study. The increase in SCOP from tier 1 to tier 2 is used to calculate the proposed MEPS at full load for 2017.

Table 8— 4: Proposed MEPS for heat pumps

	Minimum energy performance standards			
	Tier 1: 2015		Tier 2: 2017	
	COP (EN 14511)	SCOP (pr EN 14825)	COP (EN 14511)	SCOP (pr EN 14825)
Split electric heat pumps (including VRF)	3.34	3.2	3.65	3.5
Split gas-engine heat pumps	1.34	1.3	1.44	1.4

8.2.2.2 Potential requirements for emissions into air

Air quality is a key environmental issue, especially in densely populated areas. The combustion processes of some heating products such as warm air heaters or gas engine heat pumps have direct emissions during the use phase, which could contribute to poor ambient air quality. The implementation of emission limit values (ELV) of NO_x and other air pollutants for heating products with direct emissions could therefore be considered.

Little information has been found on emissions of warm air heaters and gas engine heat pumps due to the lack of standardised data. Manufacturers claim that although NO_x emissions are tested for heaters, they are difficult to measure and very dependent on local conditions and fuel quality. The environmental impacts of emissions to air assessed in Task 5 of this preparatory study are based on generic life cycle inventories rather than real test data from manufacturers, so they can only be seen as a rough indication of the life cycle impacts.

There exist testing methods and standards for gas and oil boilers to measure NO_x emissions. These can be extended to warm air heaters, but currently these are not covered in the standard. It is therefore proposed to align any recommendations for NO_x ELV with ENER Lot 1 for the second and third tiers as burners used in warm air heaters are similar to the burners used in boilers, although the heating medium and heat exchangers are different. In the first tier only information requirements are set.

Gas engine heat pumps are also similar to those connected to hydronic heating systems, and therefore are included in the same requirements. There is limited information regarding the emissions of liquid fuelled warm air heaters and heat pumps for the proposition of other tiers than those based on ENER Lot 1 for the second tier.

Following the proposal of Ecodesign regulation for boilers preparatory study, the ELV for central air-based heating products are presented in Table 8-5.

Table 8— 5: Proposed ELV of nitrogen oxides for warm air heaters

Type of heater	mg/kWh fuel input in terms of *Gross Calorific Value*[2]		
	Tier 1: 2015	Tier 2: 2017	Tier 3: 2019
Warm air heaters using gaseous fuels	-	70	70
Warm air heaters using liquid fuels	-	120	120
Heat pump space heaters equipped with external combustion using gaseous fuels	-	70	70
Heat pump space heaters equipped with external combustion using liquid fuels	-	120	120
Heat pump space heaters equipped with internal combustion engine using gaseous fuels	-	240	240
Heat pump space heaters equipped with internal combustion engine using liquid fuels	-	420	420

Regarding the NOx ELV for gas engine heat pumps, DG ENV suggested some lower limits following results of a research carried out by the US NREL[3]: Some improvements have been made in reducing NOx emissions from natural gas engines (from 2004 to 2007 the EPA limit for

[2] Some stakeholders expressed their concerns about establishing ELV in relation to fuel input instead of heat output capacity. If using heating capacity as a reference, the efficiency of the heat generation would be taken into account. However, the ELV proposed follow the current standardised testing methods for NO_x emissions in boilers, which can be applicable to warm air heaters.

[3] US National Renewable Energy Laboratory (2004) Demonstration of a Low-NOx Heavy-Duty Natural Gas Engine.

NO_x was reduced by about 40%, from 2007 to 2010 by about 60%). This would suggest that by 2015 it might be feasible to lower the emissions to around 200mg/kWh energy input for gas engine heat pumps, and by 2019 to around 120mg/kWh.

However, this research was carried out for a gas motor over 300 kW of capacity, and it is not clear whether it would be applicable to smaller gas engine heat pumps around.

On the other hand, some manufacturers of gas engine heat pumps and industry associations suggested ELV of around 380 mg/kWh-ouput (which would be 270 mg/kWh-input) or a starting value of 500 mg/kWh-output (which would be 360 mg/kWh-input) and a gradual reduction to 350 mg/kWh-output (which would be 250 mg/kWh-input).

It is suggested that the values proposed in Table 8-5 are revised once a standard for testing gas engine heat pumps and test results are available (see recommendations in section 8.2.5.1 on Information requirements and section 8.2.5.2 on Standardisation mandates).

Regarding CO, HC, particular matter and other pollutants it has not been possible to establish ELV due to the lack of data. A standardisation mandate for the development of appropriate test standards for air emissions could be proposed, as it could help establish the emissions related with air-based heating products. The needs for standards are discussed in section 8.2.5.2. Nevertheless, the harmonisation of the different regulations regarding pollutant air emissions is a key issue. The proposal of implementing measures for central heating boilers does not include other ELV than for NO_x. If ELV have to be set for CO, HC and particular matter, these should include all heating products fired by fuel (see Table 8-1).

In section 8.2.3, the requirements from the Blue Angel ecolabel for gas heat pumps connected to hydronic systems are presented. However, these emission limits for NO_x, CO and dust could be used as reference for gas-engine driven air-to-air heat pumps and warm air heaters, since the fuel combustion is similar and the values are given in kWh of fuel input. It has to be noted that these criteria are a requisite for ecolabel certification, which is supposed to award the "best-in-class" products, and would not be achievable by all the products in the market.

8.2.2.3 *Potential noise requirements*

It is recommended to set noise emission requirements for the following products:

- Central gas warm air heaters
- Central oil warm air heaters
- Central electric warm air heaters
- Split heat pumps:
    - Air-to-air heat pumps
    - Water-source to air heat pumps
    - Ground-source to air heat pumps
    - Gas engine air-to-air heat pumps

For all non-ducted heat pumps, the noise requirements proposed are presented in Table 8— 6. The noise requirements are the same as those proposed as Ecodesign requirements for heat pump heaters.

Table 8— 6: Proposed noise requirements for non-ducted heat pumps

Type of heat pump	Maximum sound power levels					
Rated heat output	Tier 1: 2015		Tier 2: 2017		Tier 3: 2019	
	Sound power level (L_{WA})					
	indoor measured	outdoor measured	indoor measured	outdoor measured	indoor measured	outdoor measured
> 12 kW and ≤ 30 kW	70 dB	75 dB	69 dB	74 dB	68 dB	73 dB
> 30 kW and ≤ 70 kW	80 dB	85 dB	79 dB	84 dB	78 dB	83 dB

For ducted heat pumps and centralised warm air heaters, the noise requirements proposed are presented in Table 8— 7.

Table 8— 7: Proposed noise requirements for ducted heat pumps

	Maximum sound power levels for indoor ducted units		
	Tier 1: 2015	Tier 2: 2017	Tier 3: 2019
Cooling capacity	Sound power, (L_{WA})		
12 < Cool. cap < = 17.5	70 dB	69 dB	68 dB
17.5 < Cool. cap < = 40	80 dB	79 dB	78 dB
40 < Cool. cap < = 70	85 dB	84 dB	83 dB

As discussed in Task 5, information on sound emissions is common practice regarding heat pumps. Yet, many manufactures publish figures in sound pressure/intensity level for indoor units rather than sound power levels. Manufacturers should either use EN 10102 standards for determining sound power levels or, EN 3741 for both the indoor and outdoor units.

The sound levels recommended above are proposed for three tiers, and are within the sound level ranges claimed by the manufacturers as described in Task 5. The second and third tiers follow the natural improvement trend observed in the market. During past 8 years the sound power level has reduced by 4-5 dB. This means a reduction of around 1 dB every two years. However, should a regulation on sound emissions be put in place, a market study should be carried out for its revision by incorporating the standardised data from manufacturers whenever it is available. For heating capacities higher than 70 kW the construction of outdoor units is usually composed of parallel units of smaller capacities, which would already be affected by the proposed limits.

Regarding warm air heaters, the indoor noise emissions are due to the fans and air friction against ducts and filters. These are already covered within the preparatory studies on residential and tertiary ventilation (ENER Lot 10 and ENTR Lot 6), so no implementing measure is proposed in this regard. Nevertheless, it is proposed that the noise levels of warm air heaters to be measured according to DIN EN 3744 to provide the information to the customers.

8.2.2.4 Potential refrigerant requirements

The choice of refrigerant can influence the performance of heat pumps. Refrigerants are important with respect to energy efficiency and greenhouse gas emissions. Often, a trade-off must be made between both parameters, when choosing refrigerant. As shown in the sensitivity analysis carried out in Task 5, the direct emissions of refrigerants can represent a significant share of the total equivalent warming impact over the entire life cycle, depending on:

- the GWP of the refrigerant;
- the horizon to which the GWP is calculated (e.g. 100 years, 20 years, etc.); and,
- the refrigerant leaks during the lifetime and at the end-of-life of the products.

With the assumptions agreed with the industry stakeholders of this preparatory study (see Task 5), the direct CO_2 emissions from the refrigerant do not represent a significant impact compared to the TEWI.

One of the options to reduce this environmental impact is to reduce the refrigerant emissions. Therefore, it is recommended to propose a revision of the EPBD requirements for annual inspection to cover air conditioning for heating and warm air central heating systems.

Other alternative is the use of refrigerants with lower global warming potential (GWP) that do not affect negatively the energy efficiency of the heat pump. In Task 6 and Task 7 of this preparatory study, different alternative refrigerants are analysed, and their potential benefits and drawbacks are discussed. As a result, it can be concluded that even if there are some promising fluids (e.g. R-32, R290, R717, R744 or R-1234yf, among others), none of them are at present an "easy-win" solution for the heat pumps analysed in this study. The benefits and drawbacks of each refrigerant fluid are discussed in Tasks 6 and 7, and will not be repeated here.

Further development of alternative refrigerants and safety technologies - or a revision of the refrigerant charge limits in the existing standards and legislation to adequate them to the state-of-the-art of safety technologies - would be desirable. This would help reduce the direct impacts of potential refrigerant leaks. Therefore, the best way forward could be a policy option that promotes the development of alternative refrigerants and at the same time increases the efficiency of the products.

Therefore, a bonus system is proposed for the use of low GWP refrigerants in all heat pumps considered in the scope of these policy recommendations. There are two main points in this policy option: the GWP limit of the refrigerant, and the extent of the bonus in terms of energy efficiency. The policy should be simple and compatible with other policies in the area, such as the

F-Gas regulation or ecolabels. For example, the bonus system is a method already used in the current EU Ecolabel requirements for heat pumps.

Another option has been proposed to the project team: the establishment of TEWI limits per heating capacity of the product. This option could be promising, as the TEWI includes the impacts derived from energy consumption and those due to refrigerant emissions. However, the calculation of the TEWI implies the establishment of different assumptions such as refrigerant charge, leakage rates, product life, etc., that would make the results of different specific products not fully comparable. An alternative option to this TEWI limits would be to establish GWP limits per product on GWP*kg of refrigerant. This option would avoid having to make assumptions on refrigerant charge, leakage, energy consumed, etc., that influence the TEWI results. However, this method would penalise heat pumps with higher capacities and longer refrigerant pipes, which is not always something a manufacturer can influence, but is up to the designer or the installer.

Finally, as the refrigerant leaks and length of the pipes (and thus total refrigerant charge of the system) are not always under the control of the heat pump manufacturers, the best option to reduce the impact of the direct refrigerant emissions is to reduce the GWP of the refrigerants used. This way, the charge and the leaks may vary depending on a number of variables, but the environmental impacts would be reduced.

The ideal target GWP would be zero or close to zero, but this should not be in detriment of the energy performance of the products. Likewise, the bonus or "benefits" of using low GWP refrigerants should not be too big since this could lead to lower efficiencies in the products and higher energy consumption. In the EU Ecolabel, the GWP limit for the bonus system is set at 150, and the bonus for lower GWP fluids is 15% reduction of the energy efficiency requirements.

Following the analysis of the previous tasks, a feasible limit based on currently available fluids and those in an advanced stage of development should be the best option. Thus, the GWP value of R32 is proposed as a reference for the bonus system.

Based on the conclusions of Tasks 6 and 7, a ban of some high GWP refrigerants is not recommendable in the short term, due to the lack of viable alternatives. In the long term, a ban of high GWP refrigerants could be considered.

Table 8— 8: Proposed refrigerant requirements for heat pumps

	Refrigerant requirements		
	Tier 1: 2015	Tier 2: 2017	Tier 3: 2019
Single split heat pumps and Heat pumps other than single split	If the refrigerant used in the heat pump has a GWP100 lower than that of R32 (i.e. 675) then the minimum requirements of the SCOP as set out in Table 8— 4, shall be reduced by 10 %.	As per Tier 1	The global warming potential over a 100 years period (GWP100) for the refrigerant must not exceed the GWP100 value of R32 (i.e. 675).

8.2.2.5 *Potential material/waste/recycling requirements*

Besides substituting traditional refrigerants with other refrigerants with lower climate change impacts, various material efficiency design options were considered in Task 6. These were:

- Reducing the material intensity, i.e. using less material for the same functionality (product lightweighting)
- Eliminating or reducing the use of harmful substances
- Increasing the amount of recycled and recyclable material, i.e. design for recycling
- Optimising the product's durability, i.e. increase the product's lifetime by making it durable, repairable and upgradeable (design for longevity)
- Substituting materials with materials that have smaller environmental impacts

Manufacturers claimed that the amounts of material used are based on careful design considerations regarding costs and performance (e.g. energy efficiency, durability). Besides having limited scope for improvement, it would be difficult to specify Ecodesign implementing measures for material intensity that could practically be implemented. Manufacturers claim that it does not make sense to specify the amount of material used in products as they are already motivated to identify the cost optimum of using as little material as possible while achieving the specified performance level. However, one may question whether manufacturers/designers are always fully rational in their decisions and behaviours when other considerations come into play. Inefficiency on allocation of material in the design phase could therefore occur. However, this study has not been able to investigate this issue any further.

The elimination and restriction of harmful substances are already covered under the Restriction of Hazardous Substance (RoHS) Directive[4]. Besides some refrigerants, no other harmful substances used in central air heaters were identified in this study.

Central air heaters are mostly composed of materials that have a high recovery and recycling value. Ecodesign implementing measures that either specify the amount of recycled content or increase the recovery and recyclability of materials could be proposed. Recycled content requirements have been set forth for EU Ecolabel criteria, but besides accepting self declaration, verifying that manufacturers comply with criteria on recycled content will require setting up appropriate audit and certification systems across the supply chain that currently are not in place. In addition, and in general, requirements related to recycled content are most effective for materials that have a low value after the recycling in order to stimulate the demand of those materials[5]. This is not the case for the products considered in this study, which are mostly made of metals that have relatively high scrap value.

Recovery and recycling rates could be increased further by both making it easier for recyclers to dismantle the products and identify the recyclable parts as well as increase the collection rates at the end of life. Based on this it could be considered to have material information requirements as

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[4] Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive (2011/65/EU)

[5] JRC (2011) Integrating resource efficiency and waste management criteria in Ecodesign - Review of resource efficiency and end-of-life requirements. European Commission, Joint Research Centre (JRC), Institute for Environment and Sustainability.

Ecodesign implementing measures. This would require manufacturers to clearly specify what materials are used in their products and which ones are considered recyclable. This is similar to the information document requirements of the End-of-Life Vehicles Directive[6]. In that case, manufacturers chose to develop a common database accessible free of charge for any commercial enterprise that handles end of life vehicles[7]. However, in the common practice this database is little used by dismantlers[8,9]. An alternative could be to include this kind of information within the technical specifications sheet of the product, and to mark the products and components with standardised identification codes.

Central air heaters have relatively long life times. In principle, there is a trade off between increased lifetime and energy efficiency as increasing the life time of these products further could compromise the potential achievable energy savings (due to keeping less energy efficient products in the installed stock for longer). This study has not investigated the size and net effect of such a trade off. Nonetheless, no implementing measures related to product durability and product life are proposed by this study.

