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Lot 15

Solid fuel small combustion installations

Task 5: Base Cases

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POLITECHNIKA ŚLĄSKA

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5. Task 5 – Definition of Base case

This task provides an assessment of the average EU solid fuel SCIs, also known as the "base cases" (or BCs). A 'BC' is "a conscious abstraction of reality" used to represent a range of products on the market in a life cycle analysis.

Life cycle analysis

In principle, the aim of a base-case assessment is to quantify the environmental impacts of a service or product throughout its life. This includes from the extraction of the materials contained within its components, to the disposal of these materials at the end-of-life. The method used to develop these impacts is life cycle analysis (LCA).

First, all incoming and outgoing flows of materials and energy are detailed for each step of the life cycle (manufacturing and design, transport, use, end-of-life). Figure 5-1 shows an example of how materials and energy flows are summarised for a simplified life cycle analysis.

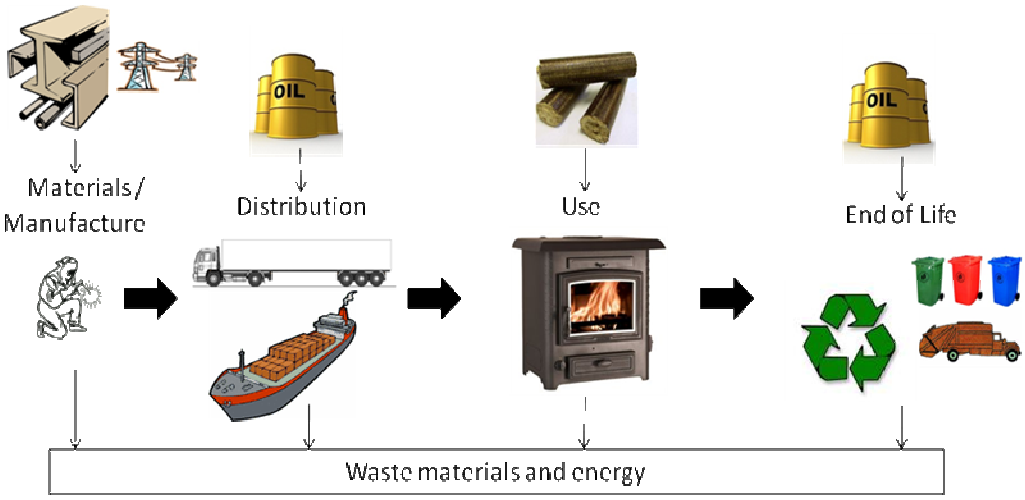

Figure 5-1: Simplified material flow diagram for life cycle analysis

These material and energy flows are then aggregated over the life time of the product to compute total environmental impacts. These environmental impacts can be expressed in many different ways, but are expressed in this study with 17 environmental indicators that were predefined for all Eco-design studies. These indicators will be described in more detail later in the report. As the results are presented through several indicators of environmental impact, the LCA is a multi-criteria approach.

The benefit of the LCA approach is that one can understand all the resources consumed, as well as all the environmental side effects caused by a product. The drawback of this approach is that each product on a market has a different life cycle and it can be difficult to determine the net environmental impact of an entire market or of a range of product groups. To help overcome this problem, BCs are created to represent a theoretical approximation of the 'average' products on the EU market and use these to extrapolate the environmental impacts of the entire market of solid fuel SCIs.

Figure 5-2 below shows a specific example of the life cycle material flows for the wood fuel supply chain.

