Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems

BACKGROUND REPORT
INCLUDING DRAFT CRITERIA PROPOSAL
Working Document

for

FIRST AHWG-MEETING FOR THE DEVELOPMENT OF ECOLOGICAL CRITERIA FOR HYDRONIC CENTRAL HEATING SYSTEMS

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Background report including draft criteria proposal Working Document

for the 1st AHWG Meeting

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Abbreviations

BED	– Boiler Efficiency Directive
CE	– Conformité Européene – European Conformity
CHeSS	– Central Heating System Specifications
CHP	– Combined Heat and Power
CH_4	– Methane
CEN TC	– European Committee for Standardization Technical Committee
CLP	– Classification, Labelling and Packaging of substances and mixtures
CO	– Carbon Monoxide
CO_2	– Carbon Dioxide
CSA	– Canadian Standards Association
dBa	– A-weighted decibel (sound pressure level)
EPA	– United States Environmental Protection Agency
EPBD	– Energy Performance of Buildings Directive
ErP	– Energy-related Product
EuP	– Energy-using Product
etas	– Seasonal space heating energy efficiency
etason	– Seasonal space heating energy efficiency in on-mode
GHG	– Greenhouse Gas (emissions)
GPP	– Green Public Procurement
HC	– Hydrocarbons
kWh	– Kilowatt hour
LCA	– Life-cycle assessment
LDPE	– Low-density polyethylene
MS	– Member State
NO_x	– Nitrogen Oxides (often measured as NO_2 – nitrogen dioxide)
PBB	– Polybrominated biphenyls
PBDE	– Polybrominated diphenyl ethers
PM	– Particulate Matter
RoHS	– Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Directive
SEDBUK	– Seasonal Efficiency of Domestic Boilers in the UK
SO_x	– Sulphur Dioxides
VOC	– Volatile organic compounds
WEEE	– Waste Electrical and Electronic Equipment

Introduction

This document serves as an input to discussing criteria areas for hydronic central heating systems for Ecolabel and Green Public Procurement at the 1st Ad Hoc Working Group meeting on 28th June, 2011.

The **European Ecolabel**[1] is an element of the European Commission's action plan on Sustainable Consumption and Production and Sustainable Industrial Policy[2] adopted on 16 July 2008. This is a voluntary scheme established to encourage manufacturers to produce goods and services that are environmentally friendlier. The EU Ecolabel flower logo should also facilitate consumers and organizations (i.e. public and private purchasers) to recognize the best environmentally-performing products and making environmentally conscious choices more easily. The EU Ecolabel covers a wide range of products and services, and its scope is constantly being widened. The process of establishing the criteria proceeds at the European level following consultation with experts and all interested parties. A product or a service awarded with this label must meet high environmental and performance standards.

Green Public Procurement (GPP), defined in the Commission Communication "Public procurement for a better environment"[3] as "a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured." This is also a voluntary instrument, which public authorities can use to provide industry with incentives for developing and marketing more environmentally sound products[4].

One of the primary goals of establishing the criteria for **heating systems** is the increase of **energy efficiency** during operation of the heating systems, as the **use-phase** has been identified to contribute most to the environmental impacts caused by this product group. In addition to energy efficiency, other aspects impacting environmental impacts overall all phases of the life cycle of the products are taken into account, as well as the environmental improvement potential.

Establishing the ecological criteria for heating systems and through the appropriate promotion of the products awarded with the flower symbol (EU Ecolabel mark), the EU Ecolabel will contribute to more environmentally friendly products, provided that the EU Ecolabel is accepted by a wide range of producers and users. Further, this should also result in other environmental benefits, as lower air emissions related to energy production and consumption, lower resource consumption, potentially higher resource efficiency management (in respect to the issue of recycling and recyclability), etc. Finally, the ecolabelled products should also bring private and public customers direct cost savings (e.g. lower energy bills).

The document consists of the following chapters. Chapter 2 introduces and discusses the product definition and scope. Chapter 3 is a technical analysis of hydronic central heating systems which is based on a life-cycle analysis of different technologies; it includes a summary of the life-cycle analysis methodology and results, followed by a discussion on toxic and/or hazardous substances, and concluding with a discussion on environmental improvement potential that the Ecolabel/GPP criteria for this product group may bring with respect to the heating technologies currently existing and used

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1 EU Ecolabel website http://ec.europa.eu/environment/ecolabel/about_ecolabel/what_is_ecolabel_en.htm.

2 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – on the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan, COM (2008) 397, available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0397:FIN:en:PDF

3 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Public procurement for a better environment, COM (2008) 400, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0400:FIN:EN:PDF

4 GPP website http://ec.europa.eu/environment/gpp/what_en.htm

in the market today. Chapter 4 is a review of policy instruments related to heating systems; its goal is to understand how different policy instruments have dealt with hydronic central heating systems, with the objective of harmonizing as much as possible the current development of Ecolabel/GPP criteria for hydronic central heating systems to the already existing criteria in currently available policy instruments. Increased harmonization of policy instruments is expected to result in reduced additional bureaucratic burden and to facilitate the adoption of the EU Ecolabel and GPP criteria by industry and public procurers. Finally, Chapter 5 contains a proposal for relevant criteria areas for the EU Ecolabel and GPP for this product group, which will be the focus of discussion at the 1st Meeting of the Ad Hoc Working Group on the 28th of June 2011.

1. PROJECT BACKGROUND

The European Commission's Directorate General for the Environment has initiated a project directed towards developing a joint evidence base for the EU policy making in the area of heating systems. This study is being carried out by the Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS) and the VHK consultancy, in cooperation with all interested parties.

The purpose of this pilot project is to develop the EU Ecolabel and Green Public Procurement criteria for **hydronic central heating systems**.

The preliminary results of the study are available at the project's website (http://susproc.jrc.ec.europa.eu/heating/) and the proposals for the future criteria, which can be feasible for the product group under study, are presented in the current working document. This document has been prepared as a starting point for discussing the potential criteria during the 1st Ad-Hoc Working Group meeting.

One of the objectives of this meeting is the presentation of the results of preliminary studies conducted in the frame of this project and a following discussion on them with all interested parties. The following aspects of the project have been drafted so far: (1) Product definition, (2) Economic and market analysis, and (3) Technical analysis. The report containing the three above-mentioned parts can be downloaded from the project's website: http://susproc.jrc.ec.europa.eu/heating/. The main goal of this meeting is focused on discussing the ecological criteria development for heating systems. It is intended to present the aspects related to life cycle of heating systems which could be considered for the criteria development and to discuss the potential criteria with the stakeholders.

The preliminary results of the study show that main environmental aspects related to heating systems are their use phase i.e. the consumption of energy during operation. Establishing ecolabel criteria to award the most energy efficient products is expected to result in environmental benefits of energy savings, and consequently reducing environmental impacts caused particularly by energy production, air pollutants, etc.

It is in general recognised that the energy efficiency of different heating technologies depends not only on the technical characteristics of the main unit, but also on how the heating system is installed, in which type of building, and in which climate. This is especially so for heat pumps, where the energy efficiency is critically sensitive to all those issues. The Ecolabel can take these issues into account, and as part of the criteria will provide advice to the consumer on how to best install the systems. However, it is not possible to control the fact that an Ecolabelled heat pump might be poorly installed, therefore missing the benefits of reduced environmental impacts. In summary, the Ecolabel can only address part of the problem and may help to guide consumer behaviour. But ultimately, consumer behaviour cannot be fully controlled, and this caveat must be acknowledged.

Regarding the choice of heating technologies, the consumer may not always be totally free to select the most environmentally preferable technology in a given situation. For example, the particular building /neighbourhood might have access to district heating only. The Ecolabel here assumes that the consumer in principle has total freedom for choosing heating technology, fuel, etc. Also, a house might have insufficient insulation, or poorly built distribution systems of the heating water, which might lead to increased heat loss and therefore reduced environmental benefits for the same installed Ecolabelled heating product. In is thus necessary to realize some of these practical limitations, which however are out of the scope of the Ecolabel program.

Apart from the design of this system, user behaviour, analyzed as part of Economic and Market Analysis, is a crucial aspect affecting energy consumption. There is a wide variety of issues which play a key role. Besides the regional differences, which can be to a certain extent connected with the climatic conditions, the cultural aspects are of importance too. Furthermore, the habits vary among users. Consumer behaviour is also connected with their environmental consciousness. In summary, user behaviour is a complex issue, and in the frame of this study, a number of assumptions had to be made.

2. PRODUCT DEFINITION AND SCOPE

In Article 3 of the Ecolabel Regulation, a "product group" is defined as a set of products that serve similar purposes and are similar in terms of use, or have similar functional properties, and are similar in terms of consumer perception". This definition is consistent with the life-cycle analysis approach in this study, which compares different technologies where all share a common function: the production of one unit of heat for ambient heating, e.g. 1 kWh of useful heat. The objective of this functional approach to heating systems is to help consumers to make a choice between different kinds of heating technologies that provide heating to a hydronic central distribution system.

A preliminary definition of the product scope is detailed below, mainly based on the product scope of the recent draft **Implementing Measures for the Energy Labelling and Ecodesign of boilers** (May 2011), in line with achieving greater harmonization between different product policy initiatives. These are draft documents that can be found online[5].

The scope of this Ecolabel study is **"water-based central heating systems (or hydronic central heating systems)",** in all relevant combinations, up to a **maximum input power of 400 kW**, a limit proposed in consistency with the Boiler Directive[6]. These types of heating systems, also called **boilers**, use water as heat transfer medium to distribute centrally-generated heat from a **"heat generator"** to heat emitters in order to reach and maintain the indoor temperature of an enclosed space such as a building, a dwelling, or a room, at a desired level.

Heat generator means the part of a boiler that generates heat to a water-based central heating system, using one of the following processes:

- Combustion of gaseous, liquid or solid fossil fuels
- Combustion of gaseous, liquid or solid biofuels
- Use of the Joule effect in electric resistance heating elements
- Capture of ambient heat from air, water or ground source, and/or waste heat
- Cogeneration (the simultaneous generation in one process of heat and electricity)
- Solar (auxiliary)
- Hybrid systems: certain combinations of the above

The above definition gives the basic elements of what constitutes a central heating boiler (a heat generator and a connection to a water-based central heating system with heat emitters). The definition

[5] http://www.eceee.org/Eco_design/products/boilers/
[6] Boiler Efficiency Directive, 92/42/EEC

allows different technologies (e.g. fossil fuel boilers, biomass boilers, heat pumps and cogeneration) to meet the definition of "a boiler".

Although it is not explicitly stated in the definitions above, it may be that the circulator forms part of the 'boiler' (is incorporated into). For larger boilers the circulator is usually supplied separately. In case the boiler is placed on the market as 'parts' (burner supplied separately from the heat exchanger, etc.) the individual products do not meet the actual definition. The supplier of these parts may however decide to label them as a configuration following e.g. the draft Energy Label Implementing Measures[7] which are discussed in Chapter 4.

The proposed scope on "hydronic central heating systems" was presented at the EUEB meeting in Brussels October 20th and distributed to EUEB and GPP Advisory Board members via two documents: "Development of EU Ecolabel and GPP Criteria for Heating and Cooling Systems", which generally describes the area and potential classification of heating systems, and "Common Benchmark Ecolabel and GPP Criteria for Hydronic Central Heating Systems", which develops the proposal for the actual scope of the product group for Ecolabel and GPP criteria (both documents available at the project's website).

As the request for comments addressed both the EUEB and the GPP Advisory Board, in total around 100 organisations were contacted, which in turn distributed the request in the respective Member States or related organisations. All replies received were taken into account. As the request for comments encouraged actively those respondents who whish to see the proposal modified or rejected as a whole, we understood those organisations which did not reply as supporters of the proposal in the context of this analysis. We received comments from 13 stakeholders: 7 from member states, 5 from industry (including two consultancies on testing and standards for heating systems) or industry organizations, and 1 from non-governmental organizations.

The main aim of the stakeholders' consultation on the two documents, especially the scoping document with a proposal to develop a common benchmark for Ecolabel and GPP criteria for hydronic central heating systems was to collect opinions regarding the suitability of the scope of the study as defined. From the 13 answers, we obtained clear positive reply and approval of the scope from 8 stakeholders. We obtained a mixed opinion from 1 stakeholder, and opposition from 4 stakeholders.

From the stakeholders supporting the scope in terms of a common benchmark for central hydronic heating systems, the reasons in support were offered as:

- A common benchmark is very necessary as a method to provide a fair comparison between different heating systems, which will also provide useful information to the consumer in making an appropriate choice.
- Central hydronic heating systems are an appropriate product group because, as presented in the scoping document, they represent the largest environmental impact in the EU-27 not only in terms of energy consumption but also taking into account a number of environmental impact parameters, including CO_2 emissions, and other air emissions.

One comment was received which tentatively supports the proposal:

- In the opinion of the stakeholder offering mixed support for the proposal, the main concern comes from the GPP point of view. In the opinion of this expert, central heating systems are not easily defined, neither as a single product group nor as a service, because they have many different parts, and because they would need to be assessed together with the building.

[7] http://www.eceee.org/Eco_design/products/boilers/

From the stakeholders with diverging or opposed opinions regarding the scope definition, the main arguments for their position were:

- The common benchmark approach was tried before when the Ecodesign studies were started, and it did not succeed.
- The systems approach is claimed not to fit with the market reality. If the common benchmark approach is implemented, it will lead to market distortions and to the discrimination of certain heating systems technologies. In particular, it will lead to a discrimination in favor of packaged systems and against ad-hoc installed systems, which are claimed to be the most commonly installed in certain member states.
- The information content of common benchmark criteria is too low to be worthwhile.
- It is necessary to exclude some fuels from the start, in particular fossil fuels. Only renewable fuels should be taken into consideration from the start.

A number of comments were received which exceeded the discussion on the proposed scope of the product group and entered into methodological issues. Regarding these very valuable methodological opinions and comments for improvement, very common positions expressed were as follows:

- A very common position is that it is necessary to always take into account the methodology of previous product policies such as Ecodesign, energy label, and the Energy Performance of Buildings Directive (EPBD), and to develop Ecolabel/GPP criteria in harmony with previous policy methodologies.
- It was a common statement that the heating system needs to be matched with the type of building where it is installed, as is done in the application of the EPBD. It is not possible to just compare heating systems alone, but a factor needs to be introduced to take into account what type of building the system is installed in.
- A very common comment was that the energy efficiency parameter alone is not sufficient to compare heating systems, but that other environmental impact parameters are important such as: CO_2 emissions, air emissions, etc.
- It was suggested to provide market surveys of companies that would be able to comply with the Ecolabel/GPP requirements
- Sometimes procurers are not able to choose between heating systems. In this case, some doubts have been expressed that the Ecolabel/GPP of a common benchmark could provide added value.
- It is necessary to take into account different climate zones, and it is suggested to follow the same methodology as was developed in Ecodesign (example for boilers and combi-boilers, Lot 1).
- It was commented that the performance of heating systems for a given technology could change because of the fuel mix in the particular member state used. However, a different opinion was also stated arguing that the EU grid is interconnected and therefore that the development of Ecolabel/GPP criteria does not need to account for differences in fuel mixes from country to country.
- It is necessary to provide data on improvement potentials. In this regard, we should also take into account the impact studies of existing Ecodesign implementing measures.

Other comments expressed by some stakeholders were:

- Regarding the suitability of heating systems for GPP, one of the stakeholders mentioned that heating systems are a product group that is suitable for both Ecolabel and GPP criteria, but especially for GPP criteria. Conversely, other stakeholders expressed that it is often the case that the consumer is not able to freely choose a given heating system because of constraints regarding the type of building, the budget, or the availability of certain systems in the particular region or member state (considered a problem both for individual purchasers in the case of Ecolabel, or the public purchaser in the case of GPP).

In the following the IPTS point of view regarding the received comments is discussed. First, regarding the comments in support:

- We fully agree that a common benchmark that allows a fair comparison between different heating systems is valuable especially because it will provide useful information to the consumer to help making the most environmentally sound purchasing choice.
- Central hydronic heating systems were indeed proposed as a product group because they represent greater than 80% of the environmental impact of all types of heating systems in buildings in the EU.

Second, regarding the comment offering mixed support:

- We understand that the product group criteria should be developed in line with both Ecolabel and GPP goals. We believe that the definition of hydronic central heating systems might present some challenges, because it will encompass a number of technologies to accomplish the function of central heating of buildings using hot water to circulate the heat. Despite potentially challenging, a definition of hydronic central heating systems is in our opinion still feasible; our position is also based on information gathered from existing Ecodesign studies of central heating systems. We will pay attention to the suggestion that the study of central heating systems needs to be conducted together with the building. In order to address this comment, we propose to study the potential inclusion of a factor that would take into account the relationship between the heating system and the type of building where the heating system is installed (as was suggested also by other experts).

In response to stakeholders with diverging opinions regarding the scope definition:

- First, it was expressed that the common benchmark approach was tried in Ecodesign studies and it did not succeed. We believe that it is technically feasible to develop a common benchmark approach to the Ecolabel/GPP criteria for hydronic central heating systems. Additional considerations that played a role in the decision not to develop a common benchmark for the Ecodesign studies will not necessarily be a factor in Ecolabel/GPP.
- The systems approach is claimed not to fit with the market reality, and a risk is perceived that the common benchmark approach could lead to market distortions and the discrimination in favor of commercially available packaged systems vs. ad-hoc installed systems (not available off-the-shelf). In this regard, the Ecolabel/GPP criteria need to address the current market, i.e. the products existing on the market. If products are not available for purchase in the market, then they are out of the scope of Ecolabel/GPP.
- It was expressed that the information content of common benchmark criteria is too low to be worthwhile. Our position is that, in order to effectively address the large impact that heating systems currently have in the EU (40% of the primary energy consumed in Europe is consumed in the heating and cooling of buildings), a combination of approaches and measures (mandatory and voluntary) will be needed. While mandatory measures mandating certain minimum performance of heating systems and energy performance of buildings might be seen as the most effective, the Ecolabel/GPP voluntary criteria will with no doubt provide valuable information to the consumers in their choice of the most environmentally sound heating systems, and will contribute positively to the reduction of energy consumption and greenhouse gas emissions from heating of buildings in the EU.
- In the opinion of some stakeholders, the Ecolabel/GPP should not be awarded to fossil-fueled heating systems, and instead the development of Ecolabel/GPP criteria should focus on renewable fuels. Our position is that the development of the common benchmark study will not be necessarily in opposition to this comment. The study will provide data that will allow a fair comparison of different heating systems technologies employing different fuels. No technology or

fuel will be excluded a priori from the analysis. However, as a result of the analysis, some technologies or fuels might be excluded on the basis of the scientific evidence from a life cycle analysis perspective collected during the study.

Below is our response to comments offering methodological suggestions:

- We agree that it is necessary and valuable to always take into account the methodology of previous product policies such as Ecodesign, energy label, and the Energy Performance of Buildings Directive, and to develop Ecolabel/GPP criteria in harmony with previous policy methodologies, and we will conduct our study in line with previous product policy studies. Past research and criteria development exercises have revealed rather broad methodological differences between Ecodesign (mandatory minimum standards) and Ecolabel (award to the best 20% performing products within a product group), which are mainly caused by the different aim and characteristics of the instruments. However, it goes without saying that existing research results are used to the maximum extent possible, and that increased coherence between the related policy instruments is sought.
- We welcome the suggestion of incorporating a factor to take into account the type of building the system is installed in, in order to address the concern that heating systems need to be matched to the type of buildings where they are installed.
- It was pointed out that the energy efficiency parameter alone is not sufficient to compare heating systems, but that other environmental impact parameters such as CO_2 and other air emissions need to be taken into account. Here there seems to be a misunderstanding. The scoping document mentioned that a number of environmental impact parameters will be considered in the study, including the abovementioned. The scoping document focused a bit too much on energy efficiency, as an example of how to compare different heating systems. Perhaps it should have made more clear that the comparison will be done on the basis of a set of parameters.
- Market aspects will be part of the study, and we will incorporate market surveys of companies that would be able to comply with the Ecolabel/GPP requirements.
- We agree that the Ecolabel/GPP criteria will only be useful when the purchaser has a free choice over different systems. We believe that a substantial part of purchasers will have a free choice and therefore that it is worthwhile to develop Ecolabel/GPP criteria to steer these decisions towards the most environmentally sound alternatives.
- We will take into account different climate zones in the study, following the same methodology as was developed in Ecodesign (e.g. for boilers and combi-boilers).
- Regarding the comment on different fuel mixes in different member states, we agree with the experts suggesting that the EU grid is interconnected and therefore that the development of Ecolabel/GPP criteria does not need to take into account different fuel mixes.
- We will provide data on improvement potentials, and we will take into account impact studies of existing Ecodesign implementing measures.

Regarding further comments:

- The advantage of the scope as a fair comparison is especially important in GPP where the individuals taking the decision on behalf of a public organization are looking to select a heating service more than a specific type of heating product.

In summary, from the comments received, 8 out of 12 experts expressed an overall support for the development of a common benchmark for hydronic central heating systems. Regarding the statements of the 4 stakeholders expressing significant concerns with the approach, we will take them into consideration and learn from previous work on common benchmark approach undertaken in Ecodesign. We would like to point out that, even though the approach might not have worked perfectly for Ecodesign, we believe it is more suitable for Ecolabel, a related but not identical methodology to Ecodesign.

Regarding the comments supporting the exclusion of fossil fuels, we still think it is worthwhile to conduct a horizontal comparison of different technologies and fuels. On the basis of the evidence collected from the study, some technologies/fuels might be then excluded from Ecolabel criteria.

Finally, there seems to be a misunderstanding on the status and progress of the project. The scope document presented is very preliminary and mainly a concept to be developed. We were looking for early feedback from the stakeholders, and we will incorporate as many comments as we can in the study that we are undertaking.

The IPTS response was again distributed to all stakeholders. We did not receive any more feedback, which we take as approval of our reply.