Ecodesign implementing measures cannot specify the use of specific technologies or materials, so no policy option was identified to regulate the type of material used (besides those covered by RoHS).

One Ecodesign implement measure that could be proposed is to require manufacturers to demonstrate that all the relevant material efficiency issues have been considered during the design of their product. This could be similar to the requirements under the End-of-Life Vehicles Directive, where manufacturers "*should make available to the approval authority all relevant technical information as regards constituent materials and their respective masses in order to permit verification of the manufacturer's calculations in accordance with the standard ISO 22628"*[10]. This would require that relevant standards for central air heating products are put in place. Such an approach would not necessarily require a system of competent bodies to check compliance, but could be based on self-declaration when placing the product on the market. Market surveillance authorities could then simply verify the calculation and material composition of the products after they were placed on the market. This type of verification is similar to what is currently done for energy efficiency. Even though the potential for further material efficiency improvements were considered limited and some of the product types are only produced in relatively small numbers , this policy option could be a simple manner in which to draw attention to the material consumption of products.

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[6] Directive 2005/64 on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability and amending Council Directive 70/156/EEC

[7] www.idis2.com

[8] EC DG FOR INTERNAL POLICIES (2010) End of life vehicles: Legal aspects, national practices and recommendations for future successful approach

[9] GHK and BIO (2006) for EC DG ENV, A study to examine the benefits of the End of Life Vehicles Directive and the costs and benefits of a revision of the 2015 targets for recycling, re-use and recovery under the ELV Directive.

[10] ISO 22628 Standard for calculation of road vehicles recyclability and recoverability.

Instead, in order to increase the material efficiency and promote recycling, it is recommended to include the obligation for manufacturers/installers to have a take-back system for central air heating products and central cooling products at the end of their life. This could be done with the current obligation to recover refrigerants (as required by the F-Gas Regulation[11]). Alternatively, the scope of WEEE Directive can be revised and extended in order to include air-based central heating systems. This is already the case in some Member States. Here the producer is obliged to take back decommissioned products of a similar type and function (irrespective of brand) when it sells new equipment, if the equipment is placed on the market prior to 13 August 2005. If the customer is simply discarding the product and not replacing it with a new product, then the customer has the responsibility to ensure environmentally sound management of the product by using an appropriately authorised waste management operator. If the equipment is placed on the market after 13 August 2005, the producer must take back and manage the discarded product from the customer or make alternative financing arrangements with the customer, i.e. there must be a formal agreement between both parties on how and who will finance the waste management. The discarded product must be transported and managed by appropriately authorised waste management operators. This requirement would apply whether or not the equipment is being replaced.

However, in the opinion of some of the stakeholders, these types of products would not fulfil the criteria to be included within the scope of the WEEE Directive. Large equipment are not part of household waste (as EEE are) and are considered construction waste. Nevertheless, these products contain some valuable materials such as copper and aluminium. Therefore the current practice is that they are collected and the materials recovered[12].

8.2.3Indicative benchmarks

In this section, some indicative benchmarks are presented for the different product groups analysed in this preparatory study. These benchmarks can serve as guidelines for other policy measures such as Green Public Procurement and economic policy instruments. The setting of non-binding benchmarks would allow the comparison and evaluation of the environmental performance of products against the best performing products.

- **Energy efficiency benchmarks**

The energy efficiency benchmarks are analysed in terms of COP (for heat pumps) and thermal efficiency (for warm air heaters), since there is no approved standard yet for seasonal efficiency calculation. Therefore, there is no publicly available data on SCOP of heat pumps or annual

[11] Commission Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases

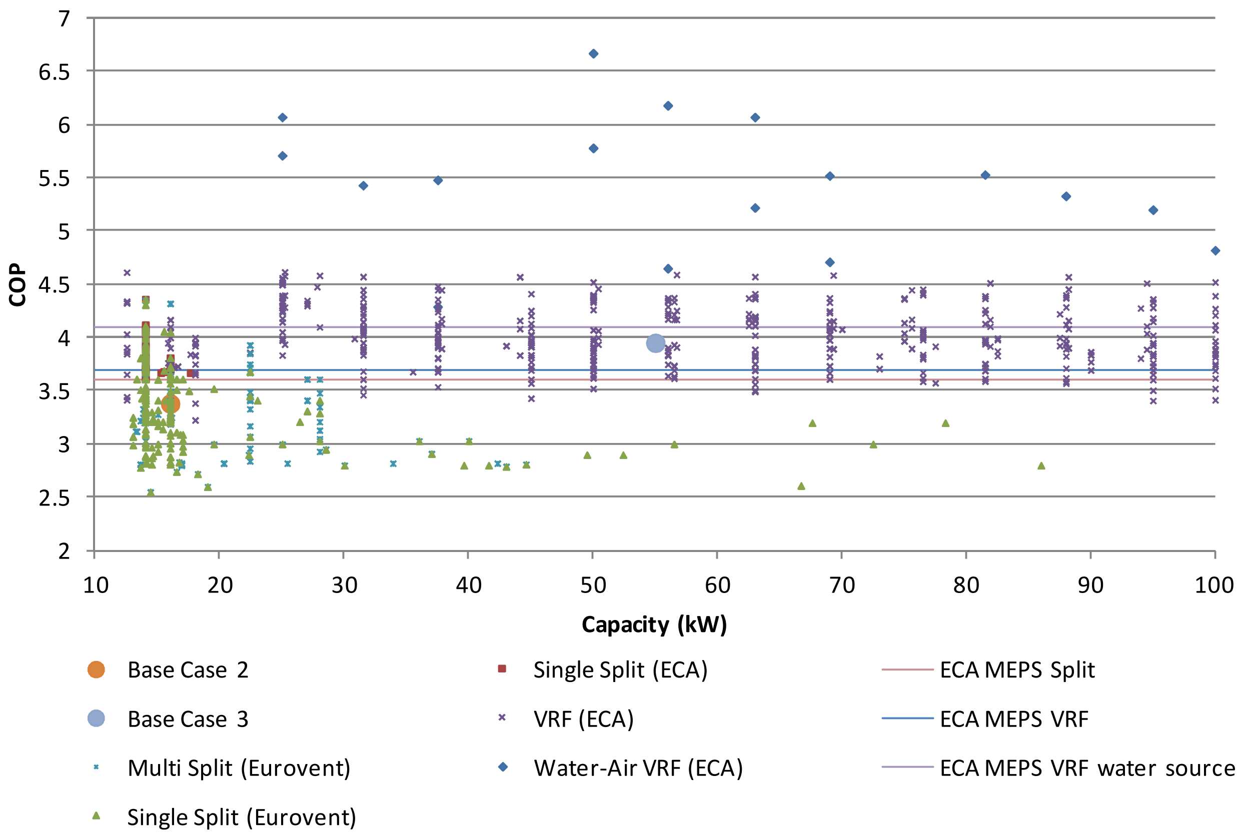
[12] According to a manufacturer, at the end of their life the refrigerants in heat pumps is recovered and then the product is shredded. Ferrous and non-ferrous fractions are separated by using a magnet. Flotation enables the separation of the different non-ferrous fractions. The rest fraction of a decommissioned heat pump represents only 14% of the original scrap unit waste. 81% of the material collected is ferrous, 4.6% is aluminium, 11.6% copper and 2.3% plastics (PP, ABS and PS).

energy efficiency of warm air heaters. COP and thermal efficiency are standardised and are currently used in the industry to provide information on the efficiency of the products.

The efficiency data presented in this section of benchmarks has been gathered from publicly available databases, e.g. the Enhanced Capital Allowance scheme in the UK and Eurovent Certification. These are certification schemes which are supposed to show some of the best performing products in the market. These databases do not give any information on the market share of each product, but only efficiency ranges of certified products. Therefore, the usefulness of this kind of benchmark is the indication of maximum feasible efficiency values that can be set as criteria or requisites for public procurement.

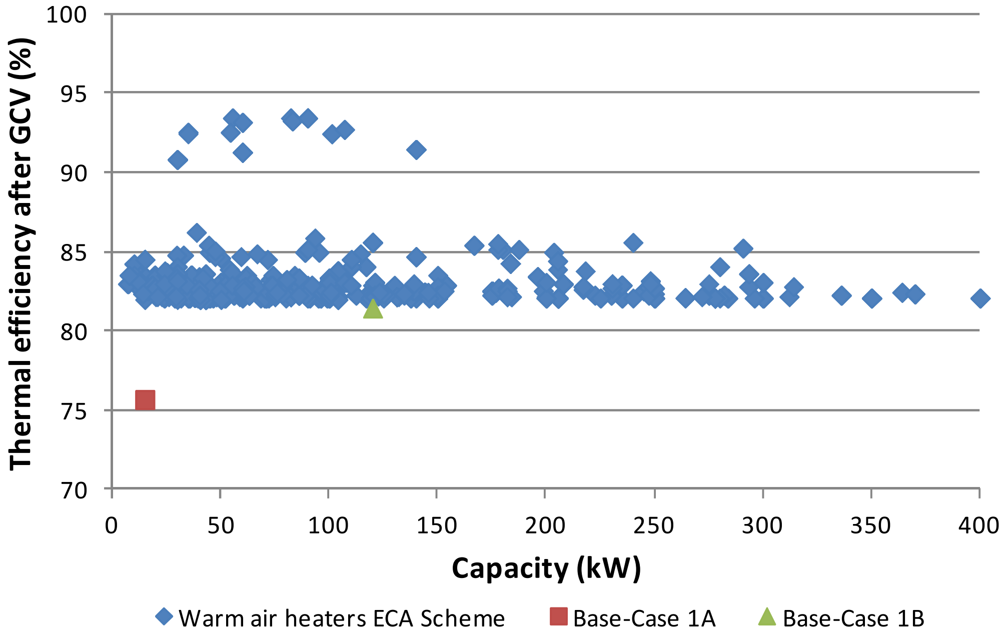
Figure 8-1 and Figure 8-2 show the efficiencies of different types of heat pumps and warm air heaters in the market, respectively.

Figure 8— 1: Efficiency of heat pumps



Considering the warm air heaters the state-of-the-art could be a thermal efficiency after Gross Calorific Value of around 93%. Regarding heat pumps, water-to-air heat pumps can reach COP values up to 6.6, VRF heat pumps can reach 4.5 COP, and single split and multi split heat pumps have maximum efficiencies of COP around 4.4.

Figure 8— 2: Efficiency of gas warm air heaters



Based on the market data at full load efficiency, the SCOP and seasonal efficiency benchmarks can be estimated by taking the Base-Case seasonal efficiency as a reference (see Task 5) and applying the benchmark's improvement ratio at full load. Nevertheless, these values need to be confirmed when standardised data from the industry is available.

Table 8— 9: Energy efficiency benchmarks

	Thermal efficiency based on GCV [%]	Annual efficiency based on GCV [%]
	Benchmarks	
Electric central warm air heaters Residential	93	76
Electric central warm air heaters Non-residential	93	63

	COP (EN 14511)	SCOP (pr EN 14825)
	Benchmarks	
Split electric heat pumps (including VRF)	4.5	3.2

- **Emissions benchmarks**

Regarding emissions to air, little information has been found on the performance of air-based heating products. However, some voluntary certification schemes present requirements for central air heating products regarding emissions to air. Table 8-9 presents the requirements of the Blue Angel environmental labelling scheme for heat pumps using absorption, adsorption or gas engine-driven compressors. These criteria apply for water-to-water, brine-to-water and air-to-water heat pumps, which are not covered in this preparatory study. Ecolabels are supposed to represent the “best in class” technology for a specific product group and enhance the best environmental aspects of product. Hence, it can be said that the requisites of these labels are close to the state of the art technology for air-to-air gas engine heat pumps and are presented as a reference of what can be achieved. Reaching those targets today can be difficult as the industry needs time to adapt its products. Further investigation into the air emissions of both heat pumps and warm air heaters is necessary for setting better reference requirements.

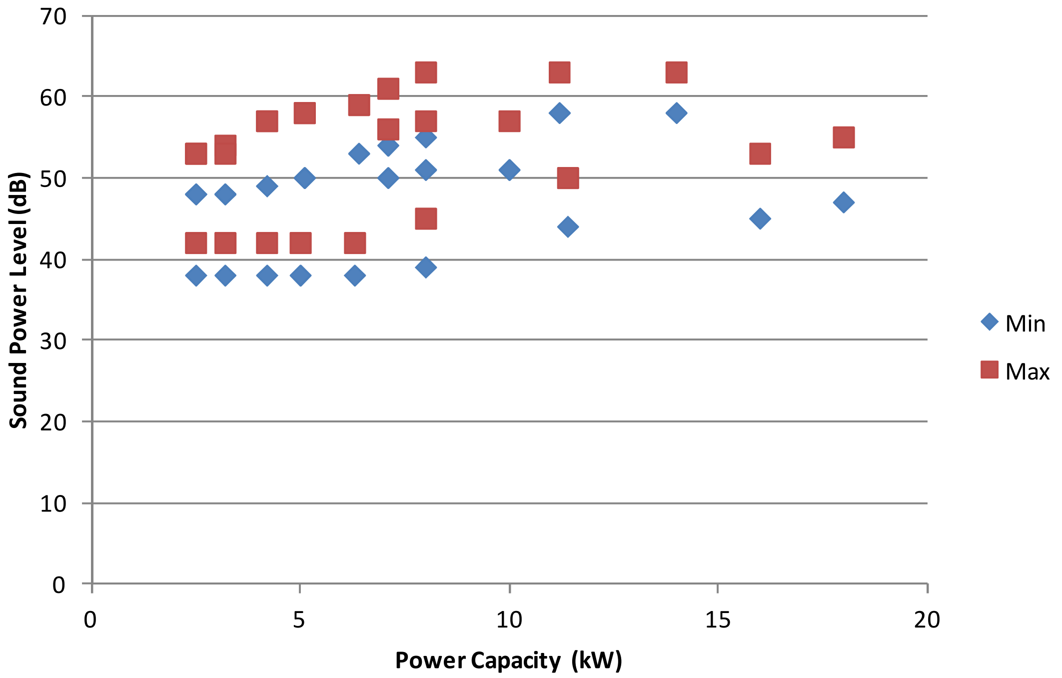
Table 8— 10: Blue Angel requirements for absorption, adsorption and gas-driven heat pumps

Requirements	Standard	Criteria
Emissions	Gas-fired heat pumps (0% of O_2)	$NO_X \leq 60$ mg/kWh $CO \leq 50$ mg/kWh
	Gas engine-driven heat pumps (5% of O_2)	$NO_X \leq 250$ mg/kWh $CO \leq 300$ mg/kWh
	Other combustion engine-driven heat pumps (O_2 content according to 1st BImSchV)	$NO_X \leq 250$ mg/kWh $CO \leq 300$ mg/kWh Total dust content ≤ 150 mg/kWh
	Heat pumps fired by other fuels (O_2 content according to 1st BImSchV)	$NO_X \leq 250$ mg/kWh $CO \leq 300$ mg/kWh

- Noise benchmarks

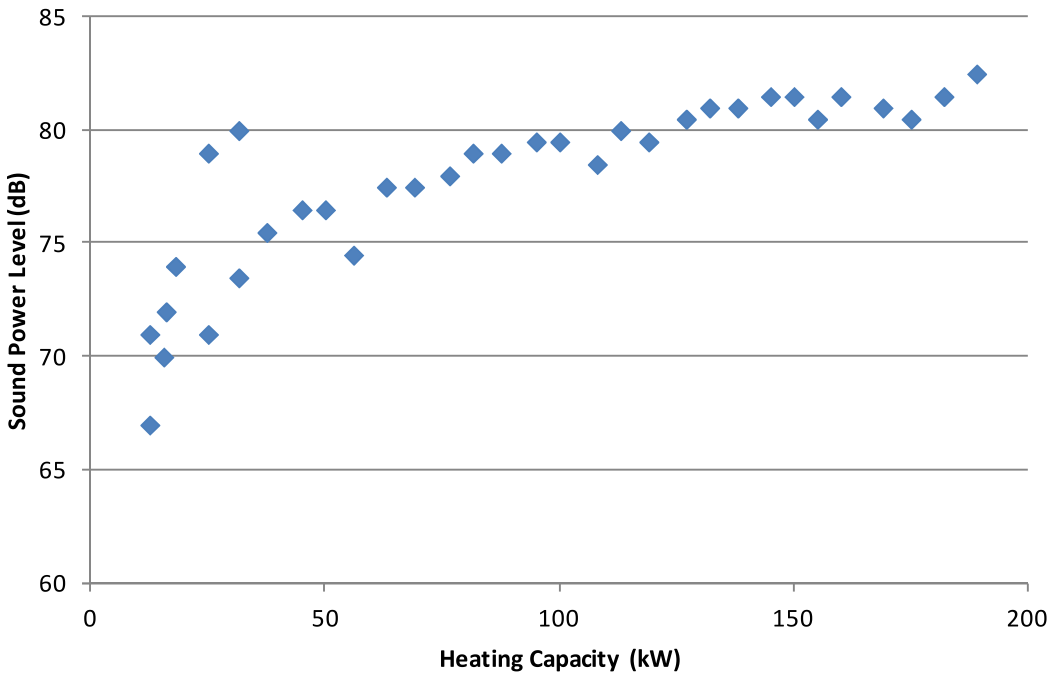
As presented in Task 5, based on market data it can be concluded that the state-of-the-art indoor unit for heat pumps produces a noise power level around 38 dB.