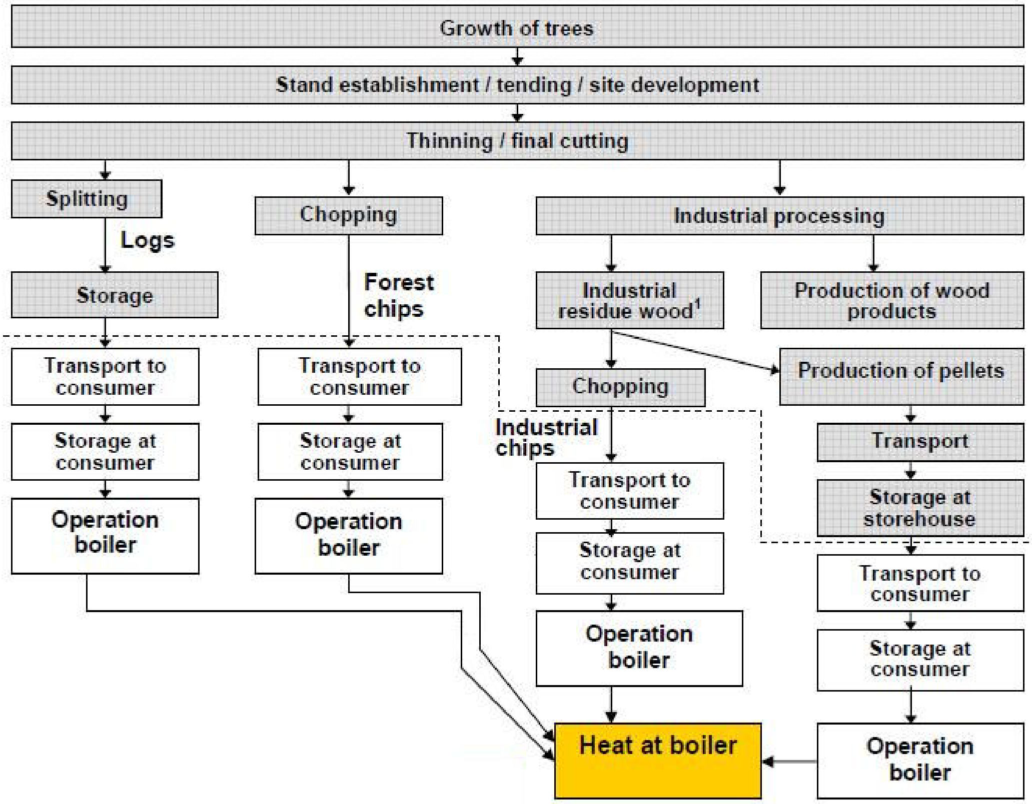

Figure 5-2: An example of the processes considered for the wood fuel supply chain for wood heat at boiler[1]

While this study has been completed as comprehensively and accurately as possible, it relies on data which has been extrapolated from the literature. The performance (notably emissions and efficiency) of real appliances can vary substantially from the data provided in this report. This is understood and mitigated to an extent as much as possible while manipulating and calculating the data during the analysis, however rough approximations are ultimately unavoidable. The results of the study nevertheless are valuable as they represent the best indication to date of the environmental impacts of the small solid fuel combustion installations in Europe.

The description of the BCs is the synthesis of the results of Tasks 1 to 4. Most of the environmental and life cycle cost analyses are built on these BCs throughout the rest of the study and it serves as the point-of-reference for Task 6 (technical analysis of BAT), Task 7 (improvement potential), and Task 8 (policy, impact and sensitivity analysis).

[1] Villigen and Uster, Life cycle inventories of energy systems: results for current systems in Switzerland and other UCTE countries, 2007

5.1. OVERVIEW OF BASE CASES

5.1.1. CRITERIA FOR DEFINING BASE CASES

According to the MEEUP methodology, the BCs should meet three criteria:

- Significant market share (typically >200 000 appliances placed on the market)
- Significant environmental impact
- Significant improvement potential

The reason for these criteria is that implementing measures should target appliances which are widespread in the EU market, cause substantial damage to the environment, and their performance can be improved. An appliance that does not meet any one of these three criteria provides little opportunity for policy action, and therefore is not considered as a BC.

For further justification of the criteria for selecting base cases, please refer to the MEEuP methodology[2]. It is out of the scope of this study to reflect further upon how and why base cases should be chosen.

The determination of the BCs is based on a rigorous assessment of each appliance category against the three MEEuP criteria. As can be seen in Table 5-1, the categorisation of solid fuel SCIs becomes more refined in each task, as technical criteria become more important (Task 4). The BCs are therefore determined on the basis of appliance categories defined in Task 4, and assessed against the results of Task 2 and expert opinion for the market criteria (see Table 5-39 in Annexes), and against the results of Task 4 and expert opinion for the other two criteria (Table 5-1). Only when all three criteria are met can a product be considered a BC. Moreover, as mentioned previously, BCs are not necessarily representative of real products. When two products have a similar bill of materials, technology and efficiency, they may be represented by a single BC.