2.1 Description of products included in the scope

The scope of heating systems considered for Ecolabel and GPP criteria development in the current project covers heating systems in domestic, commercial or industrial premises with the primary aim of heating indoor spaces, in order to reach and maintain the indoor temperature of an enclosed space such as a building or a dwelling at a desired level.

Nevertheless, due to the different functions fulfilled by some of the products (e.g. the provision of domestic sanitary water, or ambient cooling in the case of reversible heat pumps), it is proposed to exclude heating systems whose primary aim is to provide domestic sanitary water, also to exclude heat pumps if their primary aim is to provide cooling, and finally to exclude those heat pumps that do not transfer heat to a water medium (i.e. to exclude heat pumps that are not hydronic).

As in Ecodesign Implementing Measures, the scope is suggested for "self-standing" heating units, without taking into consideration their combination with other parts such as controls.

Boilers are part of a set of several elements, including pipe work, boilers, radiators, heat exchangers, hot water storage cylinders and insulation. The exact nature of the different elements will depend on the type of distribution of the heating. Heating in any house or building is key to the overall building energy efficiency and the boiler is a key element that will influence the overall environmental impact of the system. The most common devices for achieving the heat distribution are circulators, which pump the hot water to the final emission points. Alternative ways to distribute heating in a central system (but outside the scope of the proposed study) are the distribution of heat by means of air forced through ductwork, or steam fed through pipes.

There are different types of processes involved in the heat emission at the final points, including:

- Heat convection in radiators. Hot water is distributed to "radiators" installed in rooms and spaces to be heated. The heat transfer to the rooms occurs mainly by convection as hot water circulates through the pipes in the radiator unit.
- Under floor heating. A type of central heating end application where the heat is distributed using conduction and radiant heat. The circulation of hot water through pipes located under floor coverings results in the heating of the floor and subsequently the room. The temperature is lower than that of radiators because it is a more efficient way to transmit the heat. Because the room is heated from the floor up, under floor heating is a very effective way of maintaining constant conditions within an area
- Ceiling heating: Operating in a similar way as under floor heating but located inside ceilings.

The heat generators (boilers) which form the scope of this study may be of different technologies:

- **Central heating boilers (CH boilers)** are devices designed to provide hot water mainly for ambient heating, with a variety of fuels (natural gas, oil, wood, biomass, electricity, etc.), and different technologies such as condensing or non-condensing technologies. Condensing boilers use the latent heat of evaporation contained in the water vapor of flue gases, and are significantly more energy efficient. Only boilers whose only or primary function is to provide ambient heating are part of the scope. If as a secondary function they provide sanitary hot water, they are called central heating combi-boilers (CH combis) and they are also part of the scope.
- **Heat pumps** are used to extract heat from a variety of sources: ground rock, ground water, surface water, air, etc. They also have a large variety of applications. Heat pumps can be used to heat water in hydronic central heating systems, typically providing heat delivery by under floor heating systems.
- **Combined heat and power (CHP),** or **cogeneration units** are based on the "simultaneous generation of thermal energy and electricity and/or mechanical energy". The heat distribution takes place by the direct use of exhaust gases, steam or hot water. Micro-CHP units are defined as those with < 50 kWe capacity, and small-scale CHP as those with < 1 MWe capacity. CHP units may be powered by a variety of energy sources including biomass and biogas.
- **Solar thermal assisted technologies** are also used as part of the solution.

Typical sources of energy depend on the specific heating technology, but may include electricity, solar thermal, heat transfer from ground, water, or air by heat pump technology, natural gas, wood, biomass, etc., and combinations of energy sources. Solar thermal heating appears to be on the increase for ambient heating and hot water provision in buildings.

This study analyzes the feasibility of developing a common benchmark to horizontally address and compare different hydronic central heating technologies as one single product group. The product group "hydronic central heating systems" represents a very large group. As presented in Table 7 of the Draft Task 1 Report on the "Development of EU Ecolabel and GPP Criteria for Heating and Cooling Systems" (IPTS, 2010), the group of hydronic central heating systems accounts for roughly 86% of the total use-phase primary energy consumption by heating systems (central and space heating systems together) in the EU, therefore representing most of the environmental impact of all types of heating systems taken together.

This study aims at a comparison between different technologies such as boilers, heat pumps, combined heat and power, etc., whose function is to provide hydronic central heating. The study will also elucidate whether attempting to develop a common benchmark performance measure would or not lead to the exclusion of any of the central heating technologies from Ecolabel & GPP criteria.

The most cited performance parameter of the boiler is the (nominal) power input in kW[8]. The scope of boilers is set to a maximum of 400 kW consistently with the Boiler Directive[9]. The heating capacity is an essential parameter for correct sizing of boiler to the building load. The heating capacity of boilers should be sufficient to cover the space heating need of a dwelling or building on the coldest day of the year or rather the last decade (as defined in relevant test standards). On the other days the boiler will function in part load.

For that reason, the test standards, discussed in the technical background report for the present study distinguish between heating energy efficiency not only at full load, but also at 30% part-load and —on

[8] The **maximum nominal power input** of large boilers, refers to the energy input (eg. m^3 of gas per hour, expressed as kW, or electric power consumption in kW electric) at nominal conditions. Nominal conditions are standardised test conditions (aka standard rating conditions) and usually refer to the maximum power input of the boiler (which may occur in normal operating conditions and can be sustained over a certain length of time) for certain set system parameters (flow rate of medium, etc.). It is therefore not the same as the maximum power output, because the boiler introduces generator losses (except for heat pumps, where the nominal power input in electric kW is lower than the power output in kW of heat, since the renewable energy input is not counted). However, for smaller boilers (e.g. <50 kW) the nominal rating often refers to OUTPUT power.

[9] Boiler Efficiency Directive, 92/42/EEC

occasion— in stand-by/zero load. As will be argued in the following chapters, this is still a very crude approximation of what happens in real-life. Various studies have shown that the average load over the heating season is more in the range of 10%. This not only due to the outdoor temperature variations over a heating season, but also due to over-sizing and —for a combi-boiler or boiler heating an indirect cylinder— due to sizing of the boiler primarily for the water heating function. Furthermore, the fixed low return (or average) boiler water temperatures for part-load operation, which are a very important parameter for flue gas energy losses and latent heat recovery, are rarely achieved in real-life. Therefore, many boiler tests describe part load tests.

A summary of scope of the product group is presented in Table 1.

Table 1. Summary of scope of product group

Component of heating system	Fuel	Nominal power input	Working principle
- Gas/oil boiler	Gas (natural or propane) or oil	4-400 kW	Combustion
- Biomass boiler	Biomass (logs or pellets)	4-400 kW	combustion
- Heat pump boiler	Electricity	4-50 kW (indicatively)	Electric compressor, driving a vapour cycle
	Gas (possibly in combination with waste heat and/or solar heat)		Gas driven engine, driving a compressor for a vapour compression cycle Gas-fired combustion, driving a sorption process
- CHP or cogeneration boiler	Gas (natural or propane) or oil (including bio-oil)	4-400 kW	Micro: external combustion (Stirling engine) Mini: internal combustion (piston engine driving a generator) Other: fuel cells, based on electrochemical principles
Solar thermal	Solar energy in combination with electric energy for pumps/controls (needs other heat generator to fulfil heating demands in all circumstances)	Not applicable (sized depends on location, budget and application)	Capturing and storage of solar irradiation

This study estimated an average EU heating demand of 7500 kWh per dwelling per year. A first assessment of Prodcom sales data (more detailed analysis presented in the technical background report) showed an annual production of 6.9 million boilers in 2009. Considering the limited value of import and export (respectively some 230 and 807 million euro) it can be concluded that most of the EU production is meant for the EU market.

Lot 1 study estimated in 2010 boiler sales of around 6.9 million units, a boiler stock of approximately 110,9 million boilers and an annual primary energy consumption of 10.5 PJ. The CO_2 emissions were estimated to be some 600 Mton and SOx emissions are some 700 kton. The screening analysis shows that central heating boilers are among the product groups with the highest energy-consumption in Europe. Development of environmental policies, like EU Ecolabel or Green Public Procurement criteria, appears feasible, also given the current proposals for Ecodesign requirements for 'boilers' and Energy labeling of 'boilers'.

Next section (Chapter 3) presents a summary of the Technical Analysis, followed by an overview of how different legal instruments, including labeling schemes, have addressed heating systems (Chapter 4). There is no ecolabel program so far that has developed criteria for all central heating systems taken together as a group, and instead have developed criteria for individual central heating products.

3. TECHNICAL ANALYSIS OF HYDRONIC CENTRAL HEATING SYSTEMS

The goal of the technical analysis of hydronic central heating systems is to compare the life-cycle environmental performance of the heating systems, in particular of seven base cases described so far (and two more base cases to be added in an updated report), in terms of a number of environmental parameters. This technical analysis consists of three parts:

- A life cycle model was built and evaluated for these seven base cases, as reported in the draft technical background report available in the project's website
- A discussion on the use of toxic and/or hazardous substances in heating products and their contribution in the overall environmental impact of these products
- Identification of the environmental improvement potential as identified using the least life cycle cost (LLCC) method

3.1 Life-cycle analysis results

A life-cycle model was specifically build to evaluate the environmental performance of a number of relevant base cases for the Ecolabel of hydronic central heating systems. The methodology is similar to the one developed in Lot 1 of Ecodesign (boilers). Lot 1 did not include biomass boilers. However, biomass boilers were part of the scope of another Ecodesign study (Lot 15 – Small solid fuel combustion installations). Therefore, some of the results from the environmental performance of biomass boilers from Lot 15 were incorporated into the life-cycle environmental performance assessment of the present study.

The life cycle of a heating product consists of a number of key phases, summarized below:

- Extraction and processing of raw materials – Mining operations, refining of ores and petroleum products and the manufacturing of materials and substances will result in environmental issues and impacts, these include high energy use, physical disturbance of the landscape and pollution from toxic emissions, which may affect land, water and air.

- Components manufacture – The manufacturing of components used in heating products has significant environmental impacts, including energy consumption, the use of materials with hazardous properties and the production of hazardous wastes.

- Transport of components to the assembly plant – The main environmental impact is energy consumption (fuel use) and associated air quality emissions by the vehicles.

- Unit assembly – Energy consumption of assembly line and overheads. There will also be hazardous waste arising from the assembly process.

- Transport of units to distribution network – again, fuel consumption by the carriers and air quality associated emissions.

- Use - Energy consumption from the utilisation of the unit. There are also fugitive emissions of refrigerants from systems.

- Maintenance – all systems will require some form of maintenance during their lifetime. Gases may need topping-up or to be replaced due to fugitive emissions along with general maintenance/ replacement of moving parts, seals and lubricants.

- End of life – the environmental impact here will depend on the management of the heating product at the end of its life; mismanagement can result in increased impacts. This may result in hazardous waste arising from the components/materials used in the heating product manufacturing process, which will need to be dealt with in an appropriate manner.

For each of the phase's there will be an element of energy input, which will vary for the different phases. In each phase there will also be emissions to air, land and water, as well as waste, which will either be suitable for reuse or recycling or have to be sent for disposal.

During the life cycle of a heating product, energy consumption is the key environmental impact, especially in the use phase.

Each of these different phases will involve the use of raw materials and energy and result in wastes and GHG emissions. A life cycle assessment of a detached house heating system for example indicated that the most important phase in terms of environmental impact from the heating system is the operational phase, as over the whole life cycle of the heating system this is where 99% of primary energy is consumed and carbon dioxide is emitted (Sasnauskaite et al 2007). This is important, as the primary energy consumption will be predominately energy from fossil fuels, although other sources will also contribute such as solid biomass.

It is therefore very important when choosing a heating system that significant consideration is given to the boiler used, as this will greatly influence the overall environmental performance of the heating system in the use phase.

3.1.1 Base cases

The preparatory study for Ecodesign Lot 1 on boilers selected 9 base cases (mainly different sizes of boilers). From this study, two boilers were selected: the M-size (nominal capacity of 22 kW output), and the relatively large XXL-size boiler (nominal capacity of 115 kW output). The M-size boiler was chosen because it is the most sold in the market. The XXL-size boiler was chosen to have an estimate on the upper limit of environmental impacts possibly caused by boilers (the larger the size, the greater the environmental impact), in order to have a conservative environmental impact evaluation.

Already in Ecodesign Lot 1, a comparison was made among different technologies used for hydronic central heating, in particular: heat pumps, co-generation, and solar. Feedback received from experts regarding the preliminary scope of the present study suggested that all of those technologies, and especially renewable sources of energy, are seen as relevant for further consideration and evaluation. Lot 1 did not consider biomass boilers. Feedback from experts in the current study especially indicated an interest in the analysis and consideration of biomass fuelled boilers, and therefore three base cases of biomass boilers have been included in the present life-cycle analysis, and extracted from Lot 15 preparatory study. Two other base cases were analyzed: a 7 kW electric heat pump, and a 22 kW cogeneration-boiler Stirling-engine. In addition, two additional base cases will be added in an updated technical background report: a gas fired boiler with a solar system, and a gas-hybrid, i.e. a gas-fired boiler with a small air-to-water heat pump attached.

Table 2 below summarizes the current seven base cases analyzed, including output power, energy input, energy efficiency (in terms of "etason" and "etas", defined below) and intermediate heat demand.

Table 2. Outline of seven base cases used in the life-cycle analysis of this study

Product cases	typical output power	energy input (thermal)	etason (thermal)	etas (intermediate efficiency)	intermediate heat demand
	kW	kWh/year	% GCV	% GCV	kWh/year
Gas/oil M	22	11.776	93,8%	89%	10.449
Gas/oil XXL	115	89.492	93,8%	88%	78.439
Small manual biomass boiler	29	19.803	61,5%	52%	10.300
Small automatic biomass boiler	29	17.328	80,0%	73%	12.565
Medium automatic biomass boiler	110	84.247	85,0%	78%	65.611
7 kW electric heat pump	7	8.460	130,0%	124%	10.449
Cogeneration boiler	6 + 16	14.867	74,3%	105% incl electricity 67.3% excl. elec, incl cascade	10.638

The efficiency parameters outlined in Table 2 are defined below. In order to arrive at a maximum extent of harmonisation and coherence among related product policy instruments it seemed straightforward to use the efficiency measurement as developed in Ecodesign Lot 1 and corresponding Implementing Measures. For more detail, please refer to the technical background document available at the project's website:

etas (thermal), η_s, is the "seasonal space heating energy efficiency" (as defined in the draft Ecodesign Implementing Measures for boilers, as explained in Chapter 4), means the ratio between the space heating demand pertaining to a designated heating season provided by a boiler, and the annual energy consumption required for its generation, expressed as a percentage.

etason (thermal), $\eta_{s,\ on}$ is the "seasonal steady-state thermal efficiency in on-mode" (as defined in the draft Ecodesign Implementing Measures for boilers)

The relation between etas and etason is given by: etas = etason – ΣF(i), where ΣF(i) is a sum of correction terms that include the effect of stand-by heat losses, pilot flame energy consumption, seasonal electric efficiency, and other factors (a detailed explanation of the methodology is available in the technical background document at the project's website).

3.1.2 Environmental impact categories

Following the MEEuP life-cycle analysis methodology, the following is the list of environmental parameters that were taken into account, all of them in the specified units per 177.634 kWh thermal output. This thermal output is chosen as reference, as it corresponds to the thermal output of an M-size condensing boiler, one of the most commonly available in the market. However, this value has been chosen arbitrarily for the normalisation of values. Alternative values for the normalisation could have been used as well.

The environmental impact categories are:

- Primary energy used, i.e. Gross Energy Requirement, GER (GJ)
  - In addition, out of the primary energy used, how much was electricity consumption in primary energy units (GJ)
- Emissions to air:
  - Greenhouse gases (t CO_2 equiv.)
  - Acidification potential (kg SO_x)
  - Volatile Organic Compounds, VOC (kg)
  - POP (mg i-Teq)
  - Heavy metals, HM (mg Ni)
  - PAH (mg)
  - PM (kg)
- Emissions to water:
  - Heavy metals (HM, in g Hg/20)
  - Eutrophication (g PO_4)
- Emissions to soil:
  - Non-hazardous
  - Hazardous
- End-of-life materials:
  - Disposed (kg)
  - Recycled (kg)

3.1.3 Results of the life-cycle analysis

Table 3 below presents the results of the life-cycle analysis for the seven base cases, where the impacts have been harmonized by reference to 177.634 kWh thermal output.

Table 3 shows different environmental impacts among different heating technologies. The results of the environmental impact analysis on this table are disaggregated by impact categories, and do not incorporate any assumption on how environmental impacts should be weighted against each other. So for example, if CO_2 emissions are considered a priority, then biomass boilers will be preferable over fossil fuel boilers. However, if other air pollution indicators are considered important, then biomass combustion is not as "clean" as good gas or oil combustion. Certain local and national policies limit therefore the emissions allowed for biomass boilers (and solid fuel boilers in general).

The following sections below provide some more detail on each of the impact categories one by one, comparing the seven bases cases for each of the impact categories.

Table 3. Normalised life-cycle environmental impacts for seven base cases (per 177.634 kWh thermal output)

			resource use				emissions to soil										
	materials		GER		water		waste		emissions to air							emissions to water	
	disposed	recycled	GER total	elec. (as prim.)	process	cooling	non-haz.	haz./incin.	GHG	AP	VOC	POP	HM	PAH	PM	HM	Eutr.
	kg	kg	GJ	GJ	m^3	m^3	kg	kg	tCO2 eq.	kgSOx	kg	mg i-Teq	mg Ni	mg	kg	g Hg/20	g PO_4
Gas/oil M	6,70	38,50	743,5	41,8	3,20	110,10	5,80	119,00	41,90	27,30	0,50	1,00	1,60	0,30	2,40	0,90	13,00
Gas/oil XXL	3,22	38,67	798,3	46,7	3,20	124,34	67,56	1,99	48,18	42,10	0,68	0,44	0,97	0,15	1,14	0,42	3,66
Small manual biomass boiler	22,21	364,18	1.230,9	17,1	2,43	29,13	1.262,62	2,28	7,97	166,27	9,37	142,23	61,34	313,86	305,89	2,39	77,10
Small automatic biomass boiler	13,65	252,30	1.560,9	16,8	1,28	35,51	686,33	0,58	3,20	140,00	3,64	372,71	85,18	292,29	54,53	1,08	77,34
Medium automatic biomass boiler	2,90	43,19	1.006,0	6,6	0,60	14,88	525,74	0,64	1,50	95,68	2,70	139,70	47,59	241,22	44,36	0,38	18,63
7 kW electric heat pump	41,69	275,75	723	704	55,63	1.847,65	1.514,50	37,47	33,90	191,83	0,46	11,04	18,49	2,99	16,00	12,73	148,99
Cogeneration-boiler	23,39	128,16	614	418	35,4-	1.121	150	6,3	39,0	76,8	0,6	0,7	3,4	0,2	0,5	0,1	45,0

3.1.3.1 Primary energy and electricity consumption

When heating systems are compared, one of the main aspects for comparison is the amount of primary energy used per unit of heating energy delivered. The following figures represent the comparison of Gross Energy Requirement (i.e. the primary energy used) in units of GJ per 177.634 kWh of thermal output, followed by the electricity consumption (as primary energy) also in GJ per 177.634 kWh of thermal output.

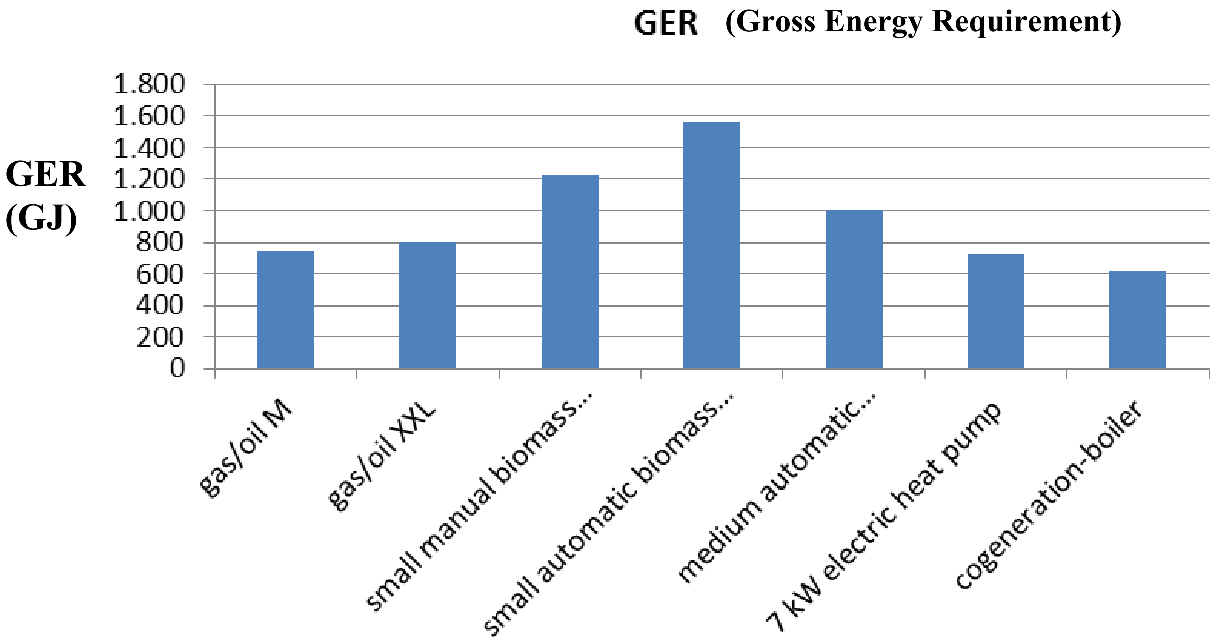

Figure 1. Comparison of Gross Energy Requirement (primary energy used) in units of GJ per 177.634 kWh of thermal output

When comparing the performance of the seven cases in terms of Gross Energy Requirement (primary energy use), it can be concluded that biomass boilers (especially the small automatic biomass boilers) have somewhat higher primary energy consumption (and therefore lower nominal efficiency) compared to other base cases, corresponding also to the higher material input. Throughout the life-cycle analysis study, it also became clear that the use-phase is the greatest contributor to total primary energy use, representing 95-99% of the total primary energy consumption, regardless of the specific boiler technology (any of the seven cases analyzed).