Figure 8— 3: Sound power levels as a function of capacity of indoor units used in VRF systems



The noise power levels of outdoor units vary with the heating capacity of the unit. For outdoor units between 12 kW and 20 kW of heating capacity, the minimum sound power level is 67 dB whereas for a unit between 45 kW and 56 kW of heating capacity, the minimum sound power level is 74.5 dB.

Figure 8— 4: VRF outdoor units - Sound power levels as a function of heating capacity



8.2.4 TWh saving potential

See Section 8.3 Scenario Analysis.

8.2.5 Other elements

8.2.5.1 Information requirements

One of the key factors to ensure energy efficient central air heating is the correct dimensioning, design and installation of the specific heating system in a building. It is therefore recommended to set requirements of minimum information that the manufacturers should provide to designers/installers.

- **Heat pumps**

For heat pumps, manufacturers should provide capacity, energy input, and COP ratings per temperature and load, at each point specified within the operating limits of the equipment:

- Outdoor temperature in increments of 5°C or less
- Indoor temperature: in increments of 2°C or less
- Load: for multiple stage appliances, the part load rating should be provided for every stage available. For continuous modulating machines, part load rating should be provided for 75%; 50%, 25% and the minimum load applicable.

These rating data should be provided within the uncertainty limits in the standard EN 14511-3, and presented as in the table below:

Table 8— 11: Capacity table for heat pumps

Rated capacity:											
Load	Outdoor air temp. (°CDB)	Indoor air temp. °CDB									
		16		18		20		22		...	
		TC	PI	TC	PI	TC	PI	TC	PI	TC	PI
		KW	KW	KW	KW	KW	KW	KW	KW	KW	KW
100%	-10										
	-5										
	0										
	5										
	10										
	20										
75%	-10										
	-5										
	0										
	5										
	10										
	20										
50%	-10										
	-5										
	0										
	5										
	10										
	20										
25%	-10										
	-5										
	0										
	5										
	10										
	20										
TC : Total Capacity PI : Power input °CDB: Dry bulb temperature											

Manufacturers should also provide the additional information necessary to calculate the SCOP, sound emission, and refrigerant type and charge:

Table 8— 12: Additional information for heat pumps

Information to identify the model(s) to which the information relates to:							
Indication if the heater is an air-to-air, water-to-air or ground-to-air heat pump:							
Indication if the heater is a low temperature heat pump: yes/no							
Indication if the heater is equipped with a supplementary heater: yes/no							
Indication if the heater is a heat pump combination heater: yes/no							
Parameters shall be declared for medium temperature application, except for low temperature heat pumps. For low temperature heat pumps, parameters shall be declared for low temperature application.							
Parameters shall be declared under average climate conditions.							
Item	**Symbol**	**Value**	**Unit**	**Item**	**Symbol**	**Value**	**Unit**
Rated heat output*	*Prated*	x,x	kW	**Seasonal Coefficient Of Performance**	*SCOP*	x,x	%
Declared capacity for heating for part load at indoor temperature 20 °C and outdoor temperature T_j				Declared coefficient of performance for part load at indoor temperature 20 °C and outdoor temperature T_j			
T_j = - 7 °C	*Pdh*	x,x	kW	T_j = - 7 °C	*COP*	x,x	%
T_j = + 2 °C	*Pdh*	x,x	kW	T_j = + 2 °C	*COP*	x,x	%
T_j = + 7 °C	*Pdh*	x,x	kW	T_j = + 7 °C	*COP*	x,x	%
T_j = + 12 °C	*Pdh*	x,x	kW	T_j = + 12 °C	*COP*	x,x	%
T_j = bivalent temperature	*Pdh*	x,x	kW	T_j = bivalent temperature	*COP*	x,x	%
T_j = operation limit	*Pdh*	x,x	kW	T_j = operation limit	*COP*	x,x	%
Bivalent temperature	T_{biv}	x	°C	Operation limit temperature	*TOL*	x	°C
Degradation co-efficient**	*Cdh*	x,x	-				
Power consumption in modes other than 'active mode'				Supplementary heater			
Off mode	P_{OFF}	x,x	kW	Rated heat output*	*Psup*	x,x	kW
Thermostat-off mode	P_{TO}	x,x	kW	Type of energy input			
Crankcase heater mode	P_{CK}	x,x	kW				
Other items				Refrigerant used:			
Capacity control	fixed/variable			Refrigerant charge:			kg
Sound power level, indoor / outdoor measured	L_{WA}	x,x / x,x	dB	GWP100 of refrigerant			
Emissions of nitrogen oxides (if applicable)	NO_x	x	mg/kWh	GWP20 of refrigerant			
Contact details	Name and address of the manufacturer or of its authorised representative.						
* For heat pumps, the rated heat output *Prated* is equal to the design load for heating *Pdesignh*, and the rated heat output of a supplementary heater *Psup* is equal to the supplementary capacity for heating *sup(Tj)*.							
** If *Cdh* is not determined by measurement then the default degradation coefficient shall be *Cdh* = 0,9.							

Warm air heaters

For warm air heaters, manufacturers should provide capacity and thermal efficiency tables based on Gross Calorific Value per load, for the following ranges:

- For multiple stage machines, the part load rating should be provided for every stage available.
- For continuous stage machines, the part load rating should be provided for at least 30% and the minimum load applicable.

These rating data should be provided within the uncertainty limits in the standard EN 1319

Table 8— 13: Information for warm air heaters

Information to identify the model(s) to which the information relates to:							
Indication if the heater is a condensing or low temperature heater:							
Indication if the heater is a cogeneration space heater: yes/no If yes, indication if cogeneration space heater is equipped with a supplementary heater: yes/no							
Item	**Symbol**	**Value**	**Unit**	**Item**	**Symbol**	**Value**	**Unit**
Rated heat output	*Prated*	x,x	kW	**Annual energy efficiency in primary energy**	η_{annual}	x,x	%
Useful heat output				Useful efficiency			
At rated heat output	P_4	x,x	kW	At rated heat output	η_4	x,x	%
At 30 % of rated heat output	P_1	x,x	kW	At 30 % of rated heat output	η_1	x,x	%
Auxiliary electricity consumption				Other items			
At full load	*elmax*	x,x	kW	Standby heat loss	P_{stby}	x,x	kW
At part load	*elmin*	x,x	kW	Ignition burner power consumption	P_{ign}	x,x	kW
In standby mode	P_{SB}	x,x	kW	Emissions of nitrogen oxides	*NOx*	x	mg/kWh
				Sound power level, measured	L_{WA}	x,x	dB
Contact details	Name and address of the manufacturer or of its authorised representative.						

The impact of noise emissions are highly dependent on the location where the warm air heaters are installed. Warm air heaters for non-residential applications are usually installed in a remote location other than the space to be heated, either outdoors or in a local or room prepared ad hoc. Residential warm air heaters can be installed outdoors or indoors. In the case of being installed indoors, they can be located in a room dedicated for that purpose or in a shared space with the living areas. For this reason, it is recommended that the manufacturers include within the technical specifications a recommendation on the place for installing the heater (whether it is intended for indoor or outdoor installation), in relation with the noise power level of the product. This can be in the form of a statement if the noise declaration of the product is above the maximum indoor noise levels in Table 8-6 as the following: "This product is not recommended for installation indoors in living accommodation".

8.2.5.2 *Standardisation mandates*

The following needs for standardised measurement and calculation methods have been identified:

- Extension of the scope of working hours in standard prEN14825 to include all electric cooling and/or heating air conditioning products. At the time of writing, the working hours established in this standard are valid only for heat pumps below 12 kW of cooling capacity. Alignment with central heating boilers, residential air conditioning and tertiary air conditioning and heating is needed in this regard.
- Standard for the determination of seasonal energy performance of gas, oil and electric warm air central heating. CEN/TC180 started recently working on a methodology for calculating seasonal performance of decentralised gas warm air heaters (applicable only to decentralised heaters and not to central warm air heaters covered in the present preparatory study). At the time of carrying out Task 5 of this preparatory study, that methodology was not available, and a technical expert in the project team developed the method presented in Task 5. This could serve as basis for the standardisation work.
- Standard for the determination of seasonal energy performance of gas engine heat pumps in cooling mode and heating mode. The CEN/TC 299 started recently the development of a testing standard for gas engine heat pumps. However, at present, no method was available.
- Standard for the determination of pollutant emissions to air (NO_x, PM, CO, HC) of gas and oil warm air central heating. Emission testing standards already exist, but the applicability to warm air heaters is not clarified.
- Standards for determining the noise emissions of heat pumps already exist (EN 12102 and EN 3741). Although no specific standards for noise emissions of warm air heaters have been identified at the EU level, the EN 3744 determines the sound power levels of equipment and machinery based on sound intensity measurements. This standard could be used for measuring the noise emissions of warm air heaters.
- Standard for setting design requirements for refrigerant fluids (toxicity, flammability, maximum refrigerant charge etc.) in refrigeration systems and heat pumps is EN 378. In this standard, the basic requirements concerning design, installation and operation parameters are presented. The definition of TEWI is also given in EN 378, which is useful for determining the direct emissions. At the time of writing this report, this standard is under revision and therefore no mandates are proposed.

The technical working groups identified in the standardisation bodies for the different product groups are the following:

- Gas warm air heaters: CEN/TC 180 - Decentralised gas heating (as mentioned some decentralised heaters can be connected to a duct)
- Oil warm air heaters: CEN/TC 47 - Atomizing oil burners and their components - Function - Safety - Testing

- Electric warm air heaters: CENELEC/TC 59x - Performance of household and similar electrical appliances
- Gas engine heat pumps: CEN/TC 299 - Gas-fired sorption appliances, indirect fired sorption appliances, gas-fired endothermic engine heat pumps and domestic gas-fired washing and drying appliances
- Electric heat pumps: CEN/TC 113/WG 07 - Heat pumps and air conditioning units - Heat Pumps, air conditioners and chilling liquid packages - testing and rating at part load conditions

8.2.5.3 Energy labelling

No energy labelling requirements are proposed for the products in the scope of these implementing measures. The market of warm air central heating and heat pumps is mostly within heating, ventilation and air conditioning (HVAC) professionals. Energy labelling is an effective policy tool for the consumer market to help consumers make the right choice of best performing product. However, energy labelling would not be effective as professional HVAC engineers and designers are capable of correctly dimensioning and designing central heating systems if they are provided with the relevant information from manufacturers.

Furthermore, based on market review, it can be concluded that there is not a large range between least and best performing products in the EU market, unlike central heating boilers and water heaters. Among these, an extensive range of efficiencies can be found in the EU market due to different heating technologies. For this reason, even if the market of boilers is also based on heating professionals, an energy label might help installers and customers differentiate the efficient products from the inefficient ones.

Conversely, the Base-Cases analysed for warm air heaters in this study have thermal efficiencies based on GCV around 76% and 82%. This level of efficiency could be set as the "average" efficiency in the EU. The maximum efficiency achieved by warm air heaters is around 94% in terms of GCV. This gives around 12-18 percentage points between the "average" product and the "best in class" product in the market. This does not give room for the establishment of several efficiency classes. For such a small efficiency step, a mandatory policy would be expected to promote the change more efficiently than the Energy Label scheme.

Regarding heat pumps, the Base-Cases selected in this preparatory study have COP of 3.34 (single split) and 3.98 (VRF). The best products found in the market perform only 20% better, although other technologies not common in the market such as water-to-air VRF heat pumps can reach COP values up to 6.6. Nevertheless, the COP is closely linked to the product group, as seen in section 8.2.3. As in the case of warm air heaters, a difference of 20% in efficiency from the "average" product in the market and the best available product is not likely to be enough for creating several efficiency classes.

8.2.6 Summary of the policy analysis

In the previous sections, carious policy options to reduce the environmental impacts of central air-based heating products have been discussed: energy efficiency, air emissions, refrigerants, and material consumption and waste production. The alternatives to the policy options discussed are "self regulation" or "no EU action".

- "Self regulation" is an available option foreseen by the Ecodesign Directive as an alternative to mandatory implementing measures. Industry in this case would be responsible for proposing feasible improvement measures for the products in the market.
- "No EU action" is an option if the market, energy consumption or saving potential of the products examined are not significant enough to justify an implementing measure.

For heat pumps, the market analysis shows a constant increase of sales and stock of these products, and consequently an increase of total energy consumption in the EU. The improvement potential per product is not huge, but the total savings potential (see section 8.3) could be important to justify the establishment of implementing measures, either by self regulation or by mandatory regulation issued by the Commission. So far, the manufacturers have not started any voluntary agreement procedures, even though the European companies are actively involved in the Ecodesign regulatory process and in R&D.

For warm air heaters, "self regulation" would be a feasible option if the industry was organised and involved in the Ecodesign process. However, these products are not very spread in the EU and the manufacturers are small players, mostly focused on regional markets. The market of warm air heaters for central heating applications is relatively small. The forecast for the future is a further decrease of sales, the stock being substituted by other types of central heating systems. According to the findings of this preparatory study, the energy consumption of warm air heaters is relatively high, the improvement potential of each product is not very large, but the total potential savings could be important. This issue will be analysed in the following section.

8.3 Scenario analysis

Based on the policy options proposed in the previous section, different scenarios were drawn up to illustrate quantitatively the improvements that could be achieved. The implementation of different sets of improvement options at EU level by 2025 was compared to a Business-As-Usual scenario (reference scenario).

An Excel tool was created to allow the impacts of the different scenarios to be modelled (2010-2025). The tool was designed in a simple manner and relies on the following assumptions:

- The model builds upon a discrete annual basis to match the available data.
- Sales and stock forecasts detailed in Task 2 were used as input.
- Primary energy consumption was judged to be the most relevant and representative indicator to be modelled using the tool and also to allow the environmental benefits to be compared with other Ecodesign Lots. The tool calculates the expenditure in Euros and primary energy in GJ related to central air heating products, under different policy scenarios. The primary energy results are not limited to the use phase, but take into account the energy required over the whole lifetime (including the manufacturing, distribution and end-of-life phases).

- Energy consumption is allocated uniformly over the lifetime of the product although in theory this is only true for the use phase. Given the relatively small shares of other life cycle phases in energy consumption (see Task 5), this assumption is considered reasonable in order to carry out the analysis; a more "realistic" modelling would not make a significant difference to the overall results.
- Expenditure measures the yearly value of the entire market. It consists of the money spent to buy the product (purchase price), taken into account at the time of purchase, and the operating costs (energy, maintenance and repair), which are spread over the lifetime of the machine.