Although the MEEuP methodology foresees one or two BCs to cover the entire EU market for the products considered in each preparatory study, in this study twelve BCs emerged. Such a high number of BCs is necessary to appropriately cover the broad range of technical specifications and functionalities of solid fuel SCIs. Based on the market estimates obtained in Task 2 of this study, the BCs chosen here represent approximately 77% of the total stock of appliances. This moderate representativeness is due to the range of solid fuel SCIs that differ widely in function and use. Nevertheless, a balance must be found between volume of data analysis and thorough market representation.

[2] (MEEuP – Methodology Study Eco-design of Energy Using Products), Kemna, R. et. al. (VHK) for DG ENTR of the European Commission, MEEuP Methodology Final Report, 2005, accessible at ec.europa.eu/enterprise/eco_design/finalreport1.pdf

Table 5-1: Criteria for consideration as a BC under the Eco-design Directive met by solid fuel SCIs

Task 1	Task 2 & Task 3	Task 4	Task 5 Base Case
Fireplace	Open fireplace	Open fireplace	BC1
	Insert / closed fireplace	Insert	BC2
		Insert + II^{ary} *air	BC2
		Closed fireplace	BC2
		Closed fireplace + II^{ary} air	BC2
Stoves	Room heater stove	Traditional stove	BC3/4
		Modern stove	BC3/4
		Continuous burning stove	
		Advanced stove	
	Slow heat release	Kachelofen	BC6
		Slow heat release stove	BC6
	Pellet	Pellet stove	BC7
Cooker	Cooker	Traditional cooker	BC5
		Advanced cooker	
Boilers <50 kW	Hand fuelled	Conventional, overfeed	BC8
		Conventional, I^{ary} air control, natural, overfire	BC8
		Conventional, II^{ary} air control, forced, overfire	
		Conventional, II^{ary} air control, forced, upperfire	
		Advanced, gravity fed, natural, underfire	
		Advanced, gravity fed, forced, underfire	
		Downdraught (gasifying), underfire, forced	BC9
	Automatically fuelled	Stoker, upperfire, forced	BC10
		Push-down, upperfire, forced	BC10
		Pellet, upperfire, forced	
Boilers 50-500 kW	Hand fuelled	Advanced, gravity fed, underfire, natural	
		Advanced, gravity feed, upperfire, forced	
		Conventional, II^{ary}, upperfire, forced	
		Downdraught (gasifying), underfire, forced	
	Automatically fuelled	Stoker, underfeed, forced	
		Pellet boiler, upperfire, forced	BC11
		Moving grate, overfeed stoker, forced	BC12
		Underfeed rotating grate, forced	

5.1.2. DESCRIPTION OF BASE CASES

The direct heating BCs for the study are summarised below:

Table 5-2: Overview and description of direct heating base cases

NAME	Base Case	Description of products represented	Fuel	Power [kW]	Test Standard Efficiency [NCV %]	Estimated Real Life Efficiency [NCV %]	Applicable Standard
OPEN FIREPLACE	BC 1	Inset direct heating appliances, <15 kW power output, unenclosed firebed, mostly masonry material, manual fuel feeding, no boiler function	Wood	9	30	25	EN 13229
CLOSED FIREPLACE, INSERT	BC 2	Inset direct heating appliances with fully enclosed combustion zones, <15 kW power output, efficiency between 50-85%, mostly ferrous material, manual fuel feeding, no boiler function	Wood	8	70	65	EN 13229
WOOD STOVE	BC 3	Freestanding direct heating appliances <15 kW power output, efficiency between 50-85%, enclosed firebed, mostly ferrous material, manual fuel feeding, no boiler function	Wood	7	70	65	EN 13240
COAL STOVE	BC 4	Freestanding direct heating appliances <15 kW power output, efficiency between 50-85%, enclosed firebed, mostly ferrous material, manual fuel feeding, no boiler function	Hard Coal	7	70	65	EN 13240
COOKER	BC 5	Freestanding direct heating appliances <15 kW power output with cooking function, efficiency between 45-85%, enclosed firebed, mostly ferrous material, manual fuel feeding, no boiler function	Wood	9	65	60	EN 12815
SHR STOVE	BC 6	Direct heating appliances , <30 kW flame power output (<6 kW output from thermal mass - long duration), efficiency between 70-85%, enclosed firebed, mostly ceramics and masonry material, manual fuel feeding	Wood	15 (3 kW- long duration)	80	75	EN 15250
PELLET STOVE	BC 7	Freestanding direct heating appliances, <15 kW power output, efficiency between 75-95%, enclosed firebed, mostly ferrous material, automatic fuel feeding, no boiler function	Pellets	9	88	83	EN 14785