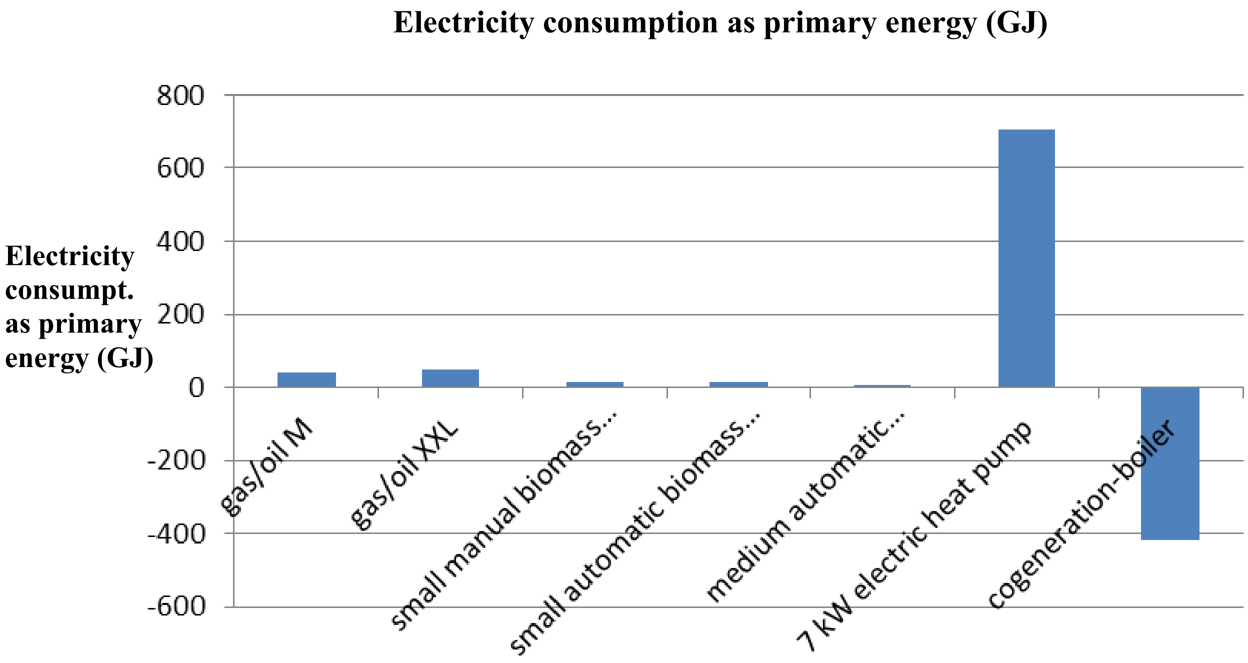

Figure 2. Comparison of electricity consumption (as primary energy) in units of GJ per 177.634 kWh of thermal output

Regarding electricity, as expected, the electricity consumption is the highest for the electric heat pump and negative (meaning net electricity production) for the cogeneration boiler.

To put the results of our research into context, we compare our analysis with similar analyses in the literature. This serves to see if the assessment is in the right range. Several other labels analyze heating systems in terms of the primary energy ratio (PER): the ratio of useful heating energy output divided by the primary energy input. This ratio is a measure of the overall energy efficiency of a heating system, taking into account the energy losses related to the generation of electricity (electricity input is converted to primary energy units)[10]. A higher PER corresponds to a more energy-efficient system.

According to the background document for the development of EU Ecolabel criteria for heat pumps (Forsén, 2005a, 2005b) on pages 26-27 of Part I, the primary energy ratio (PER)[11] is used to compare different heat pumps and boilers.

[10] Electricity production is considered to have a conversion efficiency of 40% (in the conversion of primary energy to electricity).

[11] **Primary energy (CEN standards).** Energy that has not been subject to any conversion or transformation process. Primary energy may be either resource energy or renewable energy or a combination of both. For a building, it is the energy used to produce the energy delivered to the building. It is the delivered energy divided by the conversion or transformation factor of each form of energy. A building generally uses more than one type of energy (e.g. gas and electricity). The primary energy approach facilitates the principle of simple addition of different types of energy (e.g. thermal and electrical) because the approach integrates the losses of the entire energy chain. Therefore the primary energy consumption may be used for comparison of different types of energy systems. The energy production losses located outside the building system boundary (e.g. district heating system) are taken into account by the primary energy approach. These losses and gains are calculated using primary energy conversion factors.

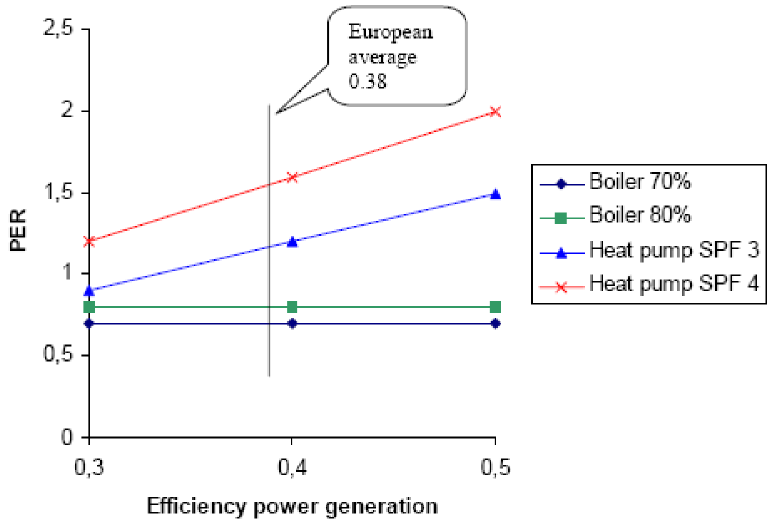

Figure 3. Comparison of primary energy ratio (PER) for boilers and heat pumps, from Figure 13, page 27 (Forsén, 2005a). A higher PER corresponds to a more energy-efficient system. SPF is the seasonal performance factor of a heat pump; a higher SPF corresponds to a more energy-efficient heat pump.

Table 4. Comparison of primary energy ratio (PER) for boilers and heat pumps based on the average efficiency of electricity generation in Europe (=0.38), from Table 6, page 27 (Forsén, 2005a). A higher PER corresponds to a more energy-efficient system. SPF is the seasonal performance factor of a heat pump; a higher SPF corresponds to a more energy-efficient heat pump.

Heating system	Primary energy ratio (PER)
Boiler 70%	0.7
Boiler 80%	0.8
Heat pump, SPF 3	1.14
Heat pump, SPF 4	1.52

The use of primary energy calculation has been introduced in other EU instruments, such as the Energy Performance of Buildings Directive. According to the recast of EPBD (2010), "effective rated output" means the maximum calorific output, expressed in kW, specified and guaranteed by the manufacturer as being deliverable during continuous operation while complying with the useful efficiency indicated by the manufacturer.

In Annex I of the recast of EPBD (2010) there is a general framework for calculating the energy performance of buildings that refers to primary energy use:

1. The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.

2. The energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator and a numeric indicator of **primary energy use**, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on-site production. The methodology for calculating the energy performance of buildings should take into account European standards and shall be consistent with relevant Union legislation, including Directive 2009/28/EC.

The EPBD directive does not give an explicit formula for calculating the efficiency, but points out that the method shall give information on the primary energy and final energy consumed by the building.

Usually, the energy efficiency ratios that are reported in the literature do not discriminate between heat and electricity, as they both have units of energy. As a result, the coefficient of performance of a heat pump is greater than 1, as the amount of heat delivered is greater than the amount of electricity input to the heat pump. It is important to understand well how the energy efficiency ratios in different references are defined.

3.1.3.2 Emissions to air: Greenhouse gases

The life-cycle assessment regarding greenhouse gas emissions include not only CO_2 emissions, but also – in the case of heat pumps – the global warming potential (GWP) of the refrigerant, with an assumption of 3% refrigerant leakage over the entire life cycle of the heat pump. The heat pumps background document (Forsén, 2005a, 2005b) also presents a magnitude for the calculation of the greenhouse gas emissions, the Total Equivalent Warming Impact (TEWI), which was developed at Oak Ridge National Lab in the 90s. The TEWI calculation incorporates direct and indirect greenhouse gas emissions over the whole lifetime into a single number expressed in CO_2 mass equivalents (also used in the heat pumps criteria in the Blauer Engel label).

In the heat pumps report (Forsén, 2005a, pages 25-26), data are provided comparing the CO_2 equivalent emissions for different gas boilers and heat pumps, for different scenarios where electricity has different emissions factors ranging from 0.1 to 0.9 kg $CO_2/kW_{electricity}$. The conclusion is that in most (but not all) cases, heat pumps result in significant reductions in CO_2 emissions when compared to gas boilers.

The present life-cycle study also uses the TEWI methodology as in the Blauer Engel label, applying the TEWI limits in Table 5 below, and as in the Ecodesign and Energy Label Implementing Measures.

Table 5. TEWI Limits (the second value - i.e. the value in brackets- will be binding from 1 January 2008)

Type of heat pump	Thermal output [kW]	TEWI value (flow temperature 35°C) [kg CO_2]		TEWI value (flow temperature 45°C) [kg CO_2]	
Water-to-Water	0 - 20	35,000	(32,500)	37,500	(35,000)
	> 20	70,000	(65,000)	75,000	(70,000)
Brine-to-Water	0 - 20	42,000	(39,000)	45,000	(42,000)
	> 20	84,000	(78,000)	90,000	(84,000)
Air-to-Water	0 - 20	51,500	(48,000)	55,000	(51,500)
	> 20	103,000	(96,000)	110,000	(103,000)
Exhaust air-to-Water	0 - 20	46,000	(43,000)	50,000	(47,000)
	> 20	92,000	(86,000)	100,000	(94,000)

The TEWI value is calculated using the following formula:

TEWI = GWP * (ER * n * m + αV * m) + n * β * Q/SPF

with the following operands:

GWP: Global warming potential [-]
ER: Emission rate [%/a]
n: Life of a system [a]
m: Filling quality of refrigerant [kg]
αv: Disposal loss [%]
β: Conversion factor [kg CO_2/kWh]
Qh: Heat demand [kWh/a]
SPF: Seasonal performance factor [-]

Calculation shall be performed using the following parameters:

- annual emission rate of 2 %
- product life of 15 years
- disposal loss of 20 %
- uniform conversion factor: 0.683 kg CO_2/kWh
- heat demand for systems up to 20 kW: 15.000 kWh/year
- heat demand for systems over 20 kW: 30.000 kWh/year

The Global Warming Potentials (GWP values) listed in Table 6 shall be used.

Table 6 Global Warming Potential of selected refrigerants (list will possibly be extended)

Refrigerant (Code designation)	Refrigerant (Chemical designation)	Global Warming Potential (GWP100)
R 134a	Tetrafluoroethane	1.300
R 290	Propane	3
R 404A	Mixture of trifluoroethane, tetrafluoroethane, pentafluoroethane	3.260
R 407C	Mixture of difluoromethane, tetrafluoroethane, pentafluoroethane	1.526
R 410A	Mixture of difluoromethane, pentafluoroethane	1.725
R 417A	Mixture of butane, tetrafluoroethane, pentafluoroethane	1.965
R 744	Carbon dioxide	1
R 1270	Propene (propylene)	3

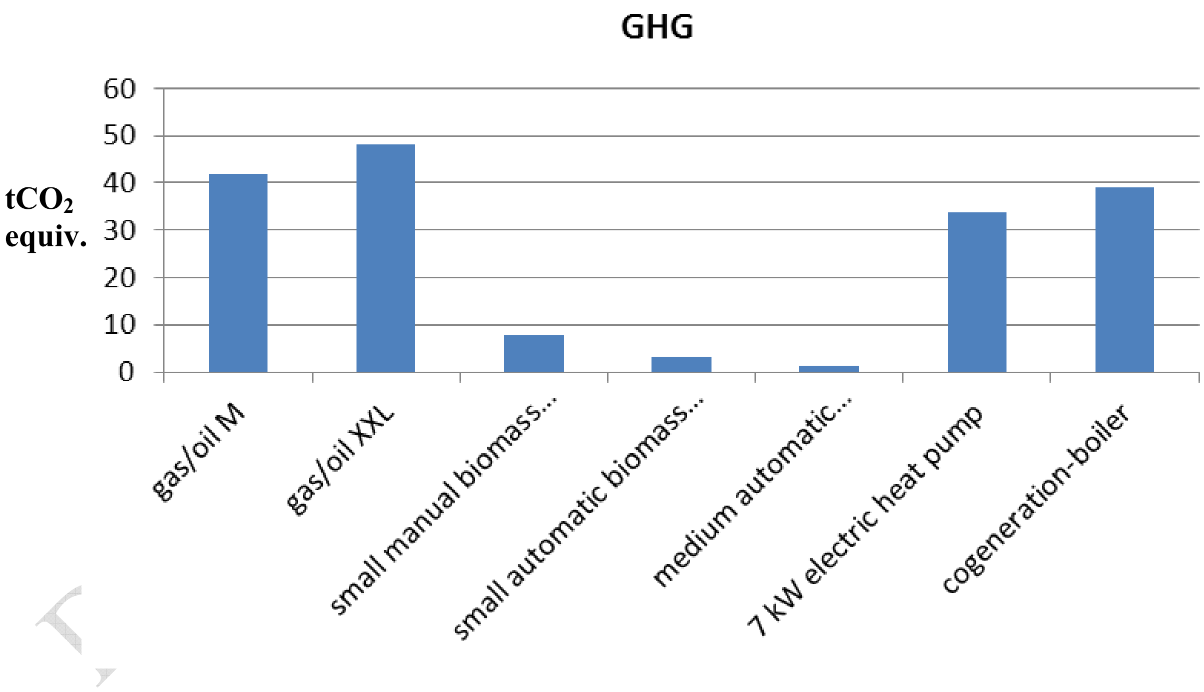

Figure 4. Comparison of greenhouse gas (GHG) emissions, in units of tCO_2 equiv. per 177.634 kWh of thermal output

As a result of the life-cycle analysis, it can be concluded that greenhouse gas emissions from biomass boilers are the lowest. The highest emissions of greenhouse gases correspond to gas/oil boilers. The heat pump achieves a reduction of GHG emissions of approx. 20% compared to the boilers.

3.1.3.3 Emissions to air: Acidification potential

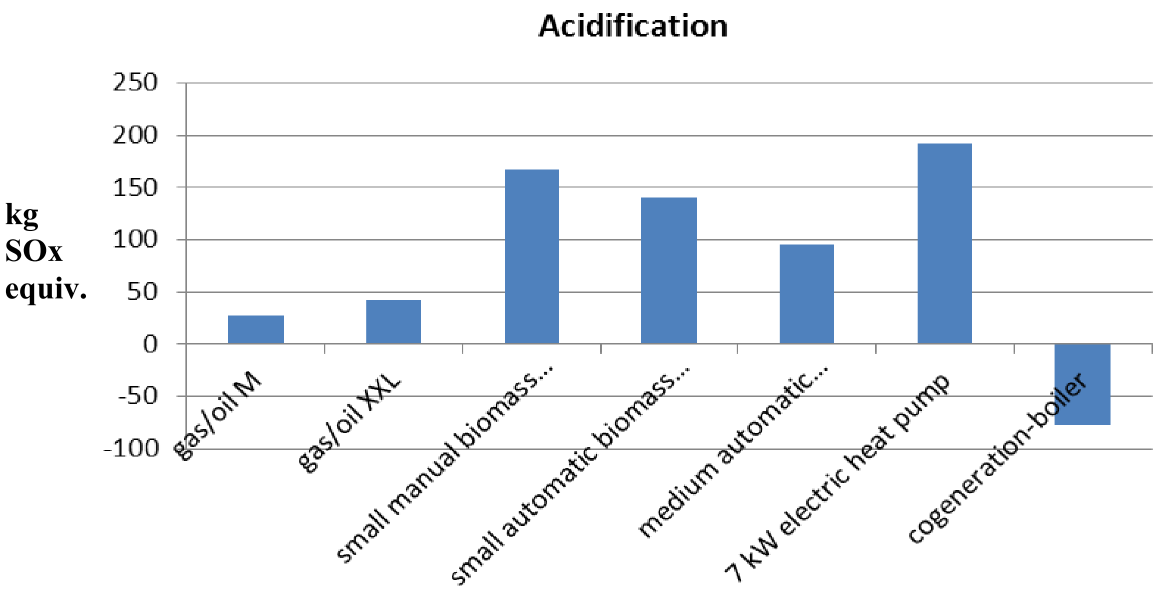

Figure 5. Comparison of acidification potential in units of kg SOx equiv. per 177.634 kWh of thermal output

Regarding acidification potential, here the NOx and SOx emissions by biomass boilers and EU electricity production appear most significant. The cogeneration boilers achieves a net reduction of acidifying emissions.

3.1.3.4 Emissions to air: Volatile Organic Compounds

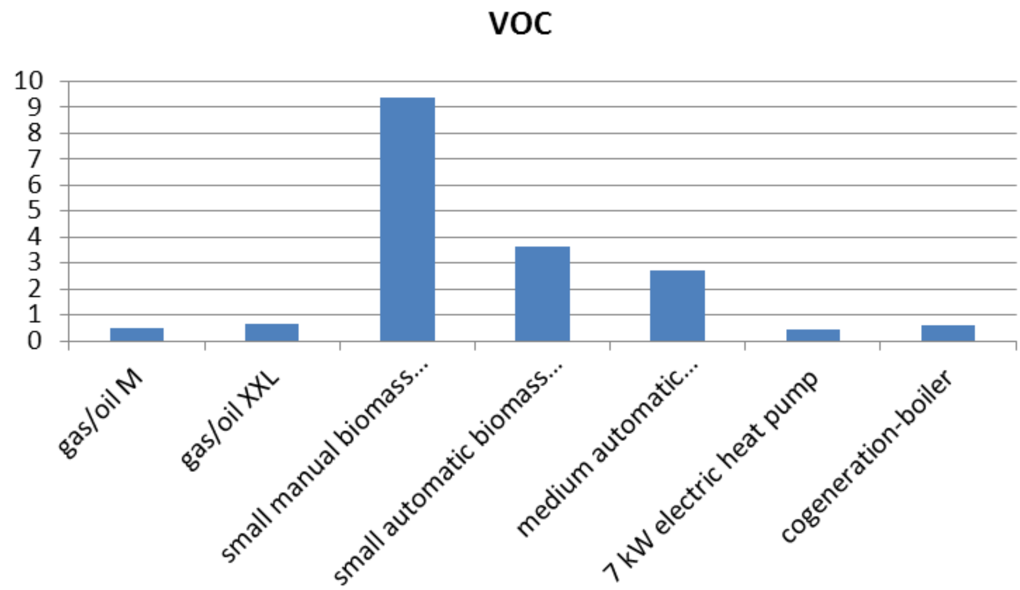

Figure 6. Comparison of Volatile Organic Compounds (VOC) emissions in units of kg VOC per 177.634 kWh of thermal output

Regarding VOC, the manual stoked wood log boiler performs the worst regarding the emissions of VOCs. This relates to both combustion efficiency and type of fuel.

3.1.3.5 Emissions to air: Persistent Organic Pollutants

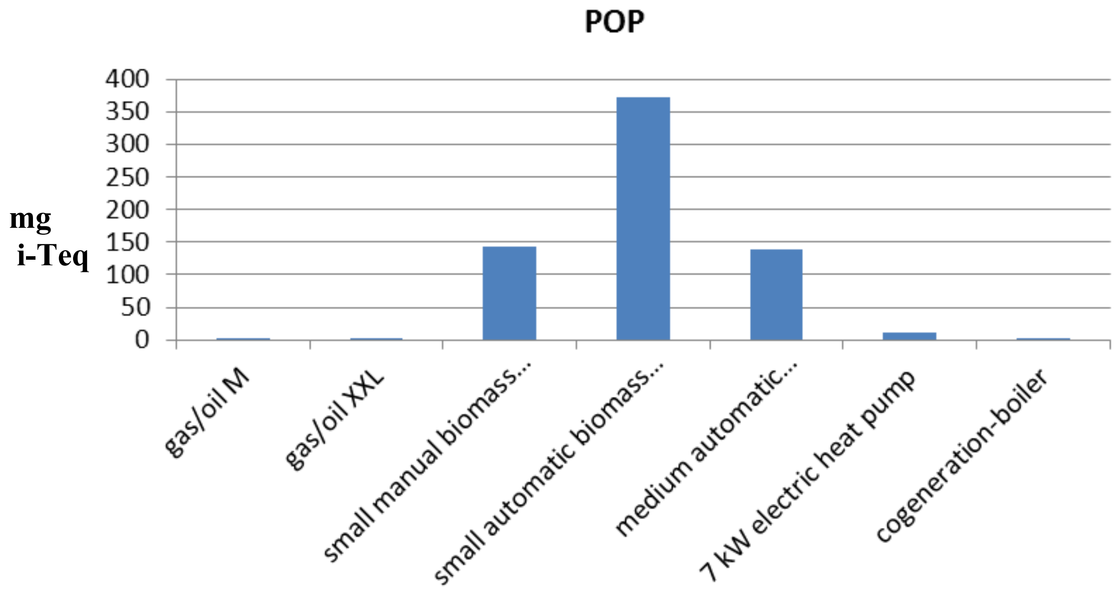

Figure 7. Comparison of Persistent Organic Pollutants (POP) emissions in units of mg i-Teq per 177.634 kWh of thermal output

In terms of persistent organic pollutants, the automatic stoked pellet boiler performs the worst, which is mainly due to the type of fuel (pellets).