In the following subsections, three scenarios are described:

- Business-as-usual (BAU), reflecting the natural evolution of the market assuming no further changes in performance of the products if no new policy is adopted.
- Scenario 1, which corresponds to Tier 1 of the recommended MEPS presented in the previous section.
- Scenario 2, corresponds to Tier 1 and Tier 2 of the recommended MEPS presented in the previous section.

Scenarios are compared to the BAU scenario in order to estimate the overall potential of the improvement options. Most of the description in the sections below refers to 2030 for comparison.

8.3.1 Scenario analysis of Base-Case 1A and 1B (central warm air heaters)

Figure 8-3 and Figure 8-4 show the breakdown by Base-Case of energy consumption and expenditure for the two central warm air heaters for the recommended scenario over the period 2010-2030. Base-Case 1B (non-residential warm air heaters) has the greatest share both in terms of energy consumption and expenditure.

- **Scenario 1: Recommended MEPS**

Figure 8— 5: Scenario 1 - Total energy consumption for Base-Case 1A and 1B over the period 2010-2030

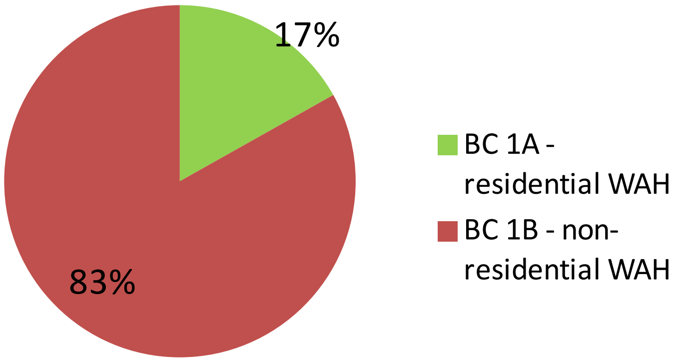


Figure 8— 6: Scenario 1 - Total expenditure for Base-Case 1A and 1B over the period 2010-2030

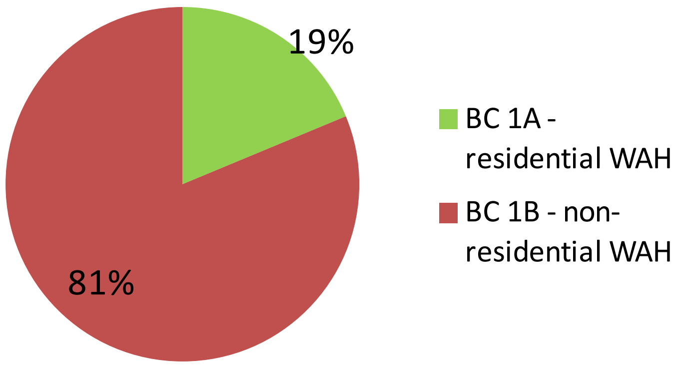


Figure 8— 7 and Figure 8— 8 present the same as above for the BAT scenario over the period 2010-2030. Again Base-Case 1B (non-residential warm air heaters) has by far the greatest share both in terms of energy consumption and expenditure.

- **Scenario 2: BAT**

Figure 8— 7: Scenario 2 - Total energy consumption for Base-Case 1A and 1B over the period 2010-2030

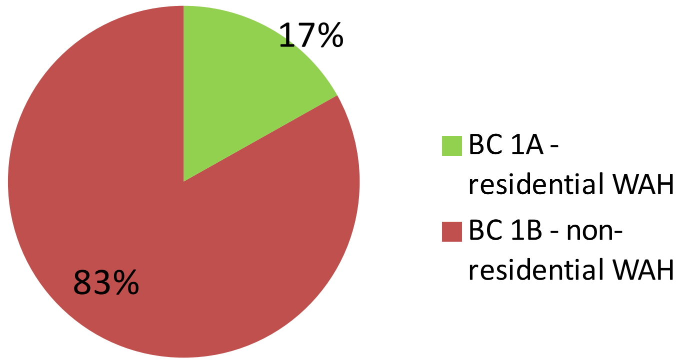


Figure 8— 8: Scenario 2 - Total expenditure for Base-Case 1A and 1B over the period 2010-2030

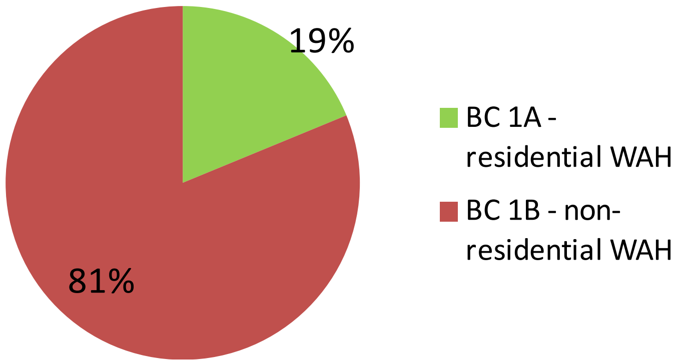


Figure 8— 9 and Figure 8— 10 present the evolution of the primary energy consumption and expenditure for each scenario and for each warm air Base-Case. Figure 8— 11 shows the same graph but with both warm air Base-Cases added together.

Table 8— 14: Summary of total energy and expenditure savings per year due to warm air heaters MEPS

Central warm air heaters in ENER Lot 21	Savings 2020	Savings 2025	Savings 2030
Primary energy (PJ)	48	93	134
Primary energy (TWh)	13.3	25.8	37.2
Expenditure (€ billion)	0.4	0.8	1.1

Figure 8— 9: Base-Case 1A Energy consumption and expenditure by Scenario 1 & 2

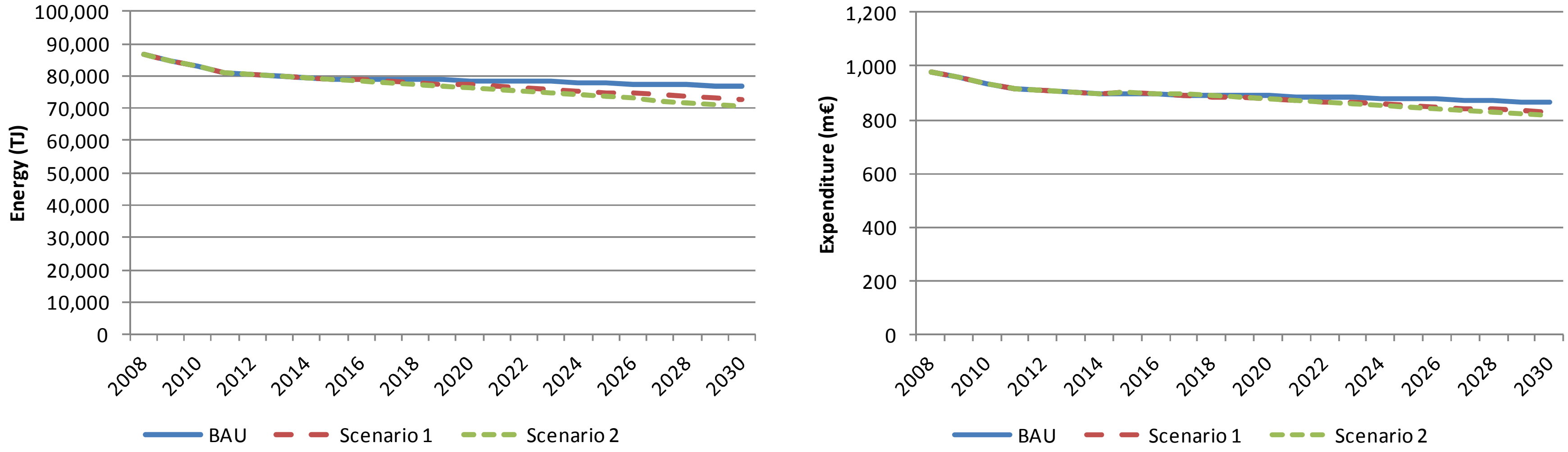


Figure 8— 10: Base-Case 1B Energy consumption and expenditure by Scenario 1 & 2

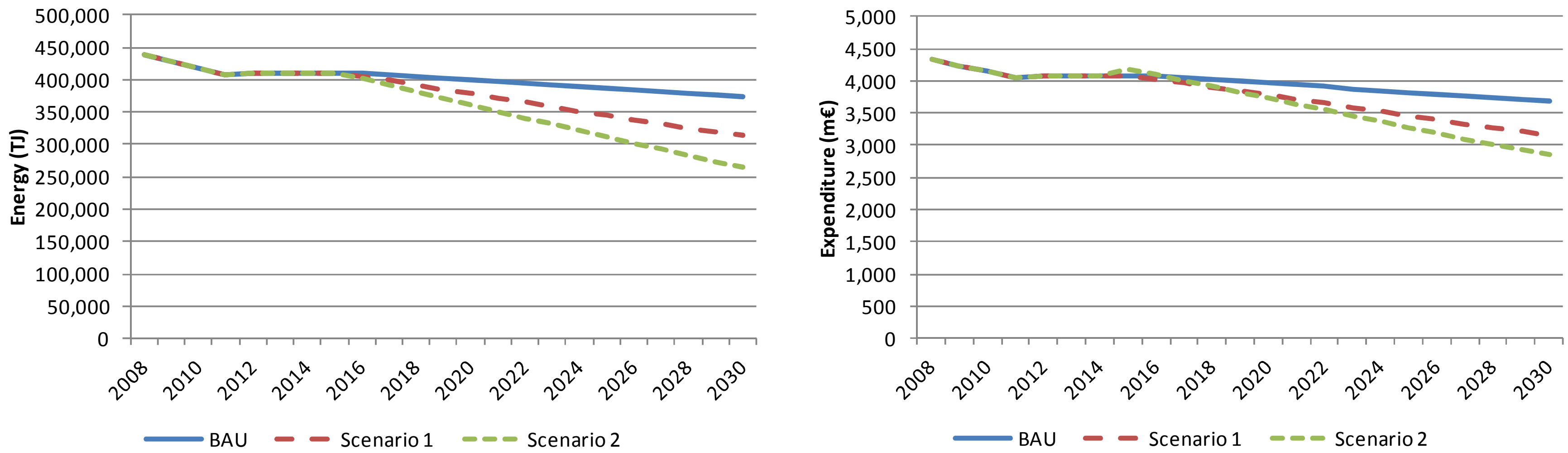
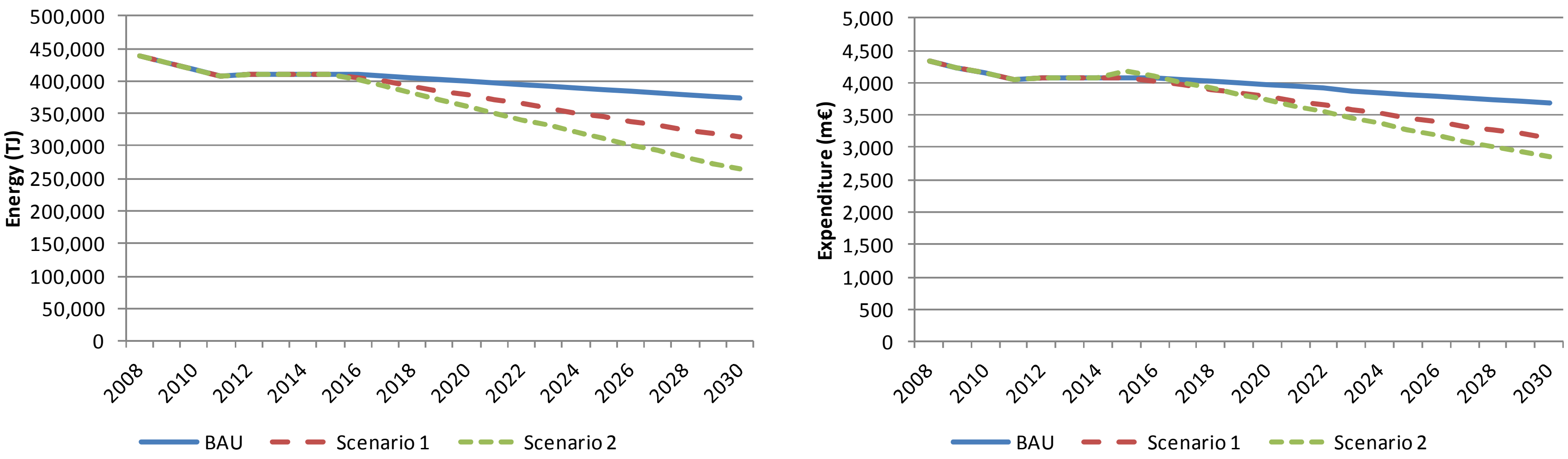


Figure 8— 11: Total energy consumption and expenditure for both Base-Cases 1A & 1B for Scenario 1 & 2



8.3.2 Scenario analysis of Base-Case 2 and 3 (heat pumps)

Figure 8— 12 and Figure 8— 13 show the breakdown by Base-Case of energy consumption and expenditure for the single split and VRF heat pumps in the recommended scenario over the period 2010-2030. Base-Case 3 (VRF heat pumps) has the highest share both in terms of energy consumption and expenditure.

- **Scenario 1: Recommended MEPS**

Figure 8— 12: Scenario 1 - Total energy consumption for Base-Case 2 and 3 over the period 2010-2030

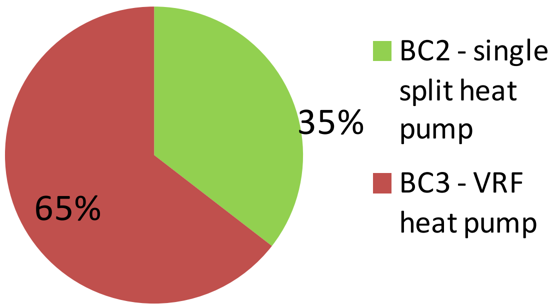


Figure 8— 13: Scenario 1 - Total expenditure for Base-Case 2 and 3 over the period 2010-2030

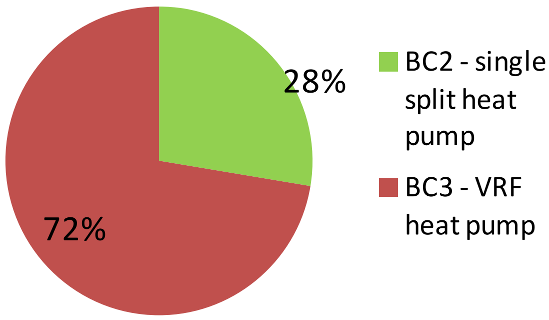


Figure 8— 14 and Figure 8— 15 present the same as above for the BAT scenario over the period 2010-2030. Again VRF heat pumps have the largest share both in terms of energy consumption and expenditure.

- **Scenario 2: BAT**

Figure 8— 14: Scenario 2: Total energy consumption for Base-Case 2 and 3 over the period 2010-2030

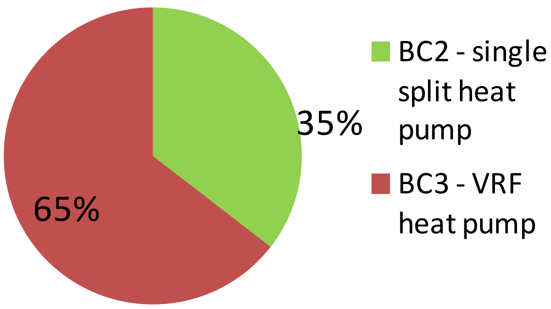


Figure 8— 15 Scenario 2: Total expenditure for Base-Case 2 and 3 over the period 2010-2030

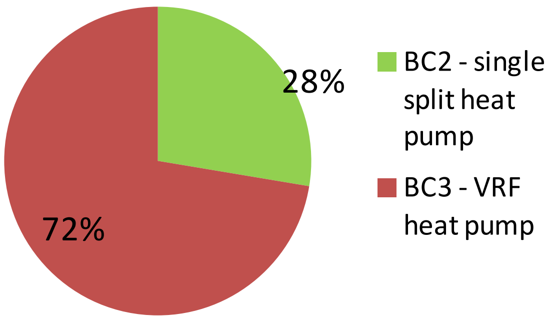


Figure 8— 16 and Figure 8— 17 present the evolution of the primary energy consumption and expenditure for each scenario and for each of the heat pump Base-Cases. Figure 8— 18 shows the same graph but with both heat pump Base-Cases added together.