3.1.3.6 Emissions to air: Heavy metals

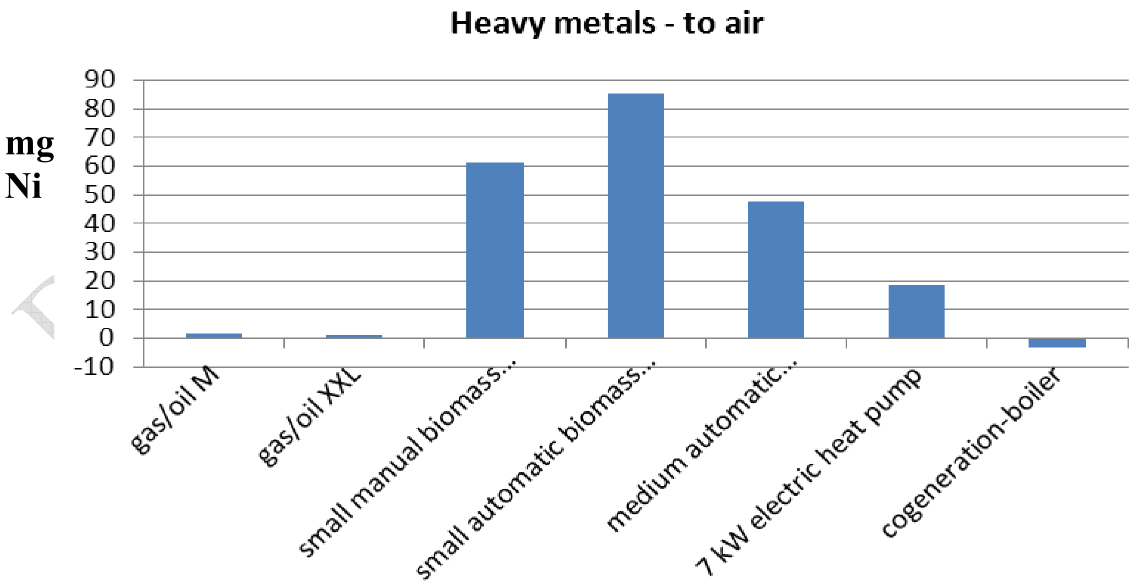

Figure 8. Comparison of heavy metals emissions to air in units of mg Ni per 177.634 kWh of thermal output

Regarding heavy metals emissions to air, again it is the pellet boiler that performs the worst, but here the electric heat pump has significant emissions as well.

3.1.3.7 Emissions to air: Polycyclic Aromatic Hydrocarbons

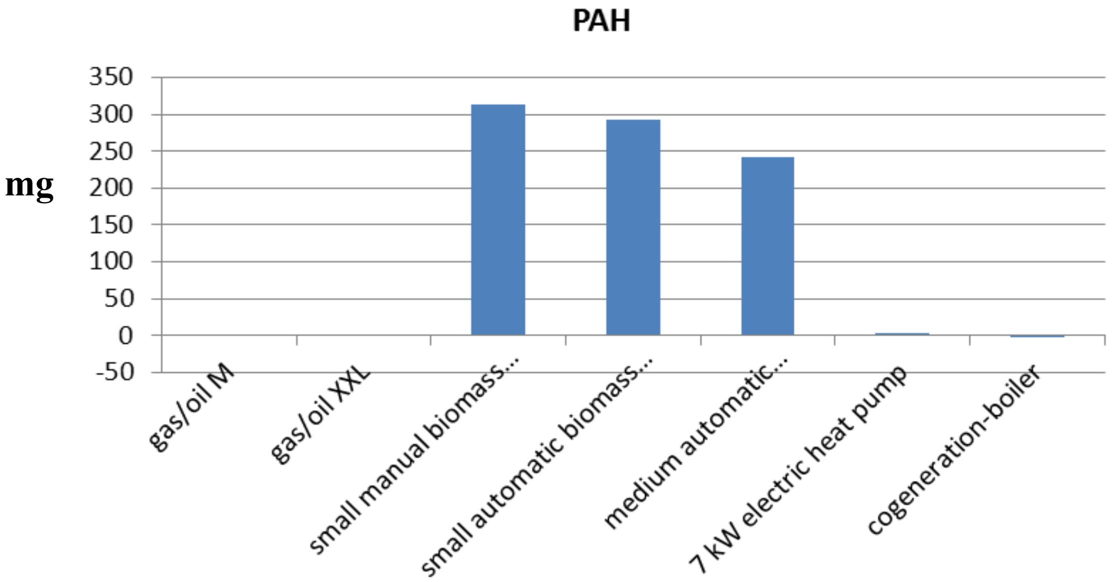

Figure 9. Comparison of heavy metals emissions to air in units of mg Ni per 177.634 kWh of thermal output

The biomass boilers emit the most PAHs but the differences in the group are less outspoken than in other impact categories.

3.1.3.8 Emissions to air: Particulate Matter

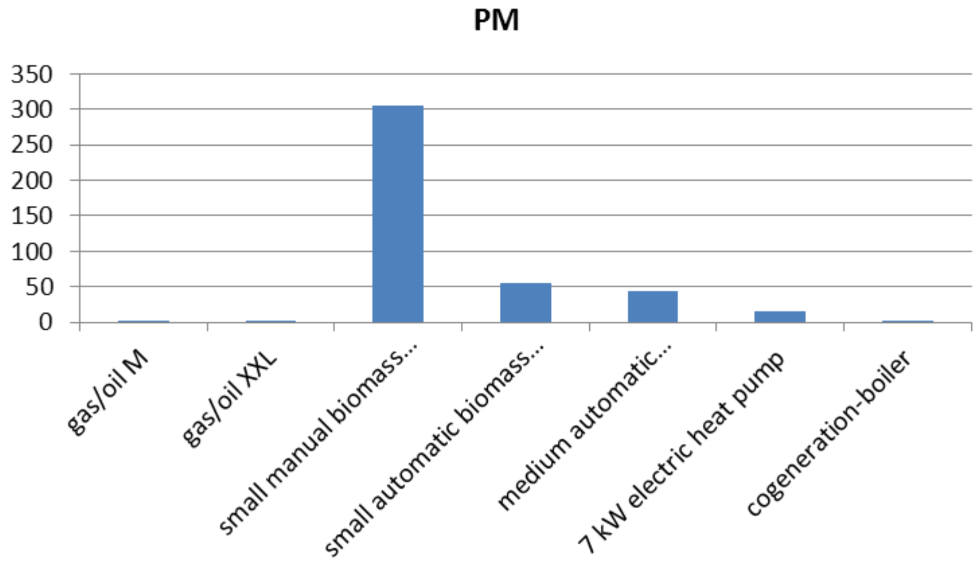

Figure 10. Comparison of particulate matter emissions to air in units of kg PM per 177.634 kWh of thermal output

As regards particle emissions the biomass boilers perform the worst, with the manual stoked wood log boiler as exceptionally high source of emissions.

3.1.3.9 Emissions to water: Heavy metals, HM (g Hg/20), and Eutrophication (g PO_4)

Indicators for emissions to water include: heavy metals and eutrophication. The technical analysis concluded that, as regards the emissions of heavy metals to water and the eutrophication impact, the biomass boilers and especially the heat pump are the heating systems causing the greatest contribution to this environmental impact area. The cogeneration boiler also has a significant contribution due to its material composition (relatively large amounts of ferrous and non-ferrous metals).

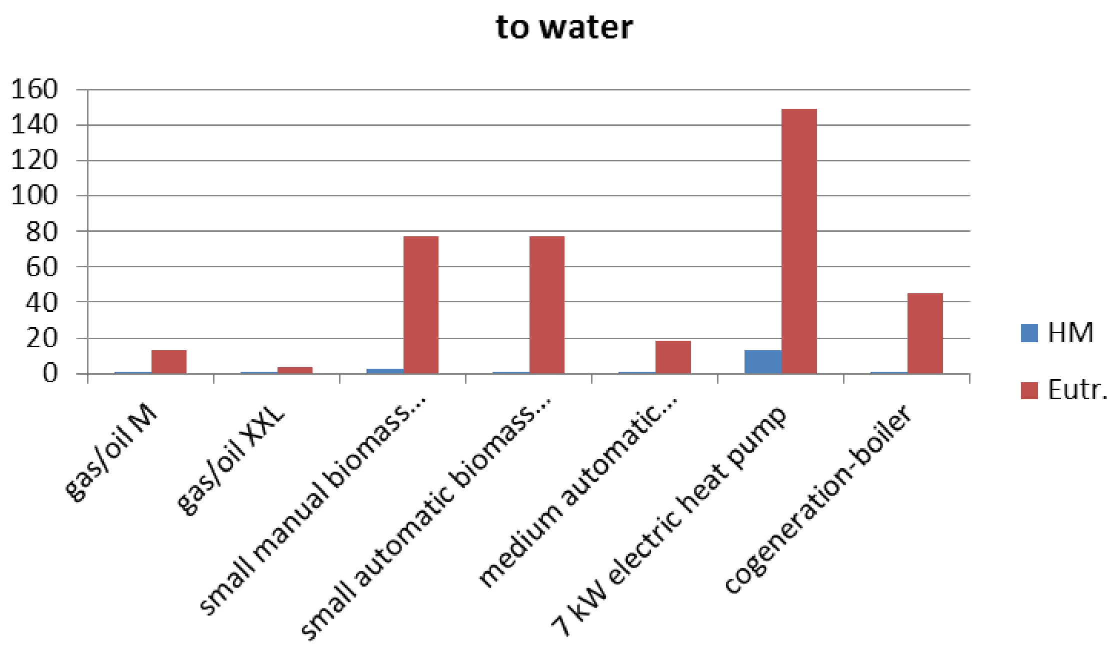

Figure 11. Comparison of emissions to water (heavy metals and eutrophication) per 177.634 kWh of thermal output

3.1.3.10 Emissions to soil: Non-hazardous and hazardous waste

Regarding non-hazardous waste emissions to soil, the technical analysis concluded that most of the impacts derive from ash resulting from biomass combustion. For the electric heat pump the waste is related to EU electricity production (as a significant share of the electricity production in the EU is coal-based).

Regarding hazardous or incinerated waste, these impacts relate to both hazardous waste (e.g. from electricity production) but also from plastics thermal recycling, which explains the visible contribution from gas condensing boilers and cogeneration boilers.

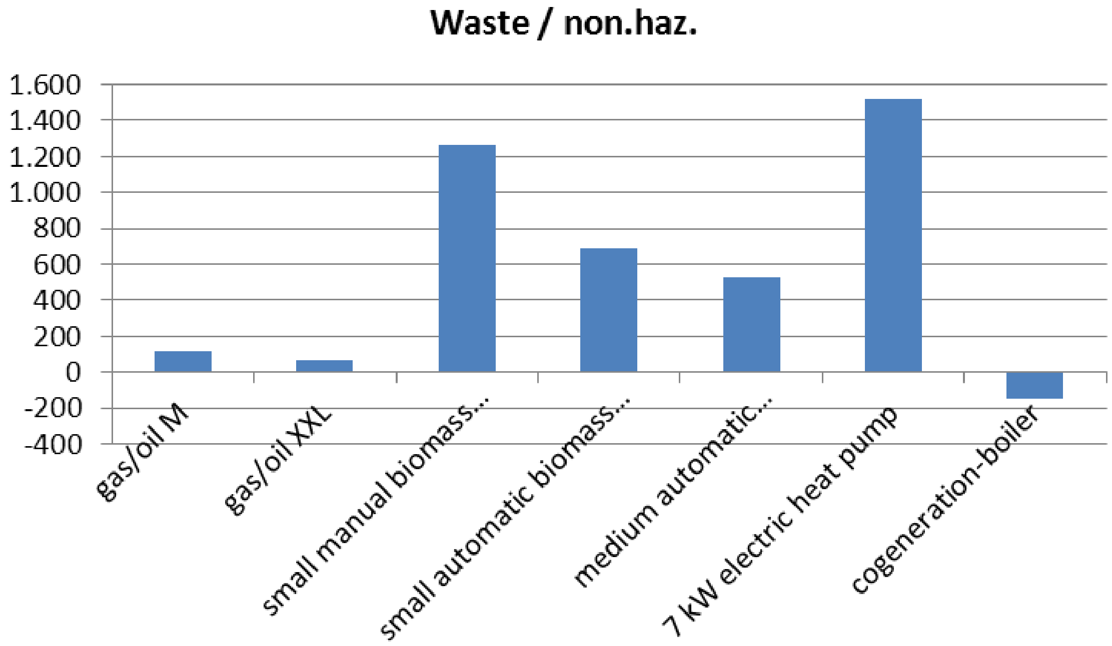

Figure 12. Comparison of non-hazardous waste emissions to soil in kg per 177.634 kWh of thermal output

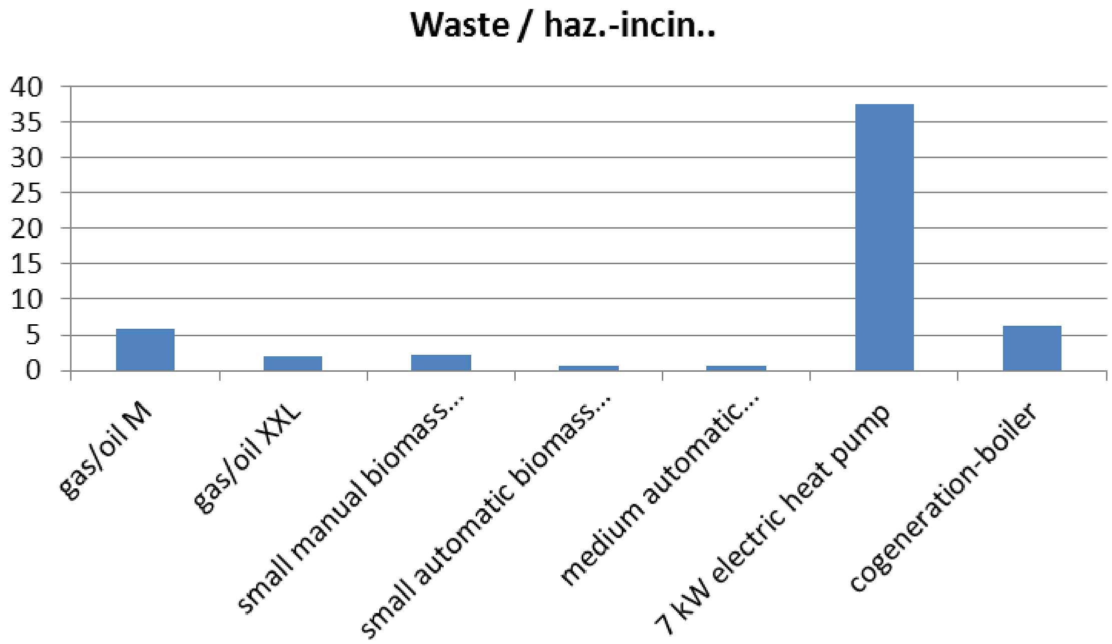

Figure 13. Comparison of hazardous waste emissions to soil in kg per 177.634 kWh of thermal output

Regarding non-hazardous waste, most of the impacts stem from ash resulting from biomass combustion. For the electric heat pump the waste is related to EU electricity production (part is coal-based, etc.);

Impacts related to hazardous waste relate to both hazardous waste from e.g. electricity production but also from plastics thermal recycling, which explains the visible contribution from gas condensing boilers and cogeneration boilers;

3.1.3.11 End-of-life materials: Disposed and recycled

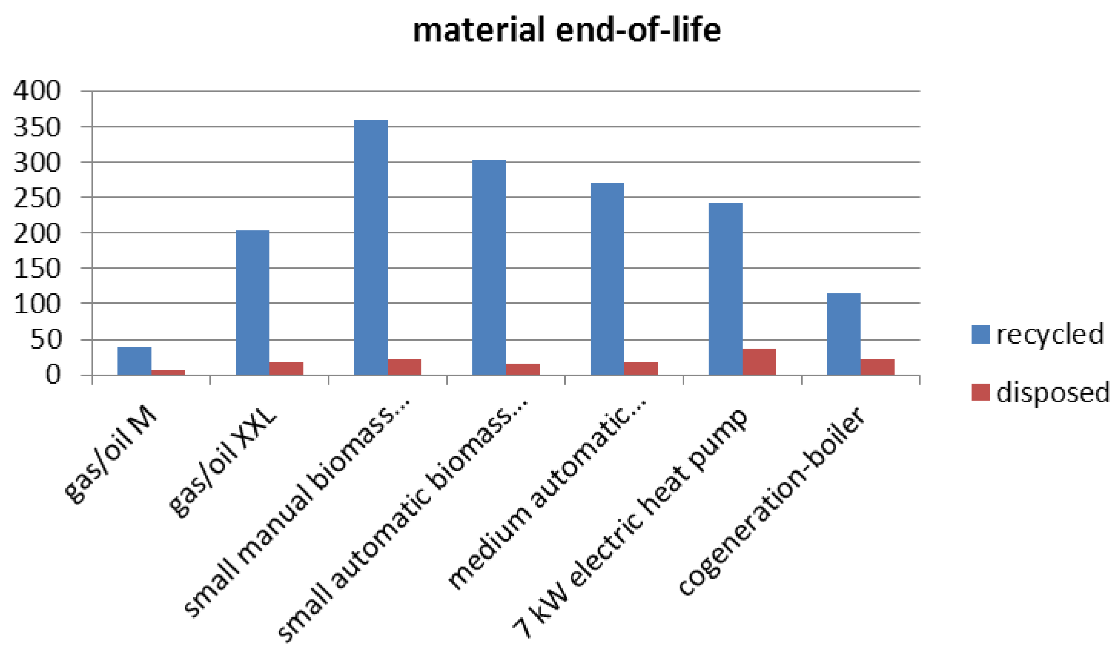

Figure 14. Comparison of recycled and disposed waste in kg per 177.634 kWh of thermal output

3.1.3.12 Summary of environmental impacts from the life-cycle analysis

In summary, the table and the graphs above provide evidence of the major differences between biomass boilers and fossil fuel boilers. Biomass boilers have much lower GHG emissions than other boilers, since the CO_2 emission from combustion is considered to be zero. However, biomass boilers exhibit substantially higher emissions in other impact categories. Only electric heat pumps have similar impacts in the categories acidification and non hazardous waste.

The life cycle model (effectively a comparison of life cycle impacts of boilers on the basis of the intermediate heat demand) does not indicate an overall favourable technology. Each boiler type has its specific advantages and drawbacks, depending on which impact category is considered. Despite this, it is obvious that improvements can be made, which reduce the impacts in the various categories:

- For gas/oil boilers the improvements would need to focus on energy efficiency (reduce GHG).
- For biomass boilers the improvements would need to focus especially on reducing harmful emissions from combustion (reduce waste, acidification, VOC, POP, HM, PAH and PM).
- For electric heat pumps improving energy efficiency would be the most effective (reduce GHG and emission related to electricity production, like acidification, (haz.) waste and heavy metals).
- For cogeneration boilers, improving energy efficiency (and material composition) would reduce most impacts.

Some general conclusions from the life-cycle analysis are that, for renewable energies, the big advantage is the carbon emissions savings. This is good since carbon saving is high in the European environmental agenda. However, it should be realized that in other aspects the biomass boilers for example emit more air pollution substances than gas/oil boilers. Other renewable sources have feasibility issues (solar and heat pumps cannot be installed everywhere). For example, for heat pumps, constraints are related to heat sources (ground probes, etc.) and heat sinks (are the emitters, central heating system and the building heating demand suitable for low temperature heating). Also, biomass requires easy access and space for fuel storage.

Given the huge existing stock of conventional boilers, the "renewables only" option is quite a drastic step that needs to be discussed among stakeholders (however Ecolabel is to award to the best products; the other products can be sold without the label). Ecolabel represents the 15-20% top environmentally performing products.

There is a difference between newly built and existing buildings, but also existing buildings need a replacement boiler every 15 years or so. One possible next step in the development of Ecolabel criteria is to think of options for boiler efficiency improvements beyond the proposed Ecodesign implementing measures, as a guideline so that possible Ecolabel criteria may emerge. These could be some important points for stakeholders to discuss.

3.2 Discussion on toxic and/or hazardous substances

This section provides a discussion on the use of toxic and/or hazardous substances in heating products and their contribution in the overall environmental impact of these products.

Central heating products can contain small fractions of hazardous substances. These can be:

- Flame retardants: used in cables and plastic parts, including synthetic foamed or expanded thermal insulation;
- Heavy metals: mainly limited to substances found in the electronic components;
- Hardeners: used in foamed thermal insulation.

The RoHS Directive 2002/95/EC already banned various types of flame retardants. RoHS is often referred to as the lead-free directive, but it restricts the use of the following six substances:

1. Lead (Pb)
2. Mercury (Hg)
3. Cadmium (Cd)
4. Hexavalent chromium (Cr6+)
5. Polybrominated biphenyls (PBB)
6. Polybrominated diphenyl ether (PBDE)

Lead used in soldering of electronic components is now phased out following an industry-wide replacement program. Lead is also used as plasticizer of PVC cables – this application is also phased out. PBB and PBDE are flame retardants used in several plastics, a.o. in printed circuit boards.

In February 2011 a further six dangerous chemicals were banned, following an assessment in the context of the REACH program [12]. The chemicals involved are a flame retardant (HBCD), a hardener (MDA), various plasticizers and a synthetic fragrance enhancer.

[12] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/11/196&format=HTML&aged=0&language=EN &guiLanguage=en

Table 7. Banned substances (REACH)

Chemical	Use	Products
HBCD (hexabromocyclododecane), a toxic substance that persists and accumulates in biological systems	Flame retardant	Polystyrene plastics, including both extruded and expanded polystyrene insulation
MDA (4,4'-diaminodiphenylmethane), a potent carcinogen	Hardener used in manufacture of 4,4"-methylene diphenyl diisocyanate (MDI), a key constituent of polyurethanes	MDI used in polyisocyanurate and spray polyurethane foam insulation as well as formaldehyde-free particleboards, agrifiber panels, plywoods, and other manufactured wood products
DEHP (bis(2-ethylhexyl)phthalate), a hormone disruptor affecting reproduction	Plasticizer for PVC products	Vinyl flooring, roofing, siding, wall coverings (industry has been phasing out the use of this plasticizer)
BBP (butyl benzyl phthalate), a hormone disruptor affecting reproduction	Plasticizer for PVC products	Used in some vinyl flooring, food conveyor belts, artificial leather
DBP (dibutyl phthalate), a hormone disruptor affecting reproduction	Plasticizer for PVC products	Used in some floor coverings, packaging, adhesives, and paint formulations
Musk xylene (5-ter-butyl-2,4,6-trinito-m-xylene), a toxic substance that persists and accumulates in biological systems, and a possible carcinogen	Fragrance enhancer	Some cleaning products

It is possible that HBCD and MDA are used in thermal insulation used in central heating products (expanded polystyrene may be used as thermal insulation of exposed parts such as valves, pumps, etc., foamed polyurethane may be used as thermal insulating material of heated water storage tanks). It is unknown how many central heating products currently on the market employ these substances.
Plasticizers may be used in PVC sheathing of electrical cables.