Table 8— 15: Summary of total energy and expenditure savings per year due to heat pump MEPS

ENER Lot 21 heat pumps	Savings 2020	Savings 2025	Savings 2030
Primary energy (PJ)	40	83	122
Primary energy (TWh)	11.1	23.1	33.9
Electricity (TWh)	4.5	11.5	13.5
Expenditure (€ billion)	0.2	0.7	1.1

Figure 8— 16: Base-Case 2 energy consumption and expenditure by Scenario 1 & 2

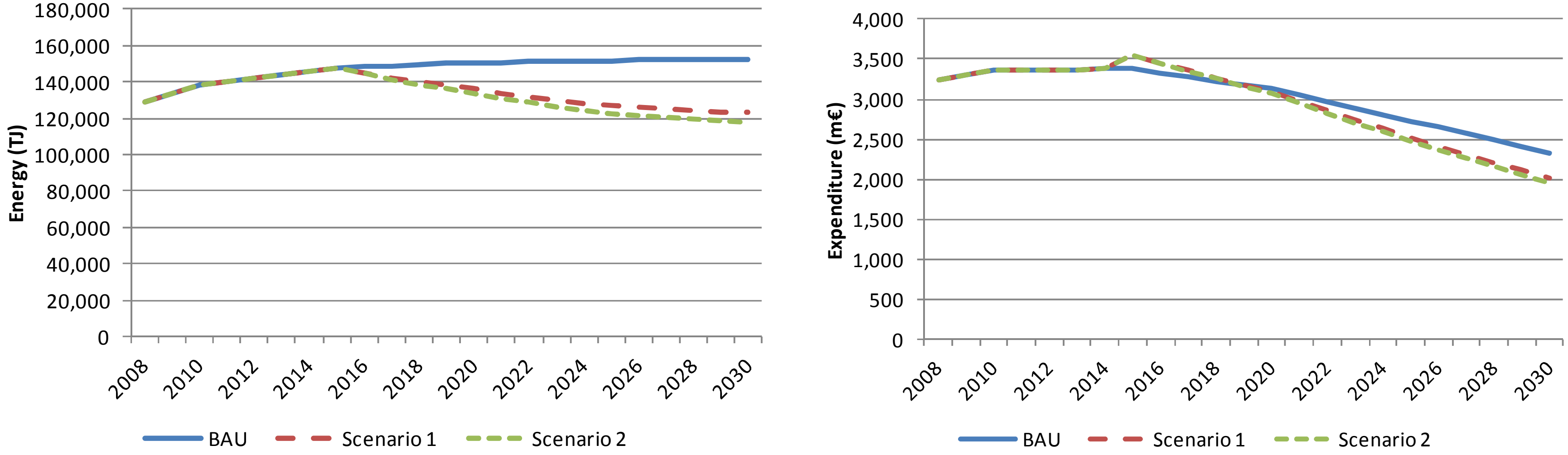


Figure 8— 17: Base-Case 3: Energy consumption and expenditure by Scenario 1 & 2

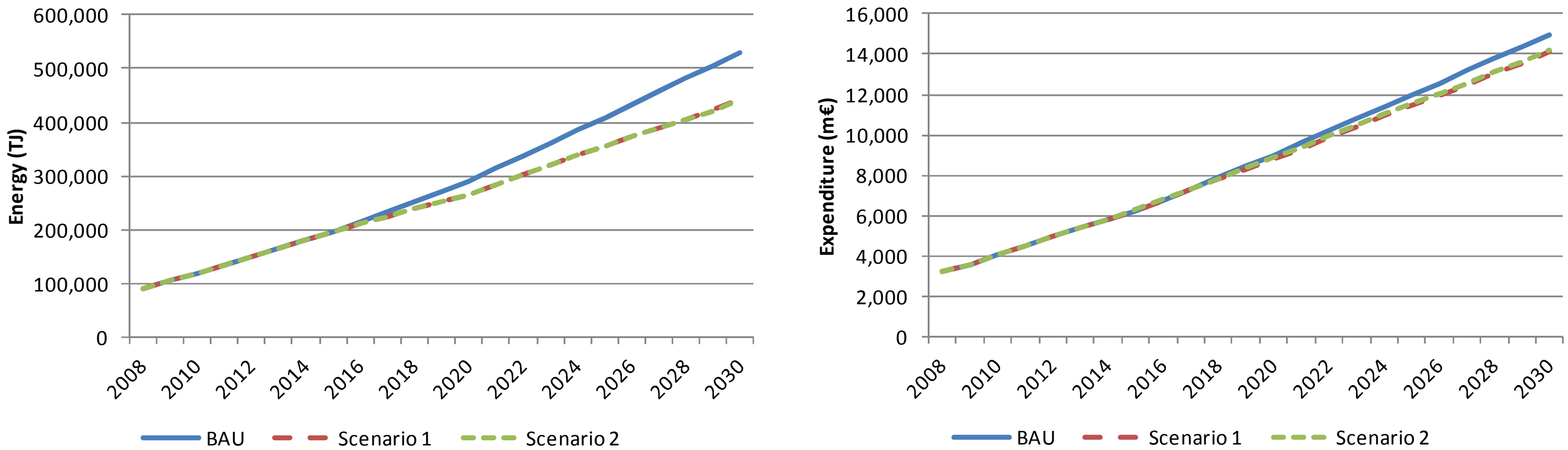
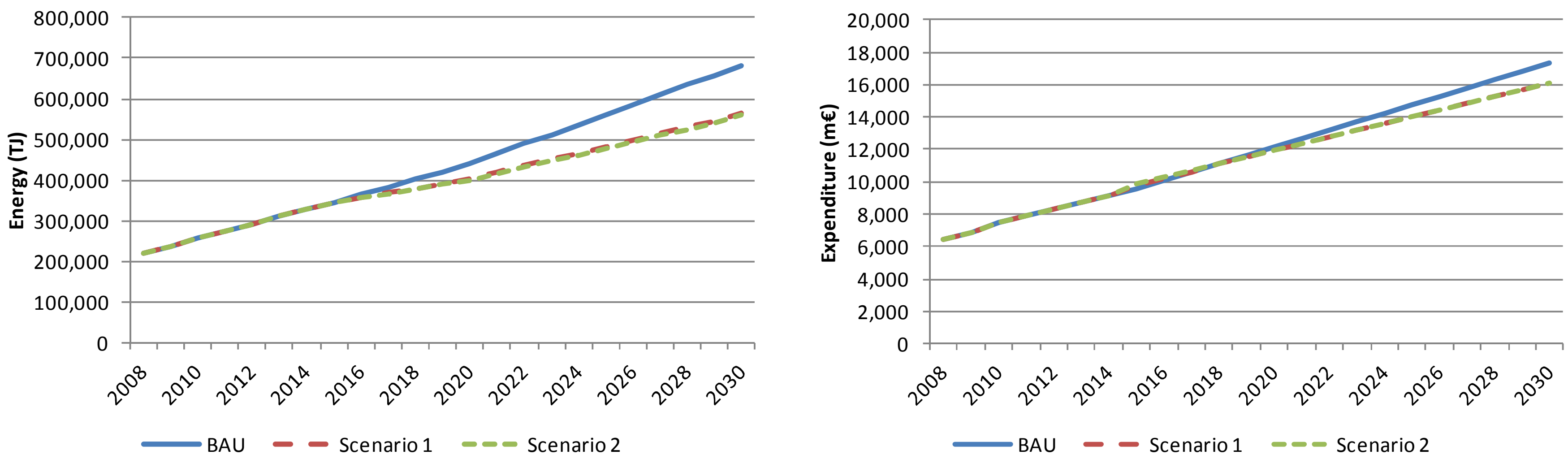


Figure 8— 18: Total energy consumption and expenditure for both Base-Cases 2 and 3 for Scenario 1 & 2



8.4 Impact analysis

The Ecodesign requirements should not entail excessive costs nor undermine the competitiveness of European enterprises and should not have a significant negative impact on consumers or other users. In this section, the following impacts are assessed:

- Impacts on manufacturers and competition
- Monetary impacts
- Impacts on consumers
- Impacts on innovation and development
- Social impacts

8.4.1 Impacts on manufacturers and competition

Although the generic economic data presented in Task 2 refer to broad product categories which are not specifically relevant to those examined in this study, they can give a rough economic overview of the sector in the EU. From the PRODCOM data presented in Task 2, it can be concluded that the external trade of air-based central heating products is not likely to be of high importance. The biggest share of the sales of these products in the EU is also for the EU market.

The market of heat pumps is dominated by Japanese and Korean companies that design and manufacture their products in the EU. The market of warm air heaters is smaller and shared between several European companies. The imports of these products to the EU account for a very small share of the market.

All the technologies described in this study and considered as improvement options in the scenarios are already available on the market. As a result, the implementation of MEPS is technically achievable although it would require an economical effort from the manufacturers.

The timeline to implement standards should take into account the sufficient time to adapt the correct products and production lines. This redesign time varies depending on the type of change to be achieved. It has been estimated that between 12 and 24 months are needed to implement any of the improvement options presented within the study. Therefore, Tier 1 has thus been set at 2015 for the MEPS and the scenario models.

The European market mainly consists of large international companies. If minimum performance standards were set, it is believed that they should all be able to keep up with the market requirements, using common technology or their own technological developments. Most of the manufacturers claim to produce high efficient products, therefore, the implementation of minimum performance standards is not expected to significantly hamper the economic development of manufacturers in the EU.

8.4.2 Monetary impacts

The scenario analysis demonstrated some of the expected monetary impacts. The possible implementation of MEPS could require manufacturers to invest more in technology and product development or in adapting their production to offer the more efficient products. Compared to the usual development investments made every year, any additional investment required by the Ecodesign requirements is thought to be limited.

In the case of any additional costs, these could be passed on to customers, but the life cycle costs would actually benefit them in the long term, although it would require more capital to purchase the more efficient products.

8.4.3 Impacts on customers

For the improvement options presented, the functional unit and the quality service given by the improved product remains the same as with the Base-Cases (this is a necessary condition to make a relevant comparative LCA).

There should be no significant trade-offs in terms of the space heating function (e.g. responsiveness) as a result of the increased energy efficiency.

8.4.4 Impacts on innovation and development

The proposed policy options will remove inefficient central air heaters from the market but it is unlikely to lead to big technological changes. This is because the products with the improvement options identified in this study already exist on the market. However, a shift can be expected towards more efficient models within the EU. The promotion of refrigerants with low global warming potential and high efficiency could affect the raw material production stage of the supply chain, where some other EU companies are involved as refrigerant manufacturers.

BNATs and current technological research in warm air heaters and heat pumps were not very examined in detail in this study due to a lack of data. Such information is obviously very sensitive for manufacturers and it is understandable that they may not be willing to disclose what they are working on.

The proposed MEPS can be seen as an opportunity for manufacturers to search for innovative and efficient technological solutions. As mentioned, it seems that with the current trend of research and development activities in EU manufacturing firms, it thought to be feasible for manufacturers to meet the proposed requirements.

8.4.5 Social impacts

Most of the manufacturers of central air heating products have production plants within the EU. Upgrading or changing production lines in the EU is often viewed as an opportunity to decide whether to relocate. If performance standards were set, they are not thought to have a detrimental impact on the number of jobs or the well-being of the EU manufacturers' employees.

In addition, the improvement options presented do not require any specific material that might be difficult to obtain within the EU so that the supply chain would not be unduly affected nor EU industries disadvantaged.

8.5 Sensitivity analysis

The scope of the sensitivity analysis is to examine the accuracy of the results of study and see how susceptible they are to unreliable data. Parameters included in the sensitivity analysis are in accordance with the Annex II of the Ecodesign Directive. The most important parameters are energy prices, raw material or production cost, discount rates and where appropriate, external environmental costs, such as avoided greenhouse gas emissions. The sensitivity analysis allows checking if any of the results change significantly with different data. This helps determine how robust and reliable the findings of this study are.

The parameters that were considered the most relevant for this sensitivity analysis (because of their importance and/or uncertainty) in the case of air-based central heating products are listed below:

- Energy consumption
- Refrigerant consumption
- Product lifetime
- Product price
- Energy (electricity and gas) prices
- Discount rate

Great variation among Member States prices exist. As a result, many of the BATs might not be as cost effective in some countries as for others. Nevertheless, the average EU values are used for all calculations.

8.5.1 Assumptions related to the product lifetime

The average product life time of all Base-Cases has been identified as 15 years and has been used throughout the sensitivity analysis tool. The upper and lower limits for the product are assumed to be 20 years, which corresponds to the technical product life, and 10 years respectively. Regarding the Life Cycle Cost over the product life for all base cases, there is no significant change between the improvement options analysed if the product life is changed for Base-Cases 1A, 1B, 2 and 3. However, the total energy consumption will change significantly (

Figure 8— 24).

- **Base-Case 1A: Residential gas warm air heater**

Figure 8— 19: Sensitivity to product lifetime for Base-Case 1A Life Cycle Cost

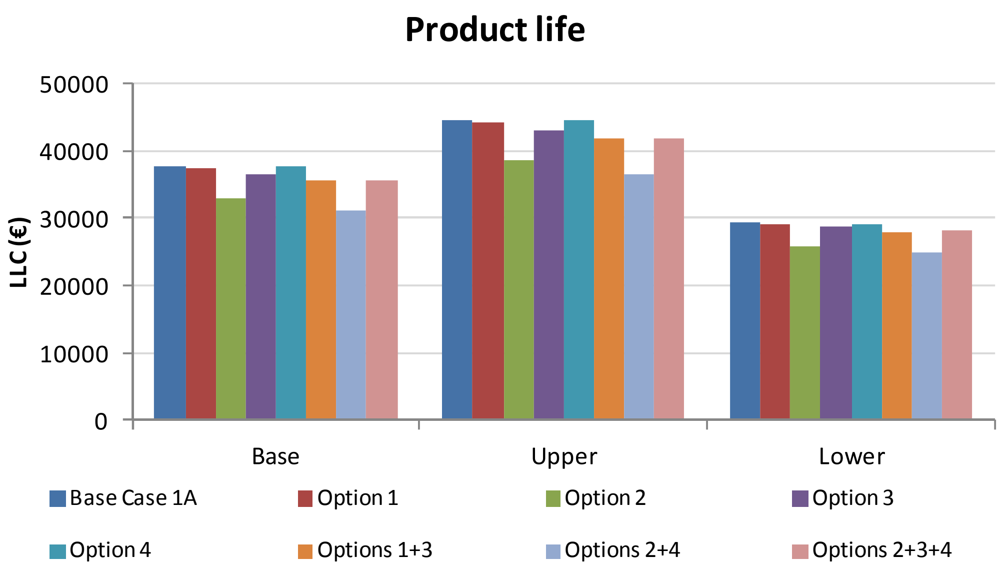
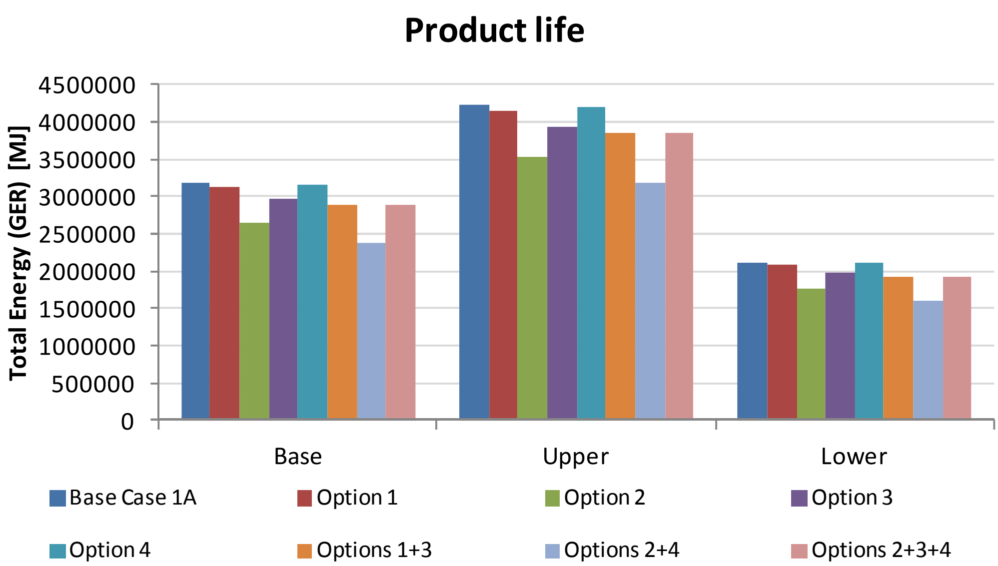


Figure 8— 20: Sensitivity to product lifetime for Base-Case 1A Total Energy



- **Base-Case 1B: Non-residential gas warm air heater**

Figure 8— 21: Sensitivity to product lifetime for Base-Case 1B Life Cycle Cost

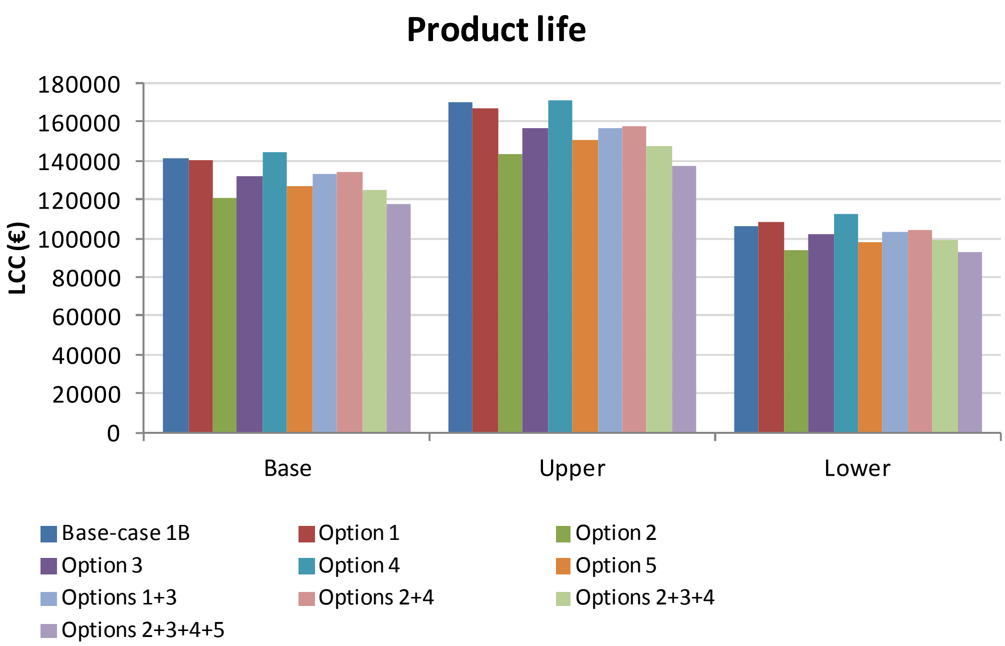
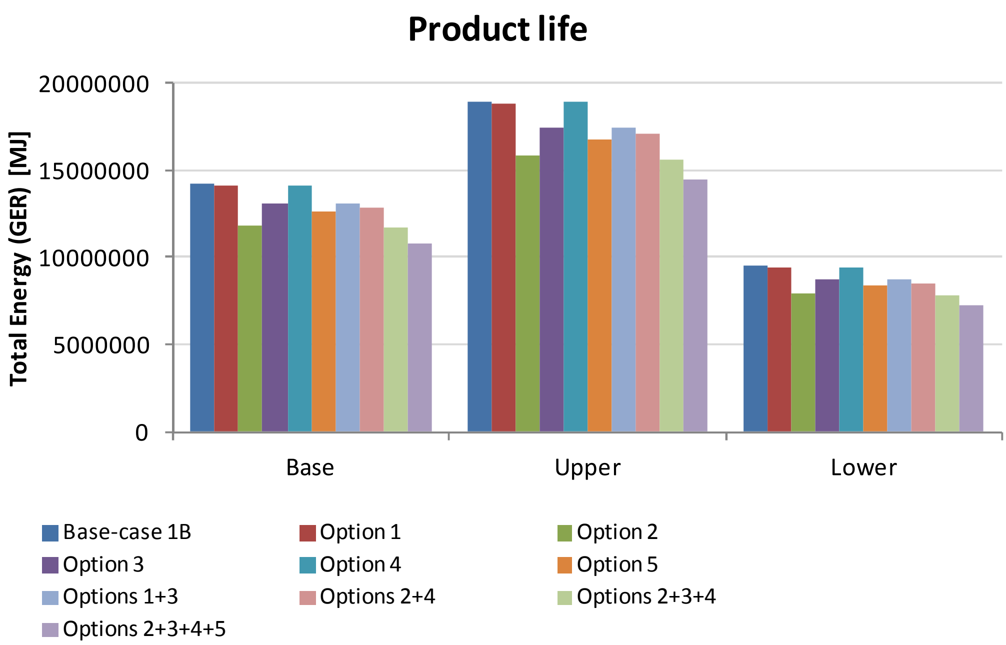


Figure 8— 22: Sensitivity to product lifetime for Base-Case 1B Total Energy



- **Base-Case 2: Single split heat pump**

Figure 8— 23: Sensitivity to product lifetime for Base-Case 2 Life Cycle Cost

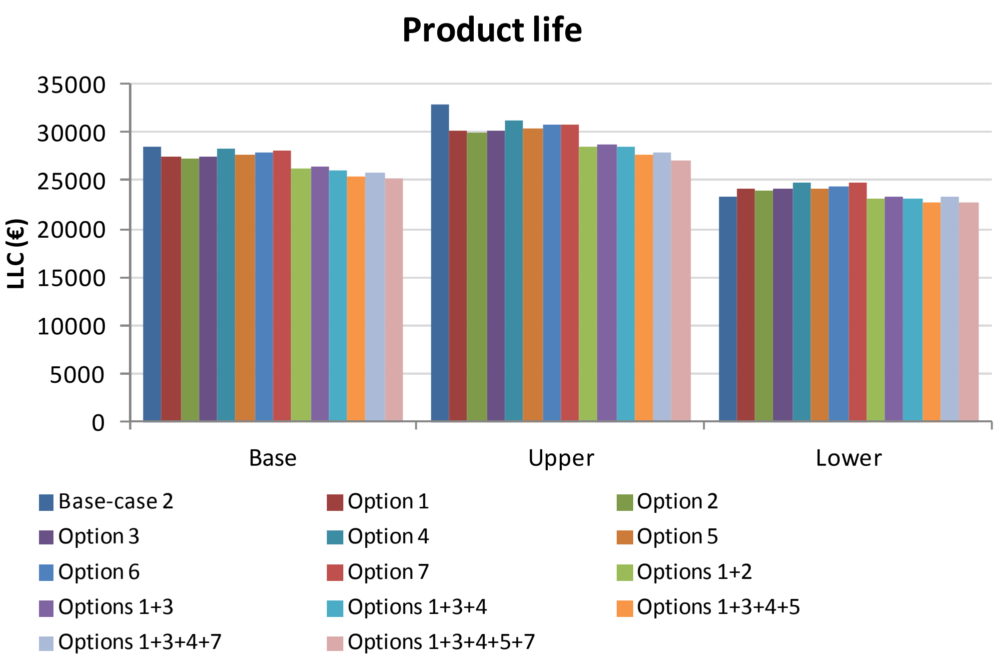
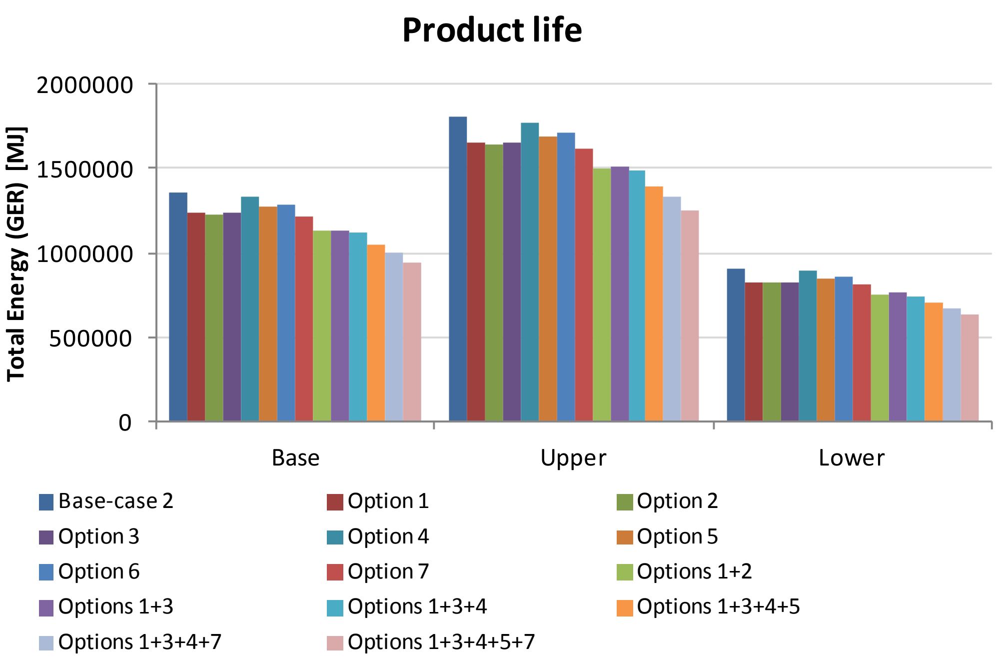


Figure 8— 24: Sensitivity to product lifetime for Base-Case 2 Total Energy



- **Base-Case 3: VRF heat pump**

Figure 8— 25: Sensitivity to product lifetime for Base-Case 3 Life Cycle Cost

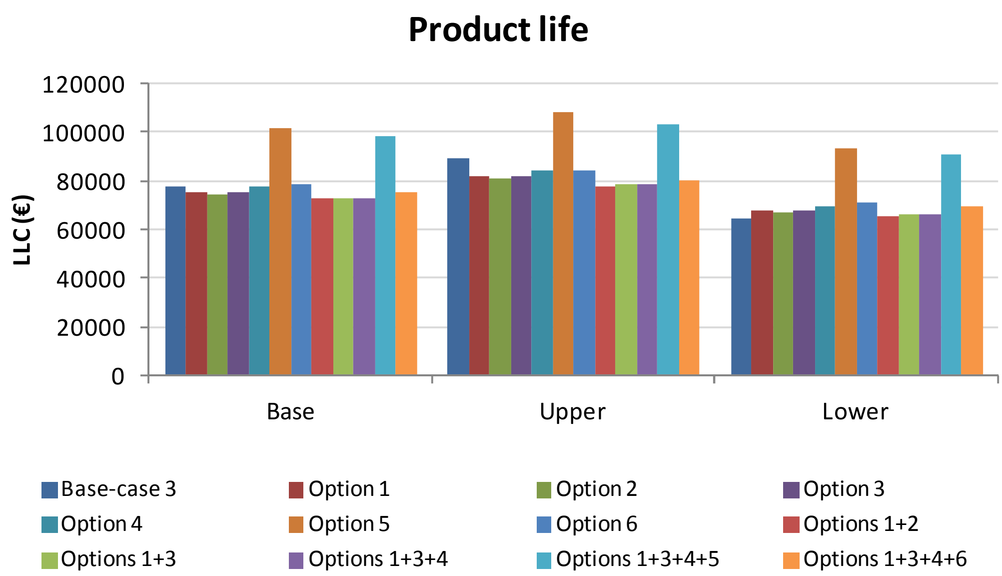
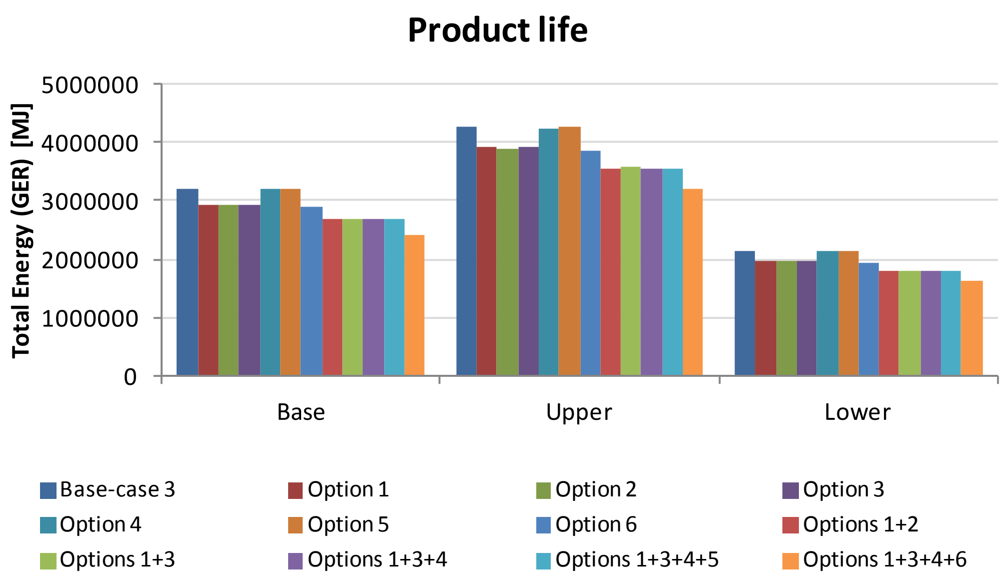


Figure 8— 26: Sensitivity to product lifetime for Base-Case 3 Total Energy

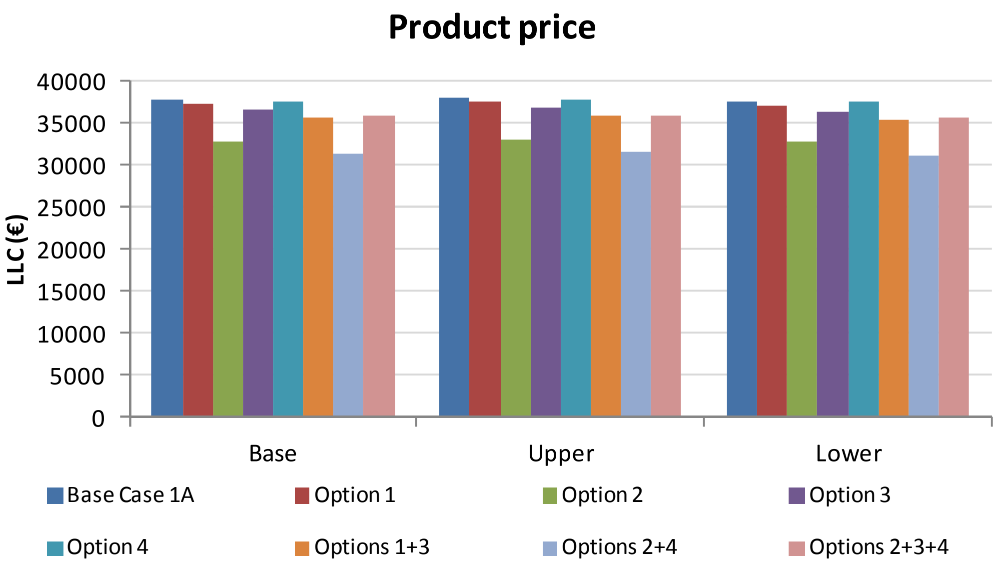


8.5.2 Assumptions related to the product price

The variation assumed over the product prices were 10% increase or decrease over the current market prices. The product prices indicated in Figure 8— 27 to Figure 8— 30 represent the Base-Case price of the product plus the additional price increase assumed for each option. As for the product life, there is no relative change between the options and their price.