Emissions of heavy metals occur mainly during the production phase, stemming both from use of electronics as well use of various other (non)ferro materials such as stainless steel, brass, copper.

The Ecoreport analysis of Lot 1 shows an average mass of boilers of 45 kg, of which only 0.7 kg (1.6%) is related to electronics (refers to boilers of M-class capacity, see also section 1.1.5.1). Some 88% of product weight is however due to use of metallic substances, the production of which also emits heavy metals. The Ecoreport estimates the contribution of electronics at less than 15% of total Heavy Metal emissions (both air and water).

Following Greenpeace's 'Greener Electronics' campaign several electronics manufacturers, such as Apple, HP, Panasonic, Philips, etc. have shown progress in reducing the use of BFR's, PVC and also some other materials such as phthalates (plasticisers), beryllium and antimony. Some of their products are completely free of PVC and BFRs. If these consumer electronics manufacturers can diminish or avoid the use of such substances, then the electronics manufacturers for central heating system could follow suit. However, the pace of improvement in that sector will be much slower, since these products are not in the 'green' spotlight of organisations like Greenpeace.

3.3 Discussion on environmental improvement potential

Both Lot 1 (gas/oil/electric boilers) and Lot 15 study (biomass boilers) present possible improvement options. These options range from gradual (incremental) improvements of the existing product up to improvements that involve a fuel change and/or configurations with supplementary equipment. Examples of the latter are:

- boilers (fossil fuel, biomass and/or electric, incl. heat pumps) combined with solar thermal collectors;

- combustion boilers (fossil fuel and/or biomass) combined with heat pumps (gas and/or electric).

The BAT (Best Available Technology) or BNAT (Best Not yet Available Technology) levels are mostly based on heat pump technology sometimes with an add-on benefit from solar installations, which would have several drawbacks for application in mandatory measures:

- Heat pumps cannot be universally applied. Especially ‘geothermal’ or ‘vertical’ ground-source heat pumps require special permissions from the waterworks and/or the commune, etc.
- Specialist installers and special equipment are necessary and (as yet) not abundant
- The efficiency of the heat pump is highly dependent on the lay-out and installation.
- Often a heat pump is a base-load device, which means that a hybrid device (e.g. with a conventional boiler) may often be an economical solution to capture both base and peak loads
- The energetic benefits are highly dependent on the climate, especially with air-based heat pumps and of course with solar energy.
- As a result of the above, the pay-back time will vary widely per country and circumstance.
- The current heat pumps are mostly electric, which means that a hypothetical full EU heat pump strategy would lead to increased emissions of everything else besides CO_2: more acidification, more VOCs, more heavy metals, etc.
- Most heat pumps are reversible, which means that they can supply both cooling an heating. If they are attached to a central heating-system the cooling options will be limited (only top-cooling), but still this could lead to a summer operation that would be detrimental to the saving and mitigation effort.

All in all, the heat pump technologies represent an interesting option with a large saving potential and should be promoted whenever and wherever possible. As such they should therefore have their place in the highest ranks in an endorsement scheme. However, the uncertainties (and the costs) of the option should be taken into account.

Regarding the solar-assisted space heating our technical and economical analysis indicates that yields are often higher than expected (usually solar heating is seen as typically for water heating only). However, the economical benefits are too small to make them qualify as LLCC-target, although in larger installations and at mass volume collector prices they can be competitive.

The technical background study in this project's website[13] includes additional data regarding the Life Cycle Cost Analysis for the estimates of improvement potentials.

[13] http://susproc.jrc.ec.europa.eu/heating/stakeholders.html

4. POLICY INSTRUMENTS RELATED TO HYDRONIC CENTRAL HEATING SYSTEMS

This section provides an overview of existing Environmental Product Policy instruments that are relevant to hydronic central heating systems, some mandatory and others voluntary. The major mandatory policy instruments are Ecodesign and Energy Label. Voluntary instruments are mainly the EU Ecolabel, national ecolabelling schemes in different countries (inside and outside the EU), Energy Star, Green Public Procurement, and some certification programs awarded by individual manufacturers' organizations.

Among the voluntary ecolabel schemes, three types of labels can be distinguished. The ISO (International Organization for Standarization) has attempted to standardise the principles, practices and key characteristics relating to three major voluntary environmental labelling types:

- Type 1 environmental labelling: A voluntary, multiple-criteria-based, third-party program that awards a license. Most eco-label schemes are Type 1.
- Type 2: Self-declaration claims.
- Type 3: Environmental declarations.

The EU Ecolabel is a Type 1 environmental label scheme, and the EU Ecolabel Regulation (2010) recommends taking into consideration existing criteria in other Type 1 environmental labels inside or outside the EU. This review therefore focuses only on Type 1 environmental label schemes.

4.1 Mandatory policy instruments

4.1.1 Ecodesign for Central Heating Boilers

The Ecodesign scheme is a mandatory program that sets minimum environmental performance requirements needed for a product to be allowed to be sold on the market. The Ecodesign Directive (2005/32/EC) establishes requirements on energy performance and emissions, and one of its important missions is to do so while at the same time contributing to the improvement in the functioning of the internal market.

In accordance with Article 16 (1) of the Ecodesign Directive[14], the Commission has established a working plan setting out a list of energy-using product groups which will be considered as priorities for the adoption of implementing measures between 2009 and 2011[15]. The 2009-2011 Working Plan under the Ecodesign Directive (EC, 2008a) indentified a number of products as priorities (for a transitional period and beyond). Among these priority products, some are related to hydronic central heating systems, in particular: heating and water-heating equipment, HVAC (heating/ventilating/air conditioning); and electric and fossil-fuelled heating equipment.

The following are the existing Ecodesign preparatory studies that are relevant for hydronic central heating systems:

[14] Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005, establishing a framework for the setting of ecodesign requirements for energy-using products.
[15] These website contain links to the working plan and the Ecodesign preparatory studies: http://ec.europa.eu/energy/efficiency/ecodesign/working_plan_en.htm,, http://ec.europa.eu/enterprise/policies/sustainable-business/sustainable-product-policy/ecodesign/

- **Boilers and combi-boilers** (gas/oil/electric): www.vhk.nl (DG-ENER Lot 1)
- **Solid fuel small combustion installation (or solid fuel boiler)**: BIO, http://www.ecosolidfuel.org/ (DG-ENER Lot 15)

Of these two preparatory studies, Ecodesign Implementing Measures are currently being developed only for boilers (DG-ENER Lot 1); a final version of the Implementing Measures is not yet publicly available.

DG-ENER Lot 1 study on boilers (task 3)[16] showed that the market for boilers is dominated by gas-fuelled boilers. In the European Union, 62% of homes with a central heating system use gas, 32% oil, 2% electric and 5% solid fuels, including biomass. Lot 1 study analyzed boilers of different heating technologies (combustion, heat pump, solar thermal, co-generation) and energy sources (oil, natural gas, solar); however, the preparatory study excluded biomass-fuelled boilers.

DG-ENER Lot 15 preparatory study dealt specifically with Solid Fuel Small Combustion Installations[17], covering a wide range of solid fuel combustion installations such as open fires, stoves, boilers and cookers, and a variety of solid fuels including fossil fuels (anthracite, coal, manufactured mineral fuels), and biomass[18] fuels (log wood, wood chips, wood pellets, etc). Lot 15 study identified that solid fuel boilers, and in particular biomass boilers, will increase in use in the future as a result of increasing gas and oil prices, and the application of policies aimed at reducing the environmental impact (in particular greenhouse gas emissions) from heating systems.

In the existing preparatory studies for boilers (Lot 1 and 15), the distinction between domestic and non-domestic/commercial boilers is not always consistent. Generally commercial boilers are defined as those with a rated output power of above 40-50 kW, although it is possible that in a smaller commercial property a ‘domestic’ sized boiler could be used[19]. The Lot 1 preparatory study on boilers (Task 1) also highlighted variation between Member States in terms of what is regarded as domestic as opposed to commercial. For example, in Italy the cut off is considered 35 kW, whereas in France it is 70 kW[20]. The EuP Lot 15 Preparatory Study defined domestic solid fuel boilers as those with an output of up to 50kW and small non-domestic solid fuel boilers as those with an output of between 50 kW-500 kW. The scope of the Lot 15 Preparatory Study does not include solid fuel boilers above 500 kW, and it also highlights that there are no absolute boundaries across the different capacity ranges[21].

4.1.1.1 Ecodesign Implementing Measures for Central Heating Boilers

The Ecodesign Implementing Measures for Central Heating Boilers are not yet publicly available. However, the existing draft Implementing Measures contain proposals for the Ecodesign requirements for boilers and these proposals are summarized in this document, as they are of interest in the development of Ecolabel/GPP criteria for hydronic central heating systems in the current project. The technologies covered are fossil-fuel boilers, heat pumps and micro cogeneration up to electrical capacity of 50 kW.

[16] http://www.ecoboiler.org/public/ecoboiler_task3_final.pdf
[17] http://www.ecosolidfuel.org/
[18] According to the definition in the Renewable Energy Directive, ‘biomass’ means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste
[19] http://www.mtprog.com/spm/download/document/id/678
[20] http://www.ecoboiler.org/public/ecoboiler_task1_final.pdf
[21] See Section 1.1.3 of EuP Lot 15 Task 1 Report for more information.

One of the important aspects of the Implementing Measures, which is relevant for the development of EU Ecolabel for hydronic central heating systems, is the definition of "seasonal space heating energy efficiency" as a magnitude for measuring energy efficiency across different types of hydronic central heating technologies. Here it is important to distinguish between Net Calorific Value (NCV) and Gross Calorific Value (GCV). Gross Calorific Value (GCV) is defined as the heat released when a certain fuel is burned completely with oxygen at a constant pressure, and when the products of combustion are returned to ambient temperature, in kWh. The Commission has decided to use GCV as part of the definition of seasonal space heating energy efficiency", as mentioned in the Draft Implementing Measures for Ecodesign and Energy Label.

Seasonal space heating efficiency (etas) is defined as the ratio between the space heating demand pertaining to a designated heating season provided by a boiler, and the annual energy consumption required for its generation, expressed as percentage.

The draft Ecodesign Implementing Measures propose limits for a number of parameters. The Regulation foresees two stages for the application of these mandatory limits, with two different deadlines. The second set of limits is the most stringent, and the one summarized here. The criteria areas are:

- Seasonal space heating energy efficiency
- A limit on global warming potential (GWP) of the refrigerant in heat pumps
- A limit of nitrogen oxides (NO_x) emissions
- A limit on sound power level for heat pumps

Table 8. Proposal (draft) for Ecodesign Implementing Measures for boilers (unpublished) regarding energy efficiency and global warming potential (GWP)

Fossil fuel boilers with 4,00 kW ≤ rated input ≤ 15,00 kW
The seasonal space heating energy efficiency shall not fall below 75,0%
Fossil fuel boilers with 15,00 kW < rated input ≤ 70,00 kW, and cogeneration boilers
The seasonal space heating energy efficiency shall not fall below 86,0%
Fossil fuel boilers with 70,00 kW < rated input ≤ 400,00 kW
The useful efficiency at 100% of the rated input shall not fall below 88,0%, and the useful efficiency at 30% of the rated input shall not fall below 96,0%.
Heat pumps with the exception of low temperature heat pumps
Heat pumps with GWP above 150: The seasonal space heating energy efficiency shall not fall below 86,0
Heat pumps with GWP not exceeding 150: The seasonal space heating energy efficiency shall not fall below 73,0
Low temperature heat pumps
Heat pumps with GWP above 150: The seasonal space heating energy efficiency shall not fall below 111,0
Heat pumps with GWP not exceeding 150: The seasonal space heating energy efficiency shall not fall below 94,0

The following requirements for emissions of nitrogen oxides apply (depending on the heating technology):

- Fossil fuel boilers using gaseous fossil fuels: emissions of nitrogen oxides shall not exceed 70 mg/kWh
- Fossil fuel boilers using liquid fossil fuels: emissions of nitrogen oxides shall not exceed 120 mg/kWh
- Cogeneration boilers using gaseous fossil fuels: emissions of nitrogen oxides shall not exceed 120 mg/kWh
- Cogeneration boilers using liquid fossil fuels: emissions of nitrogen oxides shall not exceed 200 mg/kWh.

In addition, a limit is introduced for the sound power level of heat pumps, as follows:

Table 9. Limits on sound power level of heat pumps

Rated capacity ≤ 6 kW		6 kW < Rated capacity	
Indoor sound power level in dB(A)	Outdoor sound power level in dB(A)	Indoor sound power level in dB(A)	Outdoor sound power level in dB(A)
60	65	65	70

4.1.2 Energy Label for Central Heating Boilers

The Energy Labelling Framework Directive 92/75/EEC was established with the goal of providing information about energy consumption of domestic appliances, in order to encourage consumers to buy more energy-efficient products, to create market transparency (and comparability for consumers of performance across technologies), and to provide incentives for innovation. The Energy Label is a 7-step graded system with A being the most and G the least energy efficient of the item among other products in the same group. With recent improvements in efficiency of certain products, some additional levels such as A+, A++ or A+++ have been introduced. The specific efficiency values corresponding to each of the levels can be found in the draft Energy Label Implementing Measures[22].

The mandatory Energy Labeling is usually applied to products that consume significant amounts of energy and show disparity in their energy efficiency. Minimum energy performance standards (MEPS) are usually based on life-cycle cost assumptions that take the learning capability and associated potential for cost reduction into account.

Individual Member State governments may then impose minimum energy efficiency standards in order for a certain appliance to be sold on the market.

[22] http://www.eceee.org/Eco_design/products/boilers/

4.1.2.1 Energy Label Implementing Measures for Central Heating Boilers

While the Ecodesign Implementing measures are restricted to the heat-generating part of the heating system only (the boiler), the approach followed by the Energy Label scheme differs in that two separate requirements are set for: (1) the boilers, and (2) their combinations with certain additional parts: controls, solar panels, storage tanks and passive flue heat recovery devices. Main elements of the Implementing Measures are:

- The "product" labels. These are suggested for: fossil fuel boilers, heat pumps and micro-generation.
- A fiche for boilers with heat input up to 70 kW. The fiche includes a sheet for each individual boiler intended for offers of boilers combined with additional parts and/or with a second boiler ("installer label"). For combination boilers, space heating and sanitary water heating are addressed by separate product and installer labels.

The scope of the Ecolabel/GPP for hydronic central heating systems is restricted to the heat-generating part (the boiler). Herewith we summarize the Energy Label Implementing Measures for the heat-generation unit, i.e. the "product label".

The product label layout differs according to boiler type, that is, there are specific layouts for fossil fuel boilers (climate independent), heat pumps (climate dependent) and micro cogeneration (electrical efficiency). The label format is suggested to be "phased in" in two steps:

- The format of the first step includes energy efficiency classes A+ to G, where class A corresponds to the performance of best technology without input of renewable energy sources (RES), and A+ requires the input of RES. This choice is suggested on the following grounds:
  - "devaluation" of the current financially most accessible energy efficient technologies should be avoided to foster quick market transformation;
  - it should be signaled that the efficiency level of best performing technology not using RES can be further enhanced to foster the uptake of heating using RES input.

- The label format is upgraded to A++ to E in a second step.

The energy efficiency ranking scale is based on seasonal space heating energy efficiency, where for electric heat pumps the seasonal coefficient of performance (SCOP) is corrected by a factor of 2.5, reflecting the average efficiency of providing electricity from primary energy sources. The label format for boilers using fossil fuels includes an indication of seasonal space heating energy efficiency, expressed as a percentage with respect to the gross calorific value of the fuel.

4.2 Voluntary policy instruments: Labelling

Voluntary policy instruments include environmental labels inside and outside the EU, and Green Public Procurement. The EU Ecolabel Regulation[23] advises to take into consideration "criteria established for other environmental labels, particularly officially recognised, nationally or regionally, EN ISO 14024 type I environmental labels, where they exist for that product group so as to enhance synergies". The Recast of the Ecolabel Regulation aims at the following:

- Increasing effectiveness and streamline its operation
- Coordination with Ecodesign requirements for EuP and ErP
- "Criteria should be limited to the most significant environmental impacts of products during their whole life cycle" (Preamble 5)

[23] Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel

- Aiming at substitution of hazardous substances by safer substances, whenever technically possible (Preamble 7)
- Enhancing coherence with other national ecolabelling schemes in the Community (Preamble 15)
- Ecolabel criteria should be based on the environmental performance of products, taking into account the latest strategic objectives of the Community in the field of environment (e.g. promotion of renewables) (Article 6.1)
- Article 3(a) provides a list of environmental impact categories, for example:
    - Article 3(b): Substitution of hazardous substances
    - Article 3(c): Durability, reusability
    - Article 3(f): Criteria in other labels, in particular EN ISO 14024 Type I
- Articles 6.6 and 6.7 provide a list of prohibited substances, in particular for example those that are: toxic, hazardous for the environment, carcinogenic, mutagenic or toxic for reproduction (CMR), following Regulation 1272/2008 (CLP)

As the development of the EU ecolabel criteria aims at harmonising the existing schemes, an analysis of the main national and international schemes covering the product group under study has been conducted in order to understand which aspects are currently included in them. This work constitutes a basis for further consideration of the EU ecolabel criteria development process.

In general it can be said that the key issue covered in all analysed schemes is the **energy efficiency** in terms of a **primary energy ratio**. Although it appears technically feasible in principle to develop common criteria for a product group "hydronic central heating systems", there is no Ecolabel program that has developed criteria for all heating systems as a group, or for all hydronic central heating systems as a group. In some specific member states labels it has been considered appropriate to support certain types of renewable fuels such as biofuel, solar energy, etc. instead of fossil fuel for heat generation. Technical reasons not to take up a systems approach so far refer to the technical heterogeneity of the different heating systems, and also to the complexity when transferring this information to end consumers in an understandable way. As a result, national labelling schemes currently follow a product oriented approach, some with a focus on renewable energies.

Voluntary labelling schemes (ISO 14024 type I) addressing boilers and other central heating products are present in multiple Member States, as described below. Labelling initiatives may be endorsement labels (indicating a preferred choice) or quality/certified performance labels (for product information).

A brief description of the European and non-European ecolabel schemes, which refer explicitly to the product group of heating systems, considered as most relevant in the current criteria development process, is presented below. Among them are EU Ecolabel for heat pumps, Engel, Nordic Swan, Blauer, the Austrian Ecolabel (Österreichisches Umweltzeichen), and the Energy Star. In addition, other several standards by individual industry associations are also presented, as well as GPP criteria for heating systems.

This section does not give a comprehensive overview of all existing scheme models, but presents different approaches on the basis of a few chosen examples, in order to support the discussion on the criteria which could potentially be considered for the EU ecolabel. For further information concerning other schemes and respective legal regulations for the European and non-European countries please consult the background report available at the project website[24].

In general it can be said that a number of labels, including the Nordic Swan, Blauer Engel, and the Austrian label, have a strong focus on renewable sources. Available EU Ecolabel criteria for heating systems are at the moment restricted to heat pumps.

[24] Draft Task 1 Report: Product definition, available at the project website: http://susproc.jrc.ec.europa.eu/heating/stakeholders.html

Table 10. Summary of heating products addressed by different ecolabel schemes

EU Ecolabel	GPP	Ecodesign Study	Ecodesign Implementing Measures	Nordic Swan	Blauer Engel	Austrian Ecolabel
	Boilers (draft)	Boilers	Boilers (draft)	Solid biofuel boilers, up to 300 kW	Gas-fired calorific-value heating devices, RAL-UZ 61 Wood pellet boilers, RAL-UZ 112	Wood-fired heating systems, UZ 37 (including wood pellet boilers)
	Combined heat and power plants				Small gas-fired cogeneration units, RAL-UZ 108 Small liquid-fired cogeneration units, RAL-UZ 109	
Heat pumps	Climate control: heat pumps and air conditioning systems (draft)		Room air conditioning	Heat pumps	Heat pumps using absorption and adsorption technology or operating by use of combustion engine-driven compressors, RAL-UZ 118 Heat pumps using an electrically powered compressor, RAL-UZ 121	

4.2.1 EU Ecolabel for Heat Pumps

The EU Ecolabel criteria for heat pumps have been specifically developed for "electrically driven, gas driven or gas absorption heat pumps"[25]. This product group comprises heat pumps which can concentrate energy present in the air, ground or water into useful heat for the supply of space heating or the opposite process for space cooling. The scope is for heat pump devices with a maximum heating capacity of **100 kW**. The scope excludes heat pumps which can only provide hot water for sanitary use, and also heat pumps which can only extract heat from a building and eject it to the air, ground or water thus resulting in space cooling.

Even though the technical know-how of heat pumping is well proven, the available preparatory studies conclude that heat pumps have not reached public recognition worldwide. In Europe, a sustainable market has only been established in countries like Sweden, Switzerland, and parts of Austria. Due to the increasing prices of oil and electricity, and the increase in energy-related taxes, the market for heat pumps has started to grow in all of Europe. Further market trends and statistics can be found at the European Heat Pump Association website[26], and at the technical background report for this study.