- **Base-Case 1A: Residential gas warm air heater**

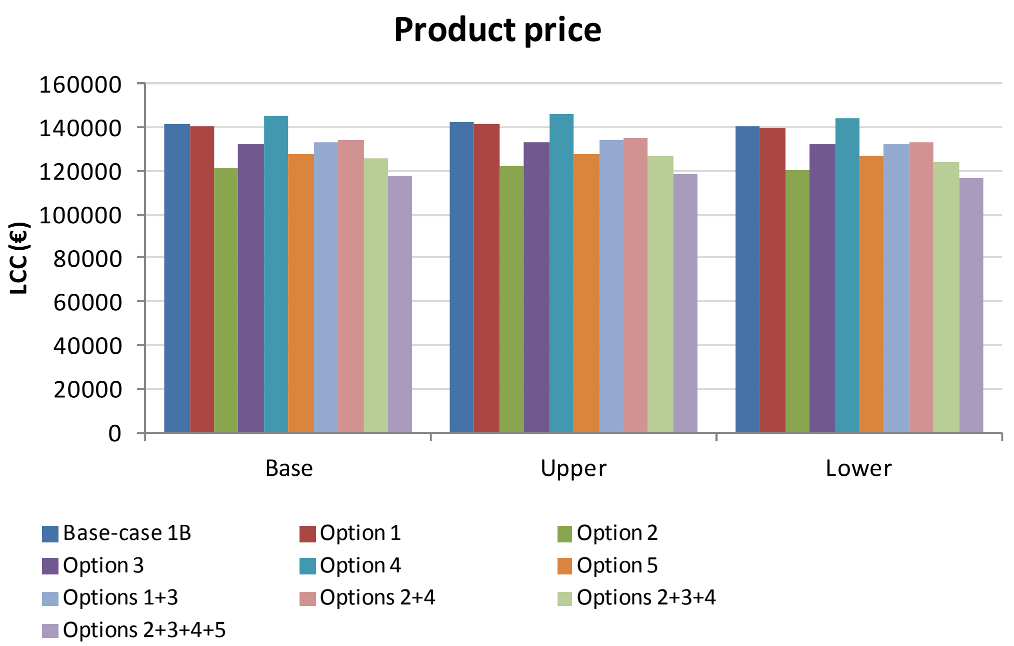
Figure 8— 27: Sensitivity to product price for Base-Case 1A Life Cycle Cost



The product price difference for Option 2+3+5 and Option 1+4 is almost eliminated for the lower limit of product price.

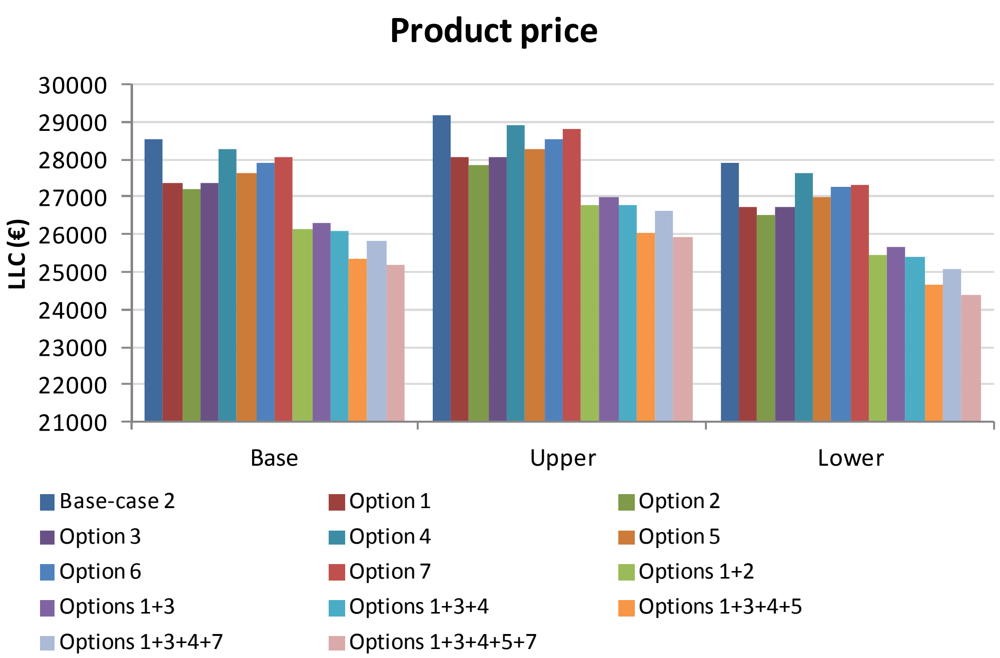
Base-Case 1B: Non-residential gas warm air heater

Figure 8— 28: Sensitivity to product price for Base-Case 1B Life Cycle Cost



Base-Case 2: Single split heat pump

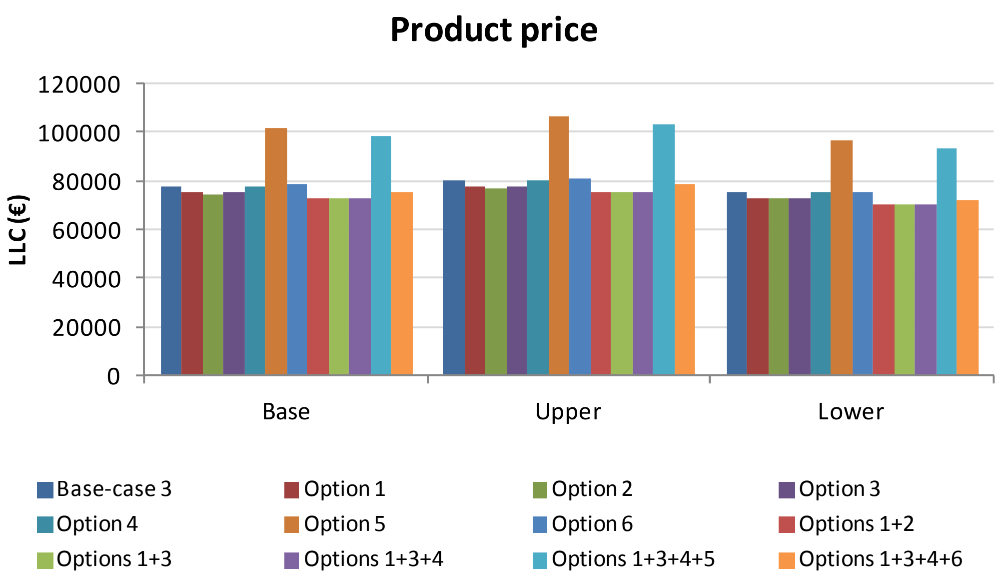
Figure 8— 29: Sensitivity to product price for Base-Case 2 Life Cycle Cost



The price difference of Option 1 and Option 2 for Base-Case 2 is almost eliminated through the life cycle for the lower limit of the sensitivity analysis. The same occurs for Options 1 and 2 for Base-Case 3.

- **Base-Case 3: VRF heat pump**

Figure 8— 30: Sensitivity to product price for Base-Case 3 Life Cycle Cost

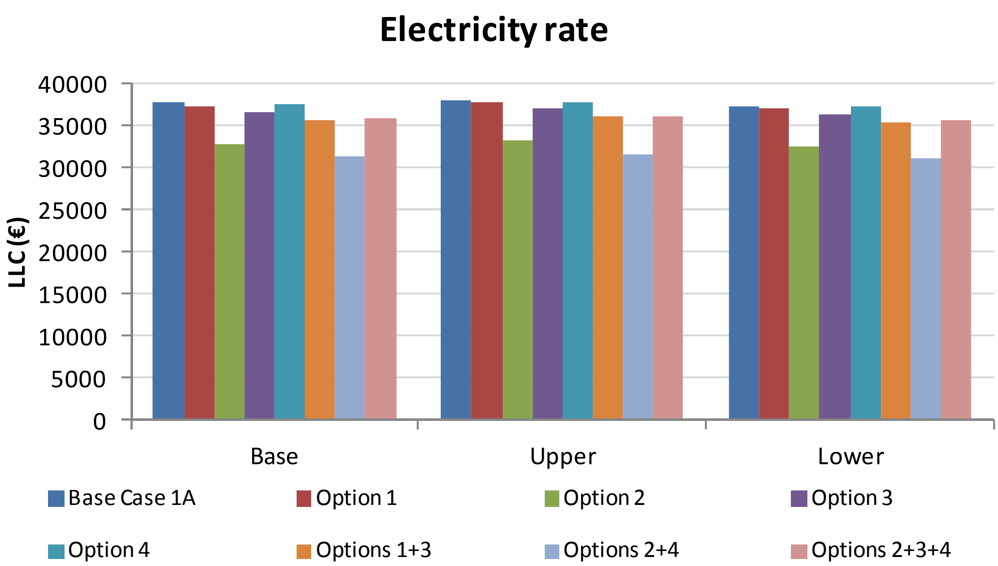


8.5.3 Assumptions related to the electricity rates

The price of electricity varies considerably across the Member States, with the lowest and highest prices being around 0.08 € to 0.27 € respectively. In most cases no relative difference over the Life Cycle Cost exists between the options. Nevertheless, there are a few options where the LCC difference with other options is eliminated or even reduced over others. Thus, making those options more or less competitive over the others. As Base-Cases 1A and 1B consume considerably more energy in the form of gas rather than electricity, there is a limited variation over the Life Cycle Cost for the various options with the upper and lower limits of electricity rate.

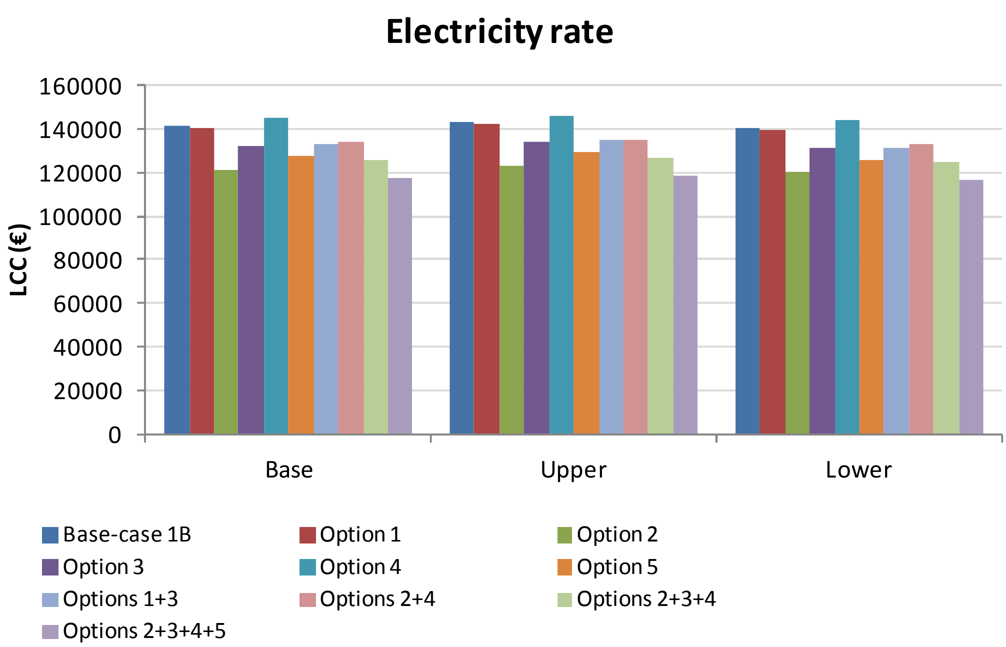
Base-Case 1A: Residential gas warm air heater

Figure 8— 31: Sensitivity to electricity rate for Base-Case 1A's Life Cycle Cost



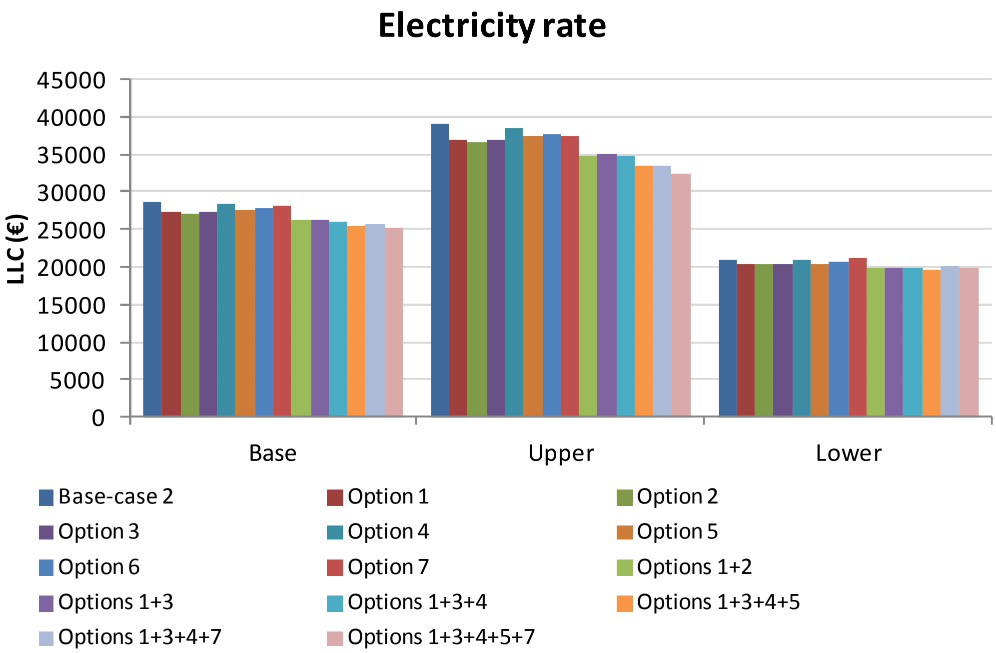
Base-Case 1B: Non-residential gas warm air heater

Figure 8— 32: Sensitivity to electricity rate for Base-Case 1B's Life Cycle Cost



Base-Case 2: Single split heat pump

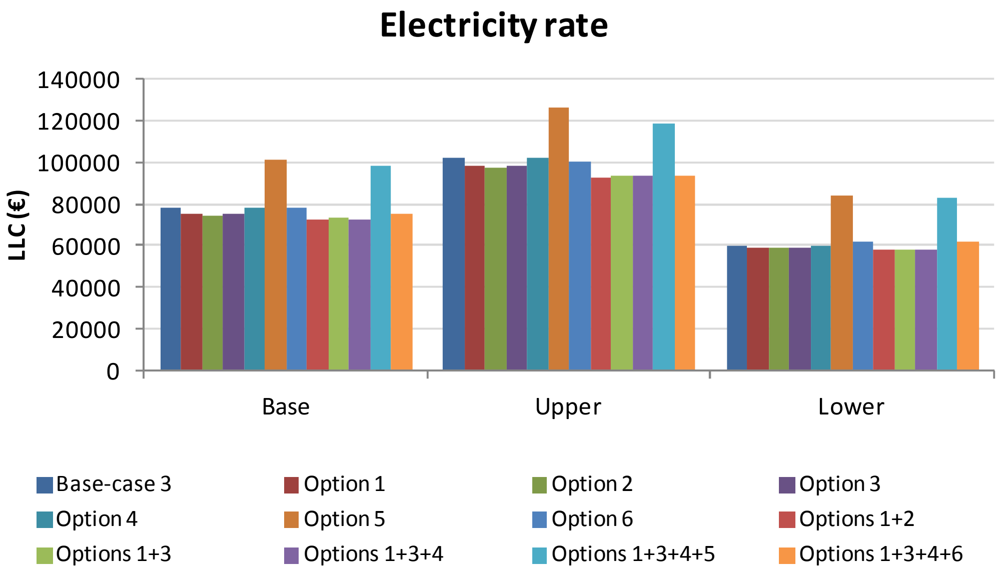
Figure 8— 33: Sensitivity to electricity rate for Base-Case 2's Life Cycle Cost



Looking at Figure 8— 33 Option 3 gains an advantage over the BAU conserving the LCC only in the upper limits of the sensitivity analysis.