The goals of the EU Ecolabel for heat pumps are stated as:

- Improving the energy efficiency of heating
- Reducing environmental impacts of heating
- Reducing the environmental and human health impacts from the use of hazardous substances
- Providing proper information on the efficient installation and operation of heat pumps to the customer

Compared to a conventional boiler, a highly efficient heat pump system will generally reduce the use of fossil fuel and reduce hazardous emissions locally. Heat pumps however may contribute to climate change emissions by means of refrigerant leakage over their lifecycle. The EU Ecolabel criteria areas for heat pumps include: energy efficiency, criteria related to greenhouse gas emissions (defined by limits in the global warming potential – GWP – of the refrigerant, criteria related to indoor air quality and air pollution in general, including NO_x, SO_x emissions, etc. More technical details are available in the technical background report, and a summary of criteria is presented below.

In the EU Ecolabel criteria for heat pumps, the energy efficiency in heating mode is given in terms of the **coefficient of performance (COP)**, defined as the heat output of a heat pump divided by the electricity or gas input to the heat pump unit. The COP should be measured according to the methodology in EN 14511:2004 for electrically-driven and gas-driven heat pumps, and using EN 12309-2:2000 for gas absorption heat pumps. The COP measures can be also expressed in terms of primary energy ratio (PER). The **primary energy ratio (PER)** is the ratio of useful heat output per primary energy used, which is a measure of **energy efficiency**. The conversion coefficients are given as:

- Primary energy ratio (PER) = 0,40 * COP, for electrically-driven heat pumps
- Primary energy ratio (PER) = 0,91*COP, for gas-driven or gas absorption heat pumps

The conversion coefficients are explained as:

- 0,40 is the current European average electricity generation efficiency including power grid losses
- 0,91 is the current average gas efficiency including distribution losses

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[25] EU Ecolabel criteria for heat pumps: 2007/742/EC
[26] European Heat Pump Association statistics, available at http://www.ehpa.org

Table 11 summarizes the EU Ecolabel criteria for energy efficiency for hydronic heat pumps:

Table 11. Efficiency criteria for EU Ecolabelled heat pumps

Type of heat pump: heat source/heat sink	Min. COP (electric heat pump)	Min. COP (gas heat pump)
Air/water **Min. PER: 1,24**	3,10	1,36
Brine/water **Min. PER: 1,72**	4,30	1,89
Water/water **Min. PER: 2,04**	5,10	2,24

In addition, the EU Ecolabel criteria establishes the following additional limits:

- The global warming potential (GWP) for the refrigerant must not exceed GWP value > 2000 over a 100 year period. If the refrigerant has a GWP of less than 150 then the minimum requirements of the coefficient of performance (COP) and primary energy ratio (PER) in heating mode shall be reduced by 15%.
- The sound power level shall be tested and stated in dB(A) on the information fiche; testing shall be performed in accordance with ENV-12 102.
- Materials in the heat pumps shall not contain heavy metals (cadmium, lead, mercury and chromium 6+) or flame retardants, i.e. poly-brominated biphenyl (PBB) or poly-brominated diphenyl ether (PBDE) flame retardants listed in Article 4 of Directive 2002/95/EC. This requirement for flame retardants shall take account of subsequent adaptations and amendments made to that Directive regarding the use of Deca-BDE.
- Additional requirements related to installer training, installation instructions, and recyclability (e.g. spare parts availability)

In order to have a more comparative view of the energy efficiency of heat pumps vs. other different heating devices, the preparatory study for the EU Ecolabel for heat pumps offered evidence of a higher energy efficiency of heat pumps when compared to oil and gas boilers, and especially when compared to other heating technologies such as electric radiators (out of the scope of the current study):

Table 12. Energy efficiency of average-performing heat pumps compared to other heating devices

Heating device	Primary energy per kWh useful energy (kWh_{pr}/kWh_u)	Corresponding average overall energy efficiency (kWh_u/kWh_{pr}, i.e. PER
Oil boiler	1.45	0.69
Gas boiler	1.37	0.73
Electric heat pump	1.05	0.95
Electric radiators	2.50	0.40

The calculations assume that 0,40 is the current European average electricity generation efficiency including power grid losses, the same factor as in the EU Ecolabel Regulation for heat pump criteria.

Finally, the preparatory study addresses some of the potential barriers to the market uptake of heat pumps in Europe, regarded as principally the low energy prices are not seen as fully reflecting the external cost of the different energies. This is often related to the fact that even if a heat pump system is economically competitive, the energy cost difference may be too small for the consumer to decide for the heat pump system, in spite of other benefits that a heat pump system offers, such as reduced CO_2 emissions, more comfort, etc. This barrier could be overcome by offering incentives, grants, renewable energy tax benefits for heat pumps, exempted or reduced CO_2 taxes, etc.

4.2.2 Blauer Engel

The following is the list of Blauer Engel labelled products relevant for our study on hydronic central heating systems:

- Low-emission and Energy-saving Gas-fired Calorific-Value Heating Devices (RAL-UZ 61)
- Wood pellet boilers (RAL-UZ 112)
- Energy-Efficient Heat Pumps using Absorption and Adsorption Technology or operating by use of Combustion Engine-Driven Compressors (RAL-UZ 118)
- Energy-Efficient Heat Pumps using an Electrically Powered Compressor (RAL-UZ 121)
- Small-Scale Gas-Fired Cogeneration Modules (RAL-UZ 108)
- Small-Scale Liquid-Fired Cogeneration Modules(RAL-UZ 109)

4.2.2.1 Blauer Engel for boilers

Blauer Engel criteria for boilers are available for gas-fuelled and biomass fuelled (wood pellet only) boilers. Blauer Engel ecolabels for gas fuelled boilers are all limited to appliances with a nominal thermal output of up to and including **70 kW.** This is much lower than the 400 kW in the scope of the EU Ecolabel study. The Blauer Engel criteria for solid biomass boilers are restricted to appliances with a rated thermal output of up to **50 kW**, and only applicable to appliances that use wood pellets.

For the case of the RAL-UZ-61, the award is given to "gas-fired calorific-value heating devices which emit much less nitrogen oxide (NO_x) and carbon monoxide (CO) and make more efficient use of the fuel than would be required under current DIN Standards and whose auxiliary power demand is much lower than usually". Criteria are given as maximum limits for pollutant emissions such as NOx and carbon monoxide (CO). Regarding energy efficiency, the "nominal utilization ratio" (equivalent to the energy efficiency benchmark in Ecodesign) should be above 100% for 10 kW, and 101% for 70 kW at temperatures of 75/60 ^oC. At temperatures of 40/30 ^oC, the nominal utilization ratio must be above 103% for 10 kW and 104% for 70 kW.

The Blauer Engel criteria for wood pellet boilers (RAL-UZ-112) refer to **wood pellet boilers with a rated thermal output of up to 50 kW which are exclusively designed for the use of wood pellet fuel**. Criteria focus on energy efficiency and low emissions during operation. The reasons that only wood pellet fuel is allowed are stated as to prevent worsened efficiency and emission behaviour of the same appliance if fuelled by some other kind of fuel (not wood). The criteria establish that the efficiency must not fall below 90% when operating at either rated load (that is, full load) or partial load. The criteria also set maximum limits for nitrogen oxides (NO_x), carbon monoxide (CO) and other pollutants such as total carbon and dust particles in the exhaust gas.

Concerning uptake rate, there is evidence that wood-pellet boilers are much more in demand from industry than the gas-fired ones.

Both the Nordic Swan and the Blauer Engel give a greater emphasis than Ecodesign criteria to using biofuels (wood pellets, biomass, etc.).

4.2.2.2 Blauer Engel for heat pumps

The Blauer Engel scheme has developed criteria for "heat pumps using absorption and adsorption technology or operating by use of combustion engine-driven compressors" (RAL-UZ 118) and "heat pumps using an electrically powered compressor" (RAL-UZ 121).

The Blauer Engel label is meant to distinguish heat pump systems that require much less primary energy to generate heating energy than would be required using standard heat pumps, or other conventional heating technologies. The drawback of heat pumps is the use of refrigerants, which contribute to global warming if they leak.

In the RAL-UZ 118 criteria, the energy efficiency ratio (ratio of heating output to the electric power input) is set at a minimum of 120%.

In the RAL-UZ 121 criteria, the energetic efficiency of the systems is expressed by the seasonal performance factor (SPF) for the respective systems (water, air), which is defined as the ratio of heating output to the electric power input. The SPF measures the heating efficiency of a system taking the local operating conditions and the course of the year into account. Global warming potential (GWP) in CO_2 equivalents is used to estimate climate impact (with a time horizon of 100 years).

The TEWI (total equivalent warming impact) is used in the heat pump criteria. This parameter measures the impact of a system on the climate by means of a CO_2 equivalent. It considers the influence of the refrigerant as well as the climate change potential arising from the driving energy. To determine the TEWI value, the following parameters are combined: SPF, GWP, and the filling quantity of the refrigerant.

The scope is electrically powered heat pumps for room heating with a total thermal output of up to **100 kW** at a flow temperature of 45 ^{o}C.

4.2.2.3 Blauer Engel for co-generation units

The Blauer Engel scheme has criteria for two types of cogeneration units:

- Small-scale gas-fired cogeneration units, RAL-UZ 108
- Small liquid-fired cogeneration units, RAL-UZ 109

Regarding small-scale gas-fired cogeneration units (RAL-UZ 108), the award is given to those units which "make a rational use of the fuel used and emit far less nitrogen oxides and carbon monoxides than conventional CHP systems". Included within the scope are: engine-driven cogeneration systems power by diesel or gasoline engines, and plants driven by Stirling engines. The scope is limited to units with an electric power of up to **30 kW** for use of gaseous fuels. The criteria establish maximum limits for nitrogen oxides (NO_x) and carbon monoxide (CO). The total efficiency must be higher than 89% at full load, and 87% at partial (50%) load.

Regarding small-scale liquid-fired cogeneration units (RAL-UZ 108), the award is given also to those units which "make a rational use of the fuel used and emit far less nitrogen oxides and carbon monoxides than conventional CHP systems". Included within the scope are: engine-driven cogeneration systems power by diesel or gasoline engines, and plants driven by Stirling engines. The scope is limited to units with an electric power of up to **30 kW** for use of liquid fuels. The criteria establish maximum limits for nitrogen oxides (NO_x), carbon monoxide (CO) and dust. The total efficiency must be higher than 85% at full load, and 83% at partial (50%) load.

4.2.3 Nordic Swan

Nordic Swan criteria for central heating systems currently address only biomass boilers and heat pumps. The Nordic Swan Ecolabel used to have criteria for gas and liquid fuel boilers included burners and burner/boiler combinations up to 120 kW. This specification for fossil fuels has been however discontinued.

4.2.3.1 Nordic Swan for biomass boilers

The Nordic Swan label is given to "solid biofuel boilers". Compared to the Blauer Engel where criteria apply only to wood pellets, a Swan-labelled boiler is fired on a wider variety of solid biofuels, including wood (split logs), pellets made of wood, briquettes, straw and chips as defined by the EN 303-5 standard. Fuel can be fed manually or automatically (wood is generally fed manually, while pellets for example automatically). The product group comprises units with an output of up to **300 kW.**

The EN303-5 standard outlines terminology requirements, testing and marking of biomass boilers; however, it does not include specific details regarding how to actually measure parameters such as efficiency and emissions to air. Tests should be carried out in accordance with appropriate methods where identified in the criteria or use other applicable standards for undertaking such testing. Authorised test houses should also be used, who are accredited to carry out the testing using the method proposed.

There are significant differences between the emission limits in Blauer Engel and Nordic Swan for solid biomass boilers. This can be attributed to the fact that the Nordic Swan includes scope to cover larger appliances, up to 300kW, compared to just 50kW for the Blauer Engel and also the fuel type. The larger size of the boilers under the Nordic Swan will mean that operating temperatures will be potentially higher, possibly resulting in higher NO_x levels. Different emissions of air pollutants are also due to the fact that the Nordic Swan permits the use of a wide range of biomass compared to the Blauer Engel. For example, logs will not burn as cleanly or efficiently as wood pellets, resulting in higher emissions of pollutants such as carbon monoxide.

The Nordic Swan ecolabels also include wider criteria in relation to labelling of materials, the use of surface treatments, fire retardants and heavy metals, training of fitters, instructions and packaging. A wood-fired boiler is generally run periodically since the hot water is stored in a hot-water tank. Nordic Swan criteria are related to emission of particles, CO, and hydrocarbons; they are also related to the energy efficiency.

Normally separate burners cannot be awarded the Swan label. But if a burner is tested together with a defined boiler, the burner may be Swan-labelled if it is sold together with the defined boiler. Single-room heat sources such as stoves, slow heat release fireplaces and open fireplaces are covered by a separate criteria document, and are out of the scope of the current Ecolabel/GPP study for hydronic central heating systems.

The following tables specify the criteria limits of the Swan label for biomass boilers.

Air emissions

The limit values specified in the table below, must not be exceeded.

Particle and NOx (nitrogen oxides) emissions are only tested at nominal load.

The limit values for OGC (organic carbon) and CO (carbon mono oxide) are tested under the following conditions:

1 Nominal load for manual feed boilers equipped with a hot-water tank.

2 Nominal load and low load for automatic feed boilers. An average is calculated from the results of the three low loads. The various loads are defined in Section 2.3.

The requirements are applicable to manual and automatic feed boilers as well.

Limit values for air emissions

	Automatic feed boiler	Manual feed boiler	
(mg/m^3 dry gas at 10% O_2)	$X \leq 300$ kW	$X \leq 100$ kW	$100 < X \leq 300$ kW
OGC	25	70	50
CO	400	2000	1000
NO_2	340	340	
particles	40	70	

Efficiency

Boiler efficiency: η_k must at least be:

Manual feed boiler: $\eta_k = 73 + 6 \log Q_N$

where Q_N is the nominal output of the boiler.

Automatic feed boiler: $\eta_k = 75 + 6 \log Q_N$,

and $\eta_x \geq 86\%$; $\eta_x = (\eta_{20} + \eta_{40} + \eta_{60})/3$

where η_{20}, η_{40}, η_{60} stand for the measured efficiency at 20, 40 and 60% load.

4.2.3.2 Nordic Swan for heat pumps

The Nordic Swan criteria for heat pumps introduces limits for energy efficiency, in terms of an "annual average efficiency". This is defined as:

Annual average efficiency = E_{prod}/EL_{con}

where E_{prod} is the annual produced useful heat in kWh, and EL_{con} is the annual electricity consumption in kWh. This is the same magnitude as the coefficient of performance (COP) in the EU Ecolabel for heat pumps.

The Nordic Swan provides criteria for two different classes of heat pumps:

- *Class I*: For single heat pump units, where its electricity consumption is calculated independent of the house in which it is installed, but taking into account climatic data for the climate zone in question. The annual average efficiency for heat production should be a minimum of 1.75 in the relevant climate zone. If refrigerant in the heat pump is HFC, the annual average efficiency for heat production should be a minimum of 2.5. Class I includes the following types of units:

  (a) Heat pump that directly heats the air in the area to be heated
  (b) Exhaust air heat pumps
  (c) Heat pumps for sanitary hot water production only

- *Class II*: Heat pump systems, where the electricity requirement is calculated for model houses of varying size and with climatic data for the relevant climate zone; the electricity consumption includes also the electricity required by circulation pumps, fans and other auxiliary equipment. The annual average efficiency for heat production should be at least 2.0 in the relevant climate zone. If the refrigerant is HFC, then the annual average efficiency for heat production should be at least 2.25 (for GWP < 1000), and 2.30 (for GWP < 2000).

These minimum standards for the annual average efficiency (same magnitude as the coefficient of performance for the EU ecolabel of heat pumps) are less stringent than the ones of the EU ecolabel (which was between 2.60 and 5.10). There are two types of Class II heat pumps:

(a) Ground-source, geothermal and air heat pumps with a heat distribution through water or brine. (this could be model for EU Ecoolabel)
(b) Air heat pumps with a heat distribution through air ducts.

The heat pump shall be classified for use in one or more climate zones. Climate zones are defined according to temperature ranges, and a map of climate zones is also provided:

- Climate zone 1: Annual average temperature below and up to 5 °C
- Climate zone 2: Between 6-10 °C
- Climate zone 3: Between 11-15 °C

For Class II, if circulation pumps and/or fans are used, electricity consumption for their operation shall be included. If solar collectors or solar cells are used in the heating system, the heat generated from these units shall be included. If heat recovery is made from external refrigerating machines, this must be regarded as a supplemental part of the system.

4.2.4 Austrian ecolabel

The Austrian ecolabel[27] (Umweltzeichen) has been established for heating systems, based on type of fuel used, and only for renewable fuels.

One of the relevant criteria documents is for wood-fired heating systems, UZ 37, which includes automatically or hand-fired room heaters and heating boilers. Of relevance for this study is the criteria for wood fired boilers. Efficiency is measured according to standard EN 303-5. Possible fuels are: wood in natural state, wood chips, and compressed wood (briquettes, pellets).

[27] http://www.umweltzeichen.at/

The criteria provide limit values on energy efficiency, criteria related to quality and longevity (the heating system has to fulfil the requirements contained in the respective standards) and the noise level of the unit. Also, the criteria include limits on air emissions of NOx, CO, organic carbon and dust, and additional provision of information, and to improve the recyclability.

4.2.5 Energy Star

Energy Star is a voluntary labelling program jointly operated since 1992 by the US Environmental Protection Agency (US EPA) and the US Department of Energy (US DOE). The Energy Star criteria are focused on energy efficiency and carbon emissions reductions.

Energy Star criteria for heating systems exist since the mid-90s. Hydronic central heating products covered today by the Energy Star[28] are: boilers[29] (gas boilers and oil boilers), and heat pumps (air-source, geothermal). Criteria for gas-fired heat pumps were discontinued in 2000.

For heating equipment in general, Energy Star eligibility is based only on efficiency, measured by standard test procedures such as AFUE (for boilers) or SEER (for heat pumps)[30] . Energy Star standard does not extend to cover air quality emission criteria or additional materials criteria.

The method for determining the AFUE for residential furnaces is the subject of ASHRAE Standard 103 (ASHRAE is the American Society of Heating, Refrigerating and Air-Conditioning Engineers). A furnace with a thermal efficiency (η_{th}) of 78% may yield an AFUE of only 64% or so, for example, under the Standard's test conditions

The criteria are not too strict as compared to other labelling schemes. For example, boilers can earn an Energy Star if their efficiency (AFUE) is greater than 85%. It is reported by Energy Star that Energy Star qualified gas or oil boilers use about 5% less energy than a regular non-labelled boiler.

Finally, information on the product's packaging, marking, or instructions provided with it should support the consumers in using the products appropriately, i.e. not to exceed certain operational requirements. Also the maintenance instruction shall explain how to return the product to its intended maximum flow rate after cleaning or exchanging the accessories.

4.2.6 Other standards

In the absence of overall EU labelling scheme for boilers, a number of Member States have implemented their own schemes with varying degrees of success. These are generally only applicable to the Member State in which they are administered.

In the UK the SEDBUK Scheme (Seasonal Efficiency of Domestic Boilers in the UK) covers domestic gas and oil fired boilers. This labelling scheme assesses boilers in terms of efficiency using a Standard Assessment procedure (SAP) and provides them with a rating between A-G, as shown Table 12.

[28] http://www.energystar.gov/index.cfm?c=products.pr_find_es_products
[29] http://www.energystar.gov/ia/partners/product_specs/eligibility/boilers_elig.pdf
[30] AFUE is annual fuel utilization efficiency, and SEER is seasonal energy efficiency ratio

Table 13: SEDBUK Energy Efficiency bands[31]

Band	SEDBUK Range
A	90% and over
B	86% - 90%
C	82% - 86%
D	78% - 82%
E	74% - 78%
F	70% - 74%
G	Below 70%

In the UK other standards are also available, for example the Central Heating System Specifications (CHeSS)[32]. This is not aimed specifically at boilers, but central heating systems as a whole and it outlines best practice specifications for the components of domestic central heating systems that are critical to energy efficiency. This includes specifying the SEDBUK rating boilers must achieve as part of the system. It also includes specifications relating to control systems, hot water store and installation.

Other Member States also have their own labelling schemes and specific standards. For example in Denmark they have used the EU Energy Label for white goods as a template to create a label for small domestic boilers. This is aimed at providing customers with clear information when they are choosing a new boiler and promote the use of high efficiency boilers. Efficiency is calculated using a program called BOILSIM[33], which was developed under the SAVE programme. A similar labelling scheme has also been developed for oil boilers.

In addition to these standards and labelling schemes, the implementation of the EPBD means Member States are taking a more holistic approach to energy performance of buildings. This includes energy efficiency requirements of boilers and it is important to recognise that Member States may have specific laws and regulations, which need to be adhered to, and go beyond the requirements of the specifications proposed by this report. The contracting authority should ensure they are aware of any laws or regulations specific to individual Member States, for example the Building Regulations in the UK include minimum standards for non-domestic properties in relation to energy efficiency and the control systems required.

Some Member States have also included standards in relation to emissions in their own rules and regulations beyond the relevant EN standards. For example in Germany[34] the legal requirement entitled *Erste Bundes-Immissionsschutz Verordnung*, 1.BimSchV in short (the First Federal Emissions Protection Order) sets out limit values for NO_x and carbon monoxide (CO).

As part of the implementation of the EPBD, a number of CEN standards are under development, with the aim of harmonisation across the different Member States. These include standards in relation to methods for expressing energy performance and for energy certification of buildings and calculation of energy use for space heating and cooling.

In addition to the labelling schemes and individual Member State laws and regulations that set various standards, some Member States have implemented fiscal measures to promote the use of high efficiency boilers and therefore reduce the disparity between the prices of the green option compared to the non green option.

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[31] http://www.sedbuk.com/pages/bands.htm
[32] http://www.energysavingtrust.org.uk/uploads/documents/housingbuildings/CE51%20Final.pdf
[33] http://www.boilsim.com/
[34] http://www.bundesrecht.juris.de/bimschv_1_1988/index.html

Preparatory studies for boilers (as will be seen in draft GPP criteria below) also include a reference to a recent project, started in January 2008, "Changing the heating market mechanisms: Boiler Information System on Efficiency" (BISON[35]), which aims to provide a web based tool for the optimisation of the choice of central heating boilers based on annual efficiency. This has the potential to be a valuable tool, as choosing the optimum equipment may contribute significantly toward energy savings and CO_2 reductions.

Other associations have developed their own quality certification, such as the EHPA (European Heat Pump Association) quality label, which is third party certified[36]. The label is available to **electrically driven heat pumps**, with a capacity of up to **100 kW**, from air, geothermal or water heat sources.

The main EHPA label requirements are:

- Conformity of all main components and compliance with the national rules and regulation (CE marking)
- Minimum efficiency values (in COP units), defined and tested according to European standard EN 14511, with values:

    - Brine to water B0/W35 - 4.30
    - Water to water W10/W35 - 5.10
    - Air to water A2/W35 - 3.10
    - Direct exchange ground coupled to water E4/W35 - 4.30

- Declaration of sound power level
- Other aspects such as: existence of functioning customer service network, appropriate warranty, availability of spare parts

4.2.7 GPP criteria for heating systems

There are published and approved GPP criteria for combined heat and power (CHP) units. There are also recently completed background studies (unpublished, and not implemented yet) on (a) boilers, and on (b) heat pumps & air conditioning systems. GPP criteria are divided into core and comprehensive criteria. **Core criteria** are defined so that they can be used across any member state, address key environmental impacts, and represent minimum additional verification efforts or cost. **Comprehensive criteria** address the best products, and additional verification is needed.

4.2.7.1 GPP criteria for CHP

CHP is seen as one of the key ways in which Europe and its Member States (MS) can meet their environmental goals. In 'An Energy Policy for Europe[37]' published in 2007 by the Commission to the European Council, the Commission states its intention to continue improving efficiency in energy generation, and specifically mentions promoting high efficient CHP as one way of achieving this.

CHP uses heat losses from the energy-generating unit for other uses such as space heating, achieving a more efficient use of resources. In general, the output from conventional power generation is 35%

[35] http://www.boilerinfo.org/bison.htm

[36] EHPA label, http://www.ehpa.org/ehpa-quality-label/, EHPA heat pumps statistics are available at: http://www.ehpa.org/heat-pump-statistics/

[37] COM (2007)1

electricity, and 65% losses. For CHP the output is 90% electricity and heat, and 10% losses. The advantage of CHP is reduced fuel use compared to the conventional situation (separate electricity and heat generation). The most important criteria relate to primary energy savings. The criteria refer to the CHP unit itself, and not the electricity produced by the CHP unit, as there are separate GPP criteria for electricity. Criteria also include: emissions of CO_2, CO, NO_x, SO_x, dust. The core criteria include a minimum overall efficiency of 75-80%, defined as: (annual sum of electricity + mechanical energy production + useful heat output) / (fuel input + electricity input).

While Cogeneration is the term used in Directive 2004/8/EC, the term Combined Heat and Power (CHP) is more commonly used with the same meaning. Although the two terms are used interchangeably CHP is the terminology of choice in GPP criteria.

In GPP, it was proposed that the scope of CHP would cover a range of scales, including micro, small, medium and large. CHP may be purchased for public sector buildings, such as schools and hospitals, but it may also be purchased for smaller buildings, such as individual community housing.

Table 14 presents the range of different scales together with typical applications to provide some perspective on the use of CHP at different scales. It is feasible that public procurement could involve the purchase of CHP plant at a variety of different scales.

Table 14. Range, Scale and Applications of CHP[38]

KW/MW Range	Scale	Application
1-3kW	Micro	Domestic use
2-50kW	Micro/Small	Primary schools, guest houses, pubs/restaurants and small offices
50kW-5MW	Small Scale and Mid Scale	Public sector buildings, Community energy schemes, Leisure centres, Hotels, Commercial, Light Industrial, Hospitals and Universities and small blocks of flats
5MW plus	Large	Industrial application and large Industrial District Energy Schemes

Where the criteria refer to different sizes of cogeneration unit i.e. small or micro, the following definitions are used:

- Micro cogeneration unit shall mean a cogeneration unit with a maximum capacity below 50 kWe
- Small Scale Cogeneration shall mean cogeneration units with an installed capacity below 1 MWe

These definitions are consistent with the Cogeneration Directive.

4.2.7.2 GPP for central heating boilers

GPP boiler criteria have been developed for four types of boilers:

- Oil fired burners/boilers with capacity up to 120 kW. The criteria require that the fuel is light fuel oil with low sulphur content, or bioliquid from renewable energy sources
- Gas condensing boilers (natural gas), with capacity up to 70 kW
- Gas fired burners/boilers with capacity up to 120 kW, fuelled with natural gas or gas from renewable sources

38 http://www.chpa.co.uk/

- Solid biomass boilers, with capacity up to 300 kW. Solid biomass could be split logs, briquettes, pellets, chips, straw, following EN 303-5 standard. The solid biomass fuel could be fed manually or automatically

General criteria areas are:

- Energy efficiency
- Air Emissions
- End-of-life waste management
- In-use phase behavioural conditions
- Provision of information
- Packaging

Background studies for GPP indicate that boilers are still predominately fuelled by fossil fuels, including gas, oil and coal. The most common fuel type used by boilers for heating systems is gas, followed by others such as oil or other liquid fuels. This is reflected by the Boiler Efficiency Directive (92/42/EEC), which focuses on the efficiency requirements for new hot water boilers fired with liquid or gaseous fuels.

For gas boilers it is important to distinguish between non-condensing boilers and condensing boilers. For condensing boilers the efficiency is higher at part load[39] compared to full load. For non-condensing boilers the opposite is true. This will obviously influence the choice of criteria.

The use of different heating systems and boilers will depend on their availability in the local market and the supply and availability of the different fuel types. In addition, the use of boilers and heating systems across different Member States will also be influenced by variations in climate across the EU.

The GPP specification focuses on boilers that use three common fuel types, namely gas, oil or solid biomass. Although electric boilers are available, they were considered still a niche market[40]. In addition, although electric boilers are very efficient, there is the potential for significant environmental impacts from the production of the electricity itself if it is produced from fossil fuels. It was therefore considered appropriate not to include electric boilers within the scope of this product group. If using an electric boiler, consideration should be given to the production of the electricity used and the existing GPP specification for Electricity[41]. This GPP specification was aimed at ensuring efficient boilers are used for the fuel types identified above, where the main lifecycle impacts relate to the use of the actual boilers.

Many of the existing standards and labelling schemes focus on boilers for domestic heating requirements. From a public procurement perspective however, contracting authorities will potentially be required to purchase boilers across a range of different technologies and at a range of scales depending on their exact needs. For example boilers may be required to be purchased for non-domestic buildings such as schools, leisure centres and offices, as well as domestic buildings such as community housing.

The choice of specific products evaluated for GPP criteria was selected in accordance with products addressed in Ecodesign Lots 1 and 15. Although the division between domestic and commercial boilers is unclear, it was important to ensure that the scope of the proposed criteria included boilers

[39] Part load is defined as the ratio between the effective output of a boiler operating intermittently or an output lower than the effective rated output and the same effective rated output – Article 2 of the Boilers Directive, 92/42/EEC. Typically boilers will operate at part load when taking account of seasonal variations, which can be for a significant part of their working life.

[40] http://www.ecoboiler.org/public/ecoboiler_task1_final.pdf

[41] http://ec.europa.eu/environment/gpp/pdf/toolkit/electricity_GPP_product_sheet.pdf

with a rated output of a sufficient size for the different range of potential uses that are applicable to GPP. The scope of GPP for boilers was therefore defined as:

> Boilers for the purposes of this GPP specification are defined as 'an appliance designed to provide hot water for space heating. It may (but need not) be designed to provide domestic hot water or other functions as well'[1]. Specifically four different types of boilers are included as outlined below:
>
> - Oil Fired boilers are combined oil burners/boilers designed to burn light fuel oil with low sulphur content or bioliquid produced from renewable energy sources, encompassing installations of up to 120kW.
> - Gas Condensing boilers are boilers designed to be used with natural gas, encompassing installations of up to 70 kW.
> - Gas Fired boilers (non-condensing) are combined burners/boilers designed to be fuelled with natural gas or gas produced from renewable sources, encompassing installations of up to 120kW.
> - Solid Biomass Boilers are combined solid biomass boilers/burners with an output of up to 300kW. Solid biomass includes split logs, briquettes, pellets and chips as defined by EN303-5. Straw is also a solid biomass. The fuel can be fed manually or automatically.

It should be noted that the GPP criteria for boilers are not applicable to heat pumps and combined heat and power. These product groups are dealt with by separate GPP specifications.

In the developing of GPP criteria for boilers, much of the information was adapted mainly from the Blauer Engel and the Nordic Swan criteria. One of the issues discussed was over the cut-off between residential and commercial boilers. Both the Blauer Engel and the former Nordic Swan criteria for gas and oil fuelled boilers potentially cover boilers that can be used for both residential and non-domestic use. However it is possible that some public procurement of boilers may involve those sized above 70kW. It was therefore decided to use the Nordic Swan criteria as the basis of the core and comprehensive GPP criteria. The exception to this was for gas condensing boilers, where the efficiency and emission limits were taken from the Blauer Engel criteria, which were specifically developed for these types of boilers.

The Blauer Engel for biomass boilers was considered to be mainly aimed at the residential sector. Therefore, given the possible variation in terms of use and size of boilers that a contracting authority may consider, it was considered more appropriate to use the Nordic Swan criteria for biomass boilers as a basis to identify the core and comprehensive GPP criteria, in order to maximise the scope and opportunity to apply these criteria in GPP.

4.2.7.3 GPP for heat pumps

There is an unpublished completed background study for GPP of heat pumps and air conditioning products, together also addressed as "climate control units" (CCU). Here we only address the part of the GPP criteria related to heat pumps whose primary function is ambient heating, and in addition, where the heat transfer medium is water. For reversible heat pumps, the present criteria development will address the heating function of heat pumps with water transfer.

Therefore the core criteria are focused on:

- Energy consumption efficiency in the use phase and
- Refrigerant compounds.

Comprehensive criteria include the core criteria and extend it to include

- Hazardous materials and substances
- Installation and maintenance

The ecolabel standards for heat pumps, in particular the EU Ecolabel and the US Energy Star cover the key issues and it is therefore proposed that they form the basis of the GPP criteria. In addition, some elements of the German Blauer Engel and Nordic Swan ecolabels are included (at the comprehensive level) to ensure a set of criteria that address all aspects of environmental impact. These include design for the environment and end of life waste management and recycling.

As well as the key aspects of energy use and refrigerants it is important that contracting authorities consider additional elements, such as making sure the size of the CCU is proportionate to the building into which it is to be installed, the provision of adequate instructions and training, electricity consumption and use of hazardous materials. These will contribute to reducing environmental impacts such as energy use and are included in the GPP specification as core or comprehensive criteria, where appropriate.

In addition to the recommended core and comprehensive technical specifications (which are criteria that have to be met by all products offered for purchase), award criteria are proposed where applicable. These are additional criteria on which the contracting authority will base its award decision. Award criteria are not pass/fall criteria, meaning that offers of products that don't comply with the criteria may still be withheld for the final decision, depending on their score on the other award criteria, including the price. To stimulate further market uptake of ever improved environmental products, award criteria should be considered depending on the specific circumstances of each case.

CCUs are just one element of the overall energy performance of buildings. A wider holistic approach is necessary. Such wider approach forms the basis of the EPBD (Energy Performance of Buildings Directive). Its implementation by the Members States and the integration of the different aspects will be key to improving the overall energy performance of buildings in the future. The recommended GPP criteria for CCUs and the development of GPP criteria for other construction elements such as boilers, insulation and windows will provide key information to public contracting authorities.

4.3 Overview of criteria areas covered in different mandatory and voluntary policy instruments

Table 15. Summary of criteria areas covered in different policy instruments

	ED	EL	EU Ecolabel	Blauer Engel	Nordic Swan	Austrian Label	E Star	GPP
Gas boiler	En. Eff.	En. Eff.		En. Eff., air pollutants (NOx, CO, total C, dust)			En. Eff.	En. Eff., air pollutants (NOx, SOx, CO, dust, SOx, dust)
Oil boiler	En. Eff.	En. Eff.					En. Eff.	En. Eff., air pollutants (NOx, SOx, CO, dust, SOx, dust)
Biomass boiler				En. Eff., air pollutants (NOx, CO, total C, dust)	En. Eff., air pollutants (NOx, CO, OGC, HC, dust), haz. Substances (heavy metals, flame retardants)	En. Eff., air pollutants (NOx, CO, OGC, dust), noise, recyclab., instruct.		En. Eff., air pollutants (NOx, SOx, CO, dust, SOx, dust)
Heat pump	En. Eff., GWP, air pollutant s (NOx), noise	En. Eff.	En. Eff., GWP, haz. substances (heavy metals, flame retardants), recyclabilit y, instructions	En. Eff., GWP			En. Eff.	En. Eff., GWP
Co-generation	En. Eff.	En. Eff.		En. Eff., air pollutants (NOx, CO, dust)				En. Eff., air pollutants (NOx, SOx, CO, dust, SOx, dust)

Explanation of parameters:

- Energy efficiency
- GWP: Means a limit on the global warming potential of the refrigerant in heat pumps
- Air pollutants: Include nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO), organic carbon (OGC), total carbon (total C), hydrocarbons (HC), dust
- Noise: Means a limit on max. sound power level of heating unit
- Recyclability: Includes availability of spare parts, design for easy recycling
- Instructions: Means provision of instructions for installation, operation

5. PROPOSED CRITERIA AREAS FOR DISCUSSION

This section is intended as a starting point for a discussion on which criteria should be covered by the EU Ecolabel and GPP for hydronic central heating systems. In this working paper no values are proposed for the criteria areas. The 1st AHWG meeting in Sevilla will serve to discuss the appropriateness of the proposed criteria areas. A 2nd AHWG meeting, planned to take place in

November/December this year in Brussels, will further serve to discuss the criteria areas and specific limit values. The expert group should feel free to comment on every issue that they consider relevant and send us their remarks and further proposals for consideration before the 1st AHWG. The expert group is also welcome to submit written comments after the 1st AHWG meeting regarding the criteria areas and specific limit values.

The EU Ecolabel EC 66/2010 states that the label criteria shall be determined on a scientific basis considering the whole life cycle of products. In the frame of the project a number of base cases have been defined and a preliminary environmental evaluation of various stages of the product life has been completed, as described in the technical analysis chapter above (Chapter 3) and the background document available on the project's website. Within data uncertainties and methodological limitations, the analysis allowed for identifying the main issues contributing to the environmental impacts. Detailed results are presented in the background document[42].

Based on the life-cycle analysis conducted in the frame of the study and on the analysis of the European and non-European labelling schemes, the key issues to be considered in the process of EU Ecolabel and GPP criteria development are proposed and presented in the following section, and outlined below:

1) **Criteria related to energy efficiency:** The focus is on the "seasonal space heating energy efficiency" (such as in Energy Label and Ecodesign Implementing Measures discussed in Chapter 4), and the rated capacity depending on the climate zone. These magnitudes were developed during the Ecodesign Lot 1 preparatory study after several round of consultation with the expert group.
2) **Criteria related to air emissions (global warming impact)**: including CO_2 emissions and GWP of the refrigerants (if applicable), overall expressed as GHG emissions in tons CO_2 equivalent
3) **Criteria related to other air emissions (some of them related to indoor air quality, i.e. related to exposure to indoor air emissions, others to acidification, etc.):** Indicators include: NOx and SOx emissions (acidification potential), volatile organic compounds (VOC), persistent organic pollutants (POP), heavy metals (HM) in air, expressed in mg Ni, polycyclic aromatic hydrocarbons (PAH), particulate matter (PM), organic carbon (OGC), and carbon monoxide (CO).
4) **Criteria related to indoor and outdoor acoustical noise**
5) **Criteria related to design of materials: Preventing the use of hazardous substances and materials**[43]. The composition of materials should not contain hazardous substances. The criterion could be developed on the basis of Ecolabel Regulation 66/2010, Articles 6.6. and 6.7. We might need to further investigate possible substances derogations based on Article 6.7 as well as further investigate possible proposals for inclusion of additional substances. Material composition/release of hazardous substances during use-phase (example, the materials in the heating system must fulfil the requirements of the RoHS Directive (2002/95/EC RoHS), composition of plastics (e.g. absence of certain phalates and certain flame retardants), surface treatments must not contain pigments based on lead, cadmium, chromium, mercury or their compounds, and they must not contain more than a certain maximum percentage of organic solvents.
6) **Criteria related to design of materials: Promotion of reuse, recycling, and generally a sound end-of-life management:** recycled material content, design for recycling, design for repair/warranty and spare parts, Blauer Engel criterion on recyclable design, criteria regarding

[42] Technical Analysis, available at the project website: http://susproc.jrc.ec.europa.eu/heating/stakeholders.html
[43] Annex I of the Ecolabel Regulation (No. 66/2010) specifically requires the "analysis of the possibilities of substitution of hazardous substances by safer substances, as such or via the use of alternative materials or designs, wherever technically feasible, in particular with regard to substances of very high concern as referred to in Article 57 of Regulation (EC) No 1907/2006".

ease for reuse/recycle, Blauer Engel criterion for marking of plastics, guarantee of repairs and maintenance of equipment, product take back requirement.

7) **Corporate criteria (including user information)**: packaging (e.g. packaging materials must not contain certain types of chlorine-containing plastics), consumer information/user instructions for installation, operation and end-of-life management, information appearing on the ecolabel, packaging requirements

5.1 Criteria related to energy efficiency

The technical analysis conducted in the frame of this study, together with a review of other product policy initiatives showed that one of the most important parameters with the highest associated environmental benefits is improvements in energy efficiency. Improvements in energy efficiency will result in significant resource saving (reduced primary resource depletion due to energy production), decreased greenhouse gas and other pollutant emissions related to energy generation and use, as well as economic benefits for the users reducing their energy bills.

All the labels and programs reviewed in Chapter 4 above include as primary criteria area the energy efficiency criteria (e.g. Nordic Swan and Blauer Engel). More precisely, boiler efficiency is defined according to CEN 303 and 304, and calculated during one year of operation. Related to energy efficiency, some of these labels also require low auxiliary power demand.

From the technical analysis conducted in this study (Chapter 3), some conclusions regarding energy efficiency were reached:

- Biomass boilers, and especially the small automatic biomass boilers, have the lowest nominal efficiency. From this result we can derive that a stricter criterion on energy efficiency would be needed for biomass boilers, compared to other heating systems.
- Regarding the electricity component of the primary energy used, the highest electricity consumption was obtained for the electric heat pumps (as expected). The electricity consumption was negative (meaning net electricity production) for the cogeneration boiler.

It is important to be aware of the means of measuring boiler efficiency when comparing different types of boilers. Efficiency can be based on the net or gross calorific value of the fuel, and will therefore vary depending on the methodology used. Efficiencies based on net calorific values can result in efficiencies of greater than 100 % for condensing boilers due to the recovery of heat from condensate. The efficiency in this study is based on the "seasonal energy efficiency" as defined in the Ecodesign Implementing Measures for boilers, and it is expressed in terms of the gross calorific value, as decided by the Commission in consultation with stakeholders during the Lot 1 study on boilers.

5.1.1.1 Seasonal space heating energy efficiency

This study proposes to use the definition of "seasonal space heating efficiency" (etas), as defined in the Ecodesign Implementing Measures for boilers (more detailed explanation in Chapter 3). The "seasonal space heating efficiency" is defined as the ratio between the space heating demand pertaining to a designated heating season provided by a boiler, and the annual energy consumption required for its generation, expressed as percentage. Variations of ways to define energy efficiency are used in every policy instrument addressing hydronic central heating systems.

According to results compiled in the GPP preparatory work on boilers, old boilers had seasonal efficiencies of 55% (heavy weight) and 65% (light weight), compared to 78% for a new non-condensing boiler and 88 % for a new condensing boiler[44]. Seasonal efficiency provides a weighted average of boiler efficiencies at different loads e.g. 30% and 100% to take into account the variation in operating loads in response to seasonal and heating demand fluctuations.

Depending on the system implemented, a condensing boiler operating at its highest efficiency can reduce primary energy consumption and carbon dioxide emissions by 11-15% in the operational phase (Sasnauskaite et al 2007).

Improvements in energy efficiency also result in a reduction in direct emissions of CO_2 from the combustion of the fuel, and there is also a concomitant reduction in the embedded impacts of the fuel: reduced emissions for the fuel life cycle from exploration, extraction, refining, processing, transportation and storage.

Consideration should also be given to the use of fuel types other than fossil fuels. Renewable fuels are now starting to be used in boilers. Boilers using biomass such as wood chips and pellets are included within the scope of this GPP specification. If biomass fuels are used, the contracting authority should ensure that the fuel used is from an accredited renewable source. Another issue is that energy efficiency depends on type of building, how the heating system is installed, and the climate zone. Also the methods and standards for measuring energy efficiency differ in various schemes.

In this respect we would like to invite the experts to comment on the appropriateness of the use of the "seasonal space heating efficiency" as the right parameter to measure efficiency, or whether other magnitudes would be appropriate.

Are differences in values necessary for different types/applications of products?

5.1.1.2 Testing methods

In order to verify whether a given product meets the criterion of energy efficiency, laboratory tests have to be conducted. The standards most commonly mentioned are the EN 303 standards.

Some labelling schemes require only submitting by a producer's a declaration of conformity, while other demand results from internal or external (certified third party) laboratory tests.

Some ecolabelling schemes require third party testing and a certification process, which covers independent measurements in certified laboratories; while other rely just on the producers' "Declaration of Conformity" with the required criteria (sometimes supported by testing results), and signed and dated by authorised personnel. Both of these approaches have their advantages and disadvantages. Usually, external certification is considered as more reliable, ensuring the high quality of the tests conducted; nevertheless they are more costly, which can constitute a potential barrier for SMEs in applying for a label.

Thus, we would also like to ask the stakeholders to comment on the methods which are most feasible for the evaluation of fulfilling the criteria of energy efficiency and which could be applied to verify the product's conformity with this potential future Ecolabel criterion.