- **Base-Case 3: VRF heat pump**

Figure 8— 34: Sensitivity to electricity rate for Base-Case 3's Life Cycle Cost

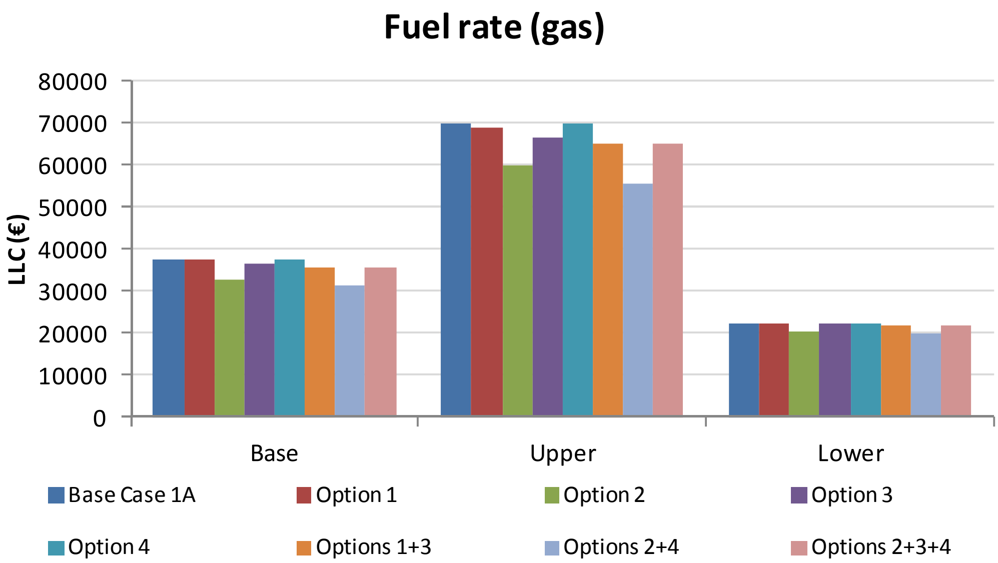


8.5.4 Assumptions related to the gas rates

Similar to the electricity rates, the gas prices vary considerably across the Member States. The upper and lower limits of gas prices are 7.6 €/GJ to 29.7 €/GJ respectively. The variation of gas rates only have influence for Base-Case 1A and 1B, since Base-Case 2 and 3 do not use fuel gas.

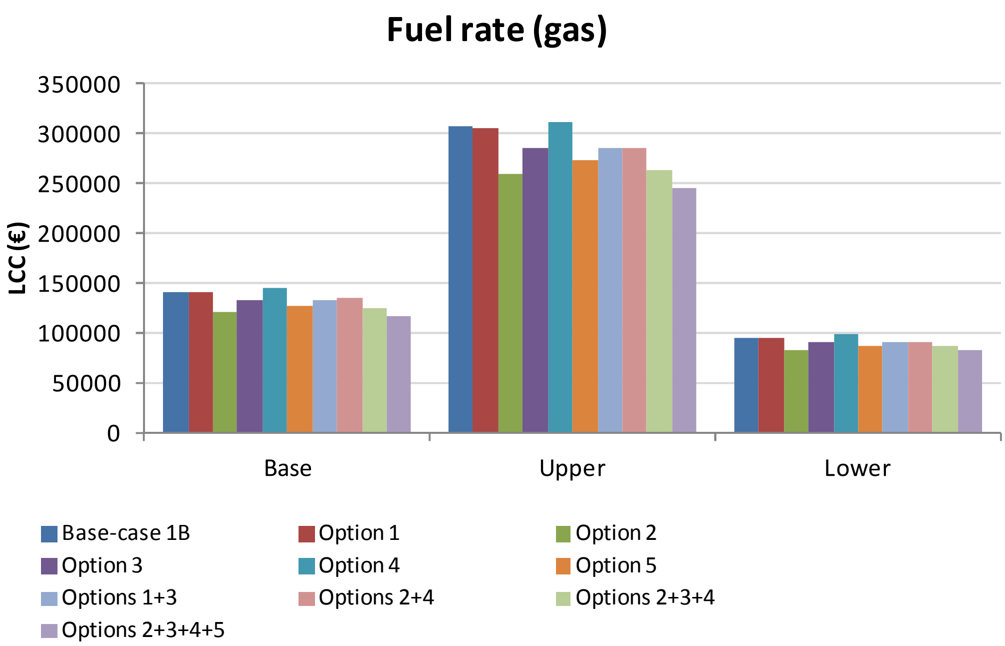
- **Base-Case 1A: Residential gas warm air heater**

Figure 8— 35: Sensitivity to gas rate for Base-Case 1A's Life cycle Cost



Base-Case 1B: Non-residential gas warm air heater

Figure 8— 36: Sensitivity to gas rate for Base-Case 1B's Life cycle Cost



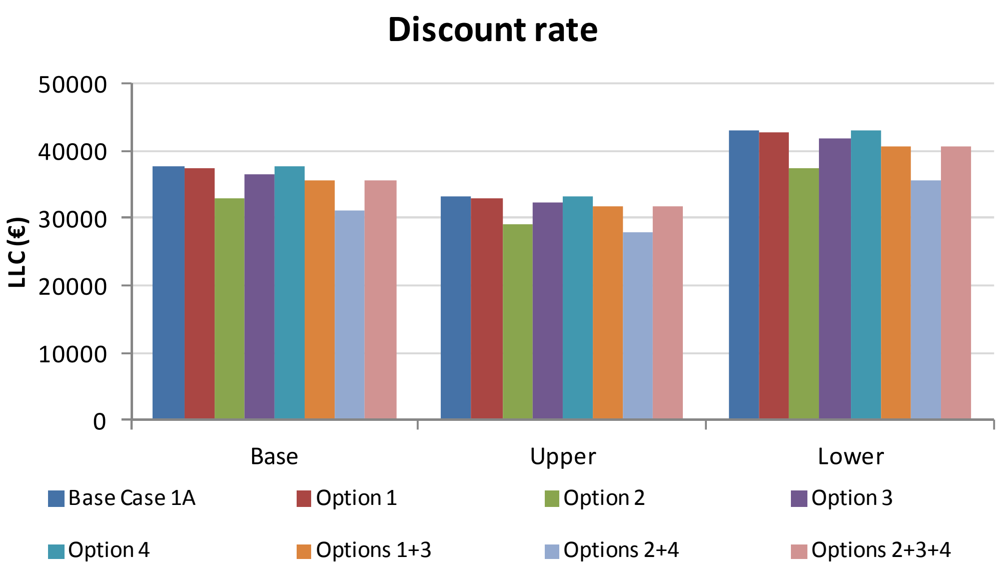
As expected looking over Figure 8— 36 it can be seen that the LCC advantage of many options over the Base Case is reduced or almost eliminated. Options 1 and 4 are two of those options that there is almost no benefit over the LCC when the lower limits of the gas prices are used.

8.5.5 Assumptions related to the discount rate

As set by the European Commission, the discount rate used is 4% with the lower and upper limits being 2% and 6%. It can be seen from the following figures that this parameter has a significant influence over the Life Cycle Cost, but it has no influence on the selection of LLCC and BAT.

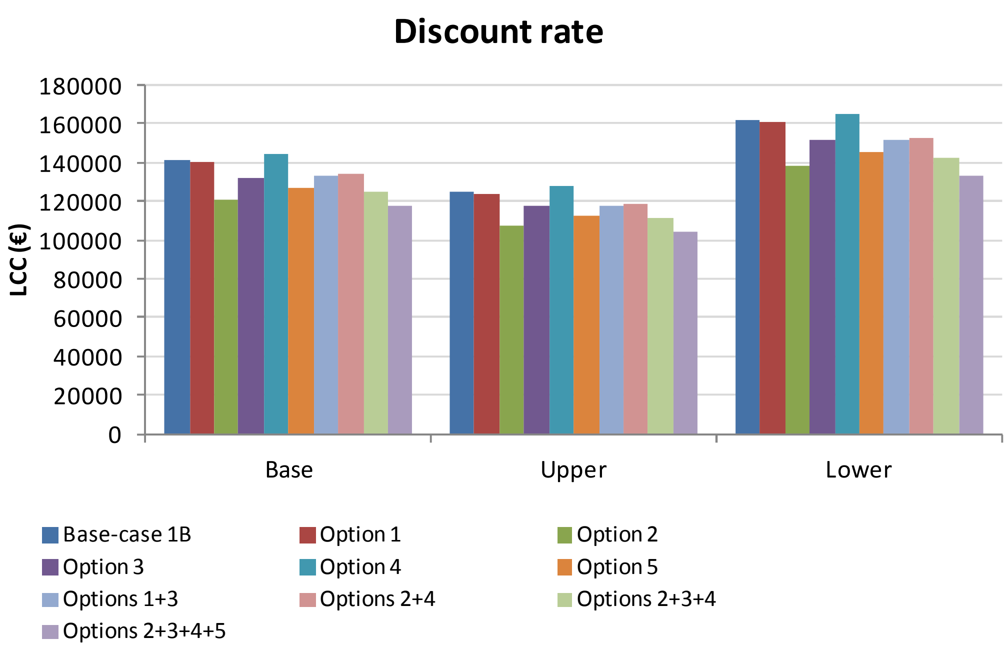
Base-Case 1A: Residential gas warm air heater

Figure 8— 37: Sensitivity to discount rate for Base-Case 1A's Life Cycle Cost



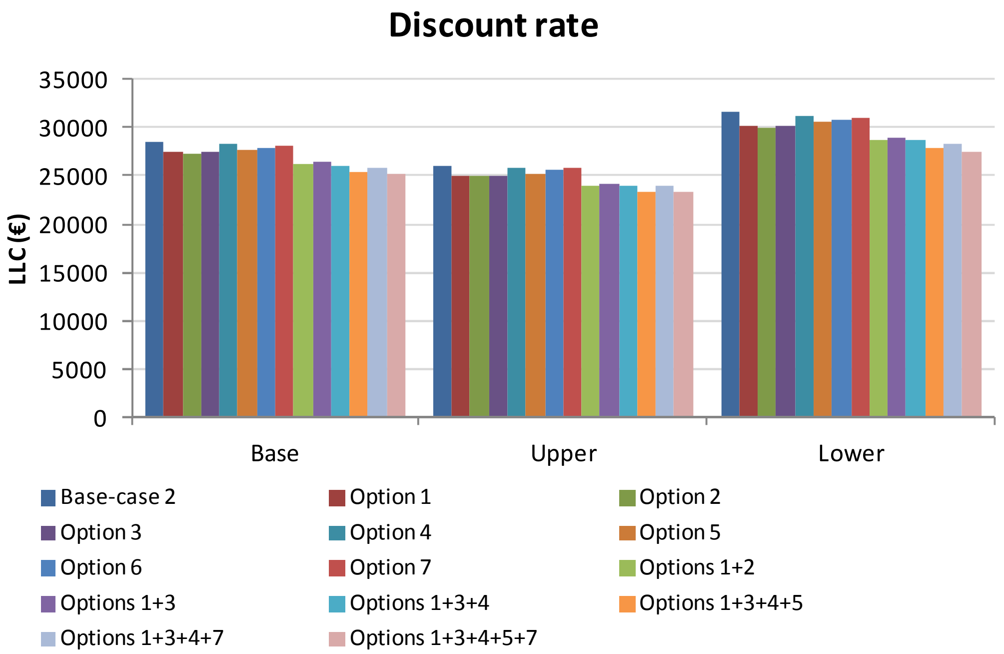
Base-Case 1B: Non-residential gas warm air heater

Figure 8— 38: Sensitivity to discount rate for Base-Case 1B's Life Cycle Cost



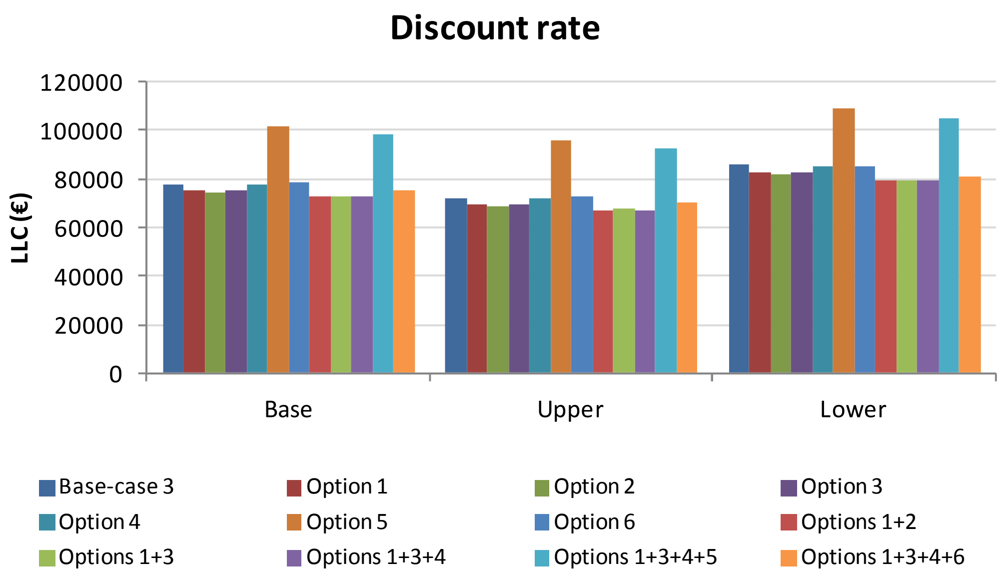
Base-Case 2: Single split heat pump

Figure 8— 39: Sensitivity to discount rate for Base-Case 2's Life Cycle Cost



Base-Case 3: VRF heat pump

Figure 8— 40: Sensitivity to discount rate for Base-Case 3's Life Cycle Cost



8.6 Conclusions

This Task report brings together the findings of the previous tasks of the preparatory study for Ecodesign requirements of central air heating products. It looked at the possibility to propose suitable requirements for warm air heaters and heat pumps to achieve significant environmental improvements.

The study showed that there was scope to set Minimum Energy Performance Standards (MEPS) for both residential and non-residential warm air heaters as well as single split and VRF heat pumps. Scenarios representing the implementation of recommended MEPS in the EU were projected over the period 2010-2030 to quantify the improvements that can be achieved with respect to a Business-as-Usual (BAU) scenario. As central air heating products require professional engineers and technicians to dimension and design the systems, relevant product information requirements were thought to be more effective than simplified energy labels.

Besides energy efficiency requirements, noise and waste/recycling requirements were also proposed. Air quality emissions for combustion heaters could also be proposed. The possibility to have requirements, or rather options, to use refrigerants with low global warming potential was also discussed.

As the heat pumps considered in this study can also be used to provide central cooling in buildings, the aim is to develop a common proposal for Ecodesign measures for ENER Lot 21 and ENTR Lot 6 (Air conditioning and ventilation). Likewise any measures related to the warm air heaters in ENER Lot 20 are aligned with the measures proposed in this study.

The likely economic and social impacts of the policy options were briefly described. Finally, a sensitivity analysis was performed to check the main assumptions used in the study and determine whether the findings remain robust and reliable.

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