[44] http://www.sedbuk.com/cgi-local/dynamicv.cgi?page=boiler8

Thus, we would also like to ask the stakeholders to comment on the methods which are most feasible for the evaluation of fulfilling the criteria of energy efficiency and which could be applied to verify the product's conformity with this potential future Ecolabel/GPP criterion

Which methods in the stakeholder's opinion can suit best for measuring the energy efficiency of a heating system?

Do you consider it necessary that the testing must be conducted by a third party or do you rather recommend producers 'Declaration of Compliance' supported by the results of tests conducted within the company?

5.2 Criteria related to air emissions

Although energy efficiency is the key area in terms of the potential environmental impacts boilers can have, there are also other potential impacts, for example emissions to air as a result of the combustion process. Depending on the fuel used the following parameters have the potential to be emitted from boilers; carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxides (SO_x), particulate matter (PM), hydrocarbons (HC), methane (CH_4), volatile organic compounds (VOC’s) and soot. The impact of these will vary depending on the fuel used, type of boiler and the use of any appropriate abatement measures.

It is important to minimise these emissions to reduce greenhouse gases and limit the contribution from boilers on climate change. The emissions from boilers also have the potential to contribute to other major environmental impacts and should also be minimised for these reasons. For example emissions of nitrogen oxides (NO_x) and sulphur dioxides (SO_x) from boilers can contribute towards the acidification, in particular of sensitive ecosystems through acid rain or dry deposition.

In addition the above emissions will have localised air quality impacts. Human health issues may arise through deterioration of local air quality, or in the gas of gas boilers, there is the risk of carbon monoxide poisoning where the boiler is not operating properly.

5.2.1 Air emissions related to climate change

Climate related emissions mainly include CO_2 emissions and GWP of the refrigerants (when applicable).

The technical analysis presented above provided evidence of the major differences between e.g. biomass boilers and fossil fuel boilers. Biomass boilers, while having less energy efficiency, have nevertheless much lower GHG emissions than other boilers, since the CO_2 production of combustion is considered to be zero. However, biomass boilers exhibit much higher emissions in all other impact categories, as will be seen in the other described criteria areas below. As discussed in the technical analysis, the greenhouse gas emissions from biomass boilers are the lowest, and the heat pump achieves a reduction of 20% compared to the gas condensing boiler.

The results of the environmental impact analysis are disaggregated by impact categories, and do not provide an evaluation on what environmental impacts are more or less serious. So for example, if CO_2

emissions are considered a priority, then biomass boilers will be more desirable than fossil fuel boilers. However, if other air pollution indicators are considered important, then biomass combustion is not as "clean" as good gas or oil combustion, as will be explained below. Certain local and national policies limit therefore the emissions allowed for biomass boilers (and solid fuel boilers in general).

As a conclusion, an important consideration in developing the Ecolabel/GPP criteria in this area is that for e.g. gas/oil boilers the improvements would need to focus on energy efficiency in order to achieve reductions in GHG emissions.

According to the GPP preparatory work for heat pumps, discharges to atmosphere of refrigerants can occur throughout the life-cycle phases of a heat pump and contribute to climate change. Below is a description of these emission types.

- **Initial:** This group includes all losses associated with making equipment functional, and specifically those associated with manufacturing, performance and leak testing, transportation, installation, initial charging, field leak testing, and initial start up. These losses are very small, except in cases where a significant leak is discovered or a failure occurs during start up.
- **Operating:** Unlike the initial losses, which occur once in the life of a machine, the operating losses are recurring. They include both leakage and purge releases. It has been estimated that 75 % of all refrigerant use was for topping up systems.[45]
- **Intermittent:** Also recurring, these releases include those from maintenance (for example in disconnecting hoses and opening systems for major service procedures), accidents, failures, unintentional venting, technician errors, and non-specific causes.
- **Disposal:** This amount accounts for the refrigerant lost at equipment retirement, a one-time event per machine.[46]

Direct emissions of refrigerants in air-conditioners and unitary heat pumps have been estimated in a study performed at Oak Ridge National Laboratory, USA (Sand et al 1997). These estimates were 4 % annual leakage for the technology available in 1997 and estimated to drop to 2 % by 2005[47].

Hermetically sealed units are essentially air-tight so there is little or no escape of gases. These units are typically window or portable units, however hermetically sealed compressors can be specified for larger fabricated systems. Hermetically sealed units containing less than 6 kg of F gas will be exempt from the F-gas regulations leak checking requirements.

There is currently a lot of discussion on the phase out of all gases that contain fluorine, known as F-gases, which includes perfluourinated carbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) of which HFCs make up approximately 90 %[45]. There is a gradual shift to Hydrocarbons (HC) and Carbon Dioxide (CO_2) as replacement refrigerants. CO_2 has a Global Warming Potential (GWP) of 1 whereas HFC134a, the most widely used, has a GWP of 1430 over a 100-year horizon according to the IPCC's 4th Assessment Report. The value used for annual national CRF and UNFCCC (Kyoto Protocol) reporting is 1300, taken from the IPCC's 2nd Assessment Report.[48]. It has been estimated that if all HCFCs and CFCs are replaced with HFCs, over the next 20 years HFCs will be responsible for 5.2 % of total global warming[45].

The Danish Government now charges a stringent tax on all HFCs with plans to phase these out all together. This groundbreaking piece of legislation is placing pressure on other European countries

45 http://www.mipiggs.org/faqs/index.html
46 'Emissions and Environmental Impacts from Air-Conditioning and Refrigeration Systems' James M Calm
47 http://ec.europa.eu/environment/ecolabel/pdf/heat_pumps/hp_tech_env_impact_aug2005.pdf
48 IPCC 4th Assessment Report: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf

with the result that they may well follow suit. For R-134a the tax is approximately €14/kg[49]. Currently the F-gas legislation governs the use of HFCs, PFCs and SF_6 in all their applications.

The Global Warming Potential is a relative measure of how much a given mass of a particular substance is estimated to contribute to global warming; this is usually measured over a period of 100 years. Carbon Dioxide (CO_2) is the reference gas to which all other gases are compared and has a GWP of 1. Methane, for example, has a GWP of 21[50] while R134a, a refrigerant has a GWP of 1430[51].

In addition (Pettersson, 2010), there should be at least a common benchmark for greenhouse gas emissions limit, given in maximum amount of grams of CO_2 per kWh of heating output[52], or per kWh of primary energy input[53].

We invite the experts to comment on the appropriateness of the use of the TEWI approach to calculate the climate change impact, and otherwise request other suggestions or comments regarding the criteria area on climate-related emissions.

5.2.2 Other air pollution emissions

These are air emissions related to indoor air quality, acidification, etc., mainly generated during use phase. Indicators include: NOx and SOx emissions (together assessed because of their acidification potential), volatile organic compounds (VOC), persistent organic pollutants (POP), heavy metals (HM) in air, expressed in mg Ni, polycyclic aromatic hydrocarbons (PAH), particulate matter (PM, example PM10, PM2.5) also called soot values, total carbon and organic carbon (OGC), and carbon monoxide (CO), volatile hydrocarbons (HC).

Some conclusions from the technical analysis are relevant to this criteria area:

- Acidification - Here the NOx and SOx emissions by biomass boilers and EU electricity production appear most significant, while the cogeneration boilers achieves a net reduction of acidifying emissions
- VOC - The manual stoked wood log boiler performs the worst regarding the emissions of VOCs, this relates to both combustion efficiency and type of fuel
- POP - Here the automatic stoked pellet boiler performs the worst, which is mainly due to the type of fuel (pellets)
- Heavy metals (to air) - Again it is the pellet boiler that performs the worst, but here the electric heat pump has significant emissions as well
- PAH - The biomass boilers emit the most PAHs but the differences in the group are less outspoken than in other impact categories

[49] http://www.care-refrigerants.co.uk/hmpg/hmpgdisplaylev2.asp?where=lev2&catid=4&catid2=21
[50] http://www.environment-agency.gov.uk/business/444255/446867/255244/substances/185/
[51] IPCC 4th Assessment Report: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf
[52] The EU Ecolabel for heat pumps establishes that the global warming impact of heat pumps must not be greater than 210 g CO_2/kWh useful heat as an average during a year.
[53] Electricity production is considered to have a conversion efficiency of 40% (in the conversion of primary energy to electricity).

- PM - As regards particle emissions the biomass boilers perform the worst, with the manual stoked wood log boiler as exceptionally high source of emissions

> Are all the pollutants relevant for possible criteria on air pollutants?
>
> We particularly welcome comments on the importance of criteria related to Indoor Air Quality.

5.3 Criteria related to indoor and outdoor acoustical noise

The noise from the heating units is a parameter that should be taken into consideration when deciding where to locate the unit, in order to minimise the noise impact upon the surrounding environment and those living and working in within it. However, criteria on noise are sometimes included but sometimes excluded from ecolabel schemes.

Noise emissions from central heating products occur mainly from either combustion air / flue gas transport (combustion boilers) or from air transport over evaporators / compressor noise (vapour compression cycle heat pumps). In the Ecodesign Lot 1 calculation methodology noise emissions were included to determine distribution losses, the rationale being that the noisier the boiler is, the further it is installed from the main living areas, thereby introducing distribution losses.

In the current proposals there is an information requirement for all boilers and a maximum noise emission requirement for heat pumps. Noise is however not quantified in the life-cycle methodology in this study.

> We would like to invite the stakeholders to comment if they consider the issue of noise level an appropriate criteria area.

5.4 Criteria related to design of materials: Preventing the use of hazardous substances and materials.

The composition of materials should not contain hazardous substances. The criterion could be developed on the basis of Ecolabel Regulation 66/2010, Articles 6.6. and 6.7. We might need to further investigate possible substances derogations based on Article 6.7 as well as further investigate possible proposals for inclusion of additional substances. Material composition/release of hazardous substances during use-phase (example, the materials in the heating system must fulfil the requirements of the RoHS Directive (2002/95/EC RoHS), composition of plastics (e.g. absence of certain phalates and certain flame retardants), surface treatments must not contain pigments based on lead, cadmium, chromium, mercury or their compounds, and they must not contain more than a certain maximum percentage of organic solvents.

In this point we would like to mention the issue of presence of hazardous substances in the product group under study, as the Ecolabel Regulation EC 66/2010 states that the 'substitution of hazardous substances by safer substances, as such or via the use of alternative materials or designs, should be considered wherever it is technically feasible'.

The Nordic Swan and the Blauer Engel impose restrictions on:

- Heavy metals and flame retardants in plastic parts.
- Heavy metals and organic solvents in surface treatment agents
- Halogenated solvents in degreasing agents
- Substances with a climatic effect in foaming agents used in insulating materials

According to the GPP preparatory work for heat pumps, there are a wide range of other materials, substances and components used in CCUs and their packaging, including metals, plastics, surface treatments and various packaging materials. It is important to ensure that the materials and substances used in CCUs do not pose a risk to the environment or end-users. To meet this need the GPP preparatory study proposed therefore to take the holistic approach of addressing the chemical characteristics of the substances in order to mitigate any potential risks arising from the use of these materials. This is best achieved by using appropriate risk phrases in the relevant criteria. By taking this more holistic approach the focus of the criteria is on the chemical and environmental properties of the substances rather than on the chemical family to which they belong and thus does not unduly exclude any one group of chemicals.

We would like to invite the stakeholders to comment if they consider the issue of hazardous substances release in the use phase of relevance for criteria development, and more specifically what substances.

5.5 Criteria related to design of materials: Promotion of reuse, recycling, and generally a sound end-of-life management

This criteria area includes aspects such as: recycled material content, design for recycling (e.g. the Blauer Engel criterion on recyclable design), design for repair/warranty and spare parts, criteria regarding easy for reuse/recycle, e.g. Blauer Engel criterion for marking of plastics, guarantee of repairs and maintenance of equipment, product take back requirement.

According to the GPP preparatory work for boilers, it is worth considering end of life management issues relating to boilers, as there may be the potential to cause harm to the environment in this lifecycle phase. They will also be of relevance to elements of the boiler or heating system that will be replaced throughout the life span of the system as a whole. Boilers consist of materials that can be recovered and recycled, for example plastics and in particular, metals. It is important that materials are marked correctly to ensure they are recycled or disposed of in the correct manner in the end of life phase.

It may be the case that a boiler is replaced before it has reached its natural end of life. It is generally better in life cycle terms to replace an older boiler that still has some life left in it with a new, more efficient one, i.e. the CO_2 emissions savings outweigh the increased wastes impacts of a boiler coming to the waste stream a bit early and its embedded carbon.

As well as the recyclable elements such as the plastic and metals, there is the potential for the use of hazardous materials or substances in boilers, for example the use of brominated fire retardants and heavy metals. The use of these materials is now restricted due to their potential harmful effects on human health and ecotoxicity.

From the GPP preparatory work on heat pumps, the end of life management of CCUs is mainly regulated by the requirements of the WEEE Directive, as such units have to be collected for proper disassembly, treatment and recycling of parts. Much of the components of CCUs can be recycled with a minimum of treatment, for example plastics and metals.

Under the EC F-gas legislation, when a CCU is recycled, reclaimed or destroyed, certified personnel must recover over all the fluorine-containing gases in order to limit the amount of fugitive emissions from disposal of the units and thereby mitigate their impact on the ozone layer (as well as reducing their global warming impact).

5.6 Corporate criteria (including user information)

According to GPP preparatory work for boilers, environmental impacts will to some extent be governed by the behaviour of end users. Energy consumption of boilers is the key environmental impact of heating systems. It is therefore imperative that end users maintain and operate the boilers and heating systems in the correct manner, as designed to achieve the maximum efficiencies. To assist this it is important that clear instructions and guidance/training are provided, highlighting where necessary the need for trained engineers.

In the wider context of the heating system as a whole, it is also important that the system has adequate control mechanisms to ensure the heating is only on and at the required temperature when there is a demand for it. Other aspects of the system also have potential environmental impacts, for example insulation foams containing greenhouse gases and asbestos-containing fire-retarding materials. This is a particular issue for systems where insulation is replaced, as older materials that have been in-situ for a number of years may contain these gases, which will need to be recovered properly.

Overall, corporate criteria could include criteria on packaging (e.g. packaging materials must not contain certain types of chlorine-containing plastics), consumer information/user instructions for installation, operation and end-of-life management, information appearing on the ecolabel, packaging requirements.

We would like to ask the experts whether this is a relevant criteria area, and any further suggestions.

5.6.1 Packaging

According to the GPP preparatory work for boilers, the Commission report published in 2006 on the implementation of the packaging directive (94/62/EC) highlights that packaging is a relatively small but not insignificant product and waste stream.

The Packaging Directive is aimed at ensuring packaging waste is dealt with effectively and sets targets for Member States with regard to the recovery and recycling of packaging materials. These targets were revised by Directive 2004/12/EC and are summarised below, with full details available in Article 6 of the Directive.

- no later than 31 December 2008 60 % as a minimum by weight of packaging waste will be recovered or incinerated at waste incineration plants with energy recovery;
- no later than 31 December 2008 between 55 % as a minimum and 80 % as a maximum by weight of packaging waste will be recycled;
- no later than 31 December 2008 the following minimum recycling targets for materials contained in packaging waste will be attained:
  - (i) 60 % by weight for glass;
  - (ii) 60 % by weight for paper and board;
  - (iii) 50 % by weight for metals;
  - (iv) 22,5 % by weight for plastics, counting exclusively material that is recycled back into plastics;
  - (v) 15 % by weight for wood.

The relevance of packaging as a key environmental impact depends on factors such as product life time and the types of materials used. Packaging can consist of various material types including paper, cardboard, plastic and metals.

In the course of the GPP study, consultation feedback suggests that using the same packaging criterion across different product groups is not an appropriate approach. In addition, for the majority of products in this study packaging is not a key issue, given their long life times, energy consumption during manufacturing and that some use energy in the use phase.

Commentators suggested that other factors also make this approach inappropriate, these are outlined below:

- The lack of a definitive evidence base to use when setting and justifying specific criteria.
- Focussing on a single parameter e.g. recycled content, may lead to sub-optimal environmental results. For example packaging with an increased recycled content may be less robust so more may be required to protect the goods whilst in transit.
- A fixed parameter value does not allow a flexible approach to the issue and may mean few suppliers can satisfy the requirement(s).

Consequently a packaging criterion was finally not included in the GPP specification. However, an explanatory note highlighting relevant issues that contracting authorities may wish to consider are included. Contracting authorities can determine for themselves the importance they wish to place on packaging and the particular issues that are relevant to them depending on their existing policies and practices.

Where a contracting authority views packaging as a significant issue, the issues they may wish to consider include;

- Primary, Secondary and Tertiary Packaging (see below)
- Life cycle impact
- Material Minimisation
- Weight
- Use of renewable raw materials e.g. bio-based products
- Recycled content

- Packaging take back
- Use of recyclable materials
- Market availability

Definitions for packaging and specific types of packaging, including primary, secondary and tertiary are included in Article 3 of Directive 94/62/EC on packaging and packaging waste. These are summarised below for information:

- 'packaging` shall mean all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer. 'Non-returnable` items used for the same purposes shall also be considered to constitute packaging.

'Packaging` consists only of:

- sales packaging or primary packaging, i.e. packaging conceived so as to constitute a sales unit to the final user or consumer at the point of purchase;
- grouped packaging or secondary packaging, i.e. packaging conceived so as to constitute at the point of purchase a grouping of a certain number of sales units whether the latter is sold as such to the final user or consumer or whether it serves only as a means to replenish the shelves at the point of sale; it can be removed from the product without affecting its characteristics;
- transport packaging or tertiary packaging, i.e. packaging conceived so as to facilitate handling and transport of a number of sales units or grouped packagings in order to prevent physical handling and transport damage. Transport packaging does not include road, rail, ship and air containers;

5.6.2 Consumer information/User instructions

Due to the fact that energy saving is to a large extent dependent on the user behaviour, appropriate consumer information and installation, maintenance and use instruction should be included with the product:

The following issues could be proposed to appear on the packaging or a leaflet attached to the product:

- correct installation instruction,
- correct operation instruction,
- information concerning appropriate disposal at end-of-life,
- information on appropriate dimensions of heating systems for different building characteristics/size.

The stakeholders are encouraged to propose other issues, which should, in their opinion, be covered by consumer information/user instructions.

5.6.3 Information appearing on the Ecolabel

The ecolabel placed on the packaging shall contain information on the advantages related to the purchase and use of the ecolabelled products. The following text is proposed to be placed on the packaging (to be discussed).

The stakeholders are encouraged to comment on the appropriateness of this area, and on relevant issues that should be covered under a possible information provision criteria as part of the Ecolabel.

5.6.4 Summary points for further discussion

The life-cycle analysis in this study does not indicate an overall favourable technology. Each boiler type has its specific advantages and drawbacks, depending on which impact category is considered. Because each heating technology entails different magnitudes of environmental impacts in different impact areas, this study concludes that it is important to compare the different technologies horizontally. The discussion at the 1st workshop will serve to further develop proposals on how to set the Ecolabel criteria that will lead to the award of the label to about 15-20% of hydronic central heating products in the market, taken together as a product group.

From the literature review and information available from product policy schemes in the area of heating systems, it can be concluded that two of the most important criteria area are related to energy efficiency, and greenhouse gas (GHG) emission reductions. Following for example the structure of currently available Ecolabel and GPP criteria, there could be two set of criteria: **mandatory/core criteria** and **optional/comprehensive criteria** (with a requirement to meet a certain number of points by excellent environmental performance in a choice of impact areas). Therefore, a possible development of common benchmark Ecolabel and GPP criteria could be based on mandatory/core criteria requiring minimum performance criteria on the most important environmental impacts, to be discussed with the support of the working group, and optional/comprehensive criteria where points can be earned by excellent environmental performance in the areas of choice depending on the specific heating technology.

The conclusions from the life-cycle analysis (Chapter 3) can be useful to understand how the different technologies perform in different impact areas. Some of the examples are highlighted below to serve as basis for further discussion at the workshop.

- For gas/oil boilers, improvements in the technology in order to earn an Ecolabel would need to strongly focus on energy efficiency (which at the same time would lead to reduced GHG emissions).
- Biomass boilers will easily meet the requirements on greenhouse gas emissions, since they have the lowest climate change impact according to the life-cycle analysis. However, for a biomass boiler to earn an Ecolabel, improvements in the technology would need to focus especially on reducing harmful emissions from combustion (reduce waste, acidification, VOC, POP, HM, PAH and PM).
- For electric heat pumps improving energy efficiency would be the most effective, which will also lead to reduced GHG emissions related to the electricity consumption. The Global Warming Potential of the refrigerant was also identified as an issue associated to GHG emissions from heat pumps.
- For cogeneration boilers, improving energy efficiency (and material composition) would reduce most impacts.

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7. UNIT CONVERSIONS

- Energy consumption data are given in terms of Total Gross Energy Requirement (GER), i.e. primary energy, in MJ (Mega Joules) primary.
- The combustion value of fuels used is measured in MJ (Mega Joules).
- 1 kW-h electricity (useful) is equivalent to 2.5 kW-h primary energy used. This conversion assumes a 40% overall efficiency in the European electricity generation.
- Energy consumption is indicated as PJ of primary energy consumption in 2005. "Primary energy" means energy contained in fossil fuels and renewable energy sources that has not been subject to any conversion or transformation process.
- mega (M) = 10^6; giga (G) = 10^9; tera (T) = 10^{12}; peta (P) = 10^{15}; exa (E) = 10^{18}
- One tonne of oil equivalent (toe) is a unit of energy corresponding to the amount of energy released by burning one tonne of crude oil, approximately 42 GJ = 4.2 x 10^{10} Joules
- One million tonne of oil equivalent (Mtoe) is the amount of energy released by burning one million tonnes of crude oil, that is, 42 PJ = 4.2 x 10^{16} Joules
- The global warming potential (GWP) of a substance is a measure of its negative impact on the climate. The GWP values are related to CO_2 as a reference substance and a time horizon of 100 years.
- 1 GJ = 277,78 kWh