The indirect heating BCs for the study are summarised below:

Table 5-3: Overview and description of indirect heating base cases

NAME	Base Case	Description of products represented	Fuel	Power [kW]	Test Standard Efficiency [NCV %]	Estimated Real Life Efficiency [NCV %]	Applicable Standard
DOM. CONV. BOILER	BC 8	Indirect heating appliances, efficiency between 47-75%, natural draught, upperfire technology, mostly ferrous materials, natural draft, manual fuel batch feeding, no modulation	Wood	18	66	50	EN 303-5
DOM. DD. GAS. BOILER	BC 9	Indirect heating appliances, gasifying downburning technology efficiency between 75-90%, mostly ferrous materials, forced draft, fuel 'semi automatic' gravity feed, modulation: 100-50%	Wood	20	88	66	EN 303-5
RETORT COAL BOILER	BC 10	Indirect heating appliances, efficiency between 75-90%, mostly ferrous materials, forced draft, retort auto fuel feeding, modulation: 100-30%	Hard Coal	25	82	64	EN 303-5
PELLET BOILER	BC 11	Indirect heating appliances, efficiency between 75-90%, mostly ferrous materials, forced or natural draft, auto fuel feeding, modulation: 100-30%	Pellets	25	88	69	EN 303-5
NON-DOMESTIC CHIP BOILER	BC 12	Indirect heating appliances, <500kW power output, efficiency between 75-90%, mostly ferrous materials, forced or natural draft, auto fuel feeing, modulation: 100-20%	Chips	160	88	70	EN 303-5

→ **GENERAL CHARACTERISTICS COMMON TO ALL BCS**

Power and Efficiency

The power and efficiency values have been chosen in an attempt to represent the products most sold for each product category.

- The power output and the efficiency (both test standard and real-life) of the base cases was determined by a mixture of expert opinion, stakeholder feedback, literature and market brochure reviews as well as data compiled in Task 4. Market brochures are not technical literature but provide insight as to what the public and industry might expect.

The way in which the power and test standard efficiency of the product cases were estimated may lead to an overestimation of the performance of EU appliances. Indeed, the data used were largely based on test standard data. This is necessary to ensure equitable comparisons between products.

To overcome the overestimation of the performance of the appliances in the market when determining the net environmental impacts for the EU over the lifetime of the products, a 'Real Life Efficiency' or 'Seasonal Efficiency' has also been estimated for each base case and has been labelled the 'real-life' efficiency. This efficiency represents the actual, real life performance of the product over its lifetime and will be used to estimate the environmental impacts of each BC.

Both measures of efficiency must be used here. Test standard efficiency allows for repeatable, comparable and measurable data to which tangible progress could be foreseen while real-life efficiency allows for a more accurate representation of the real environmental impacts of the products. The real-life efficiency of direct heating products is an entirely different phenomenon than the real-life efficiency (or seasonal efficiency) of indirect heating products, and as such they have been developed in entirely different manners:

- The real-life efficiency of direct heating appliances, especially those batch fed, accounts for two operational characteristics not addressed in test standards: real-life consumer misuse and part load operation. Misuse would include, for example, using fuels with high moisture content, improper arrangement of fuel, improper air control settings and long duration of smouldering fires. By including part load operation an attempt to incorporate less than ideal operation of the appliance associated with reductions in efficiency of either over-heating a room (and therefore wasting heat) or running an appliance at less than nominal efficiency with air restriction controls. The values of expert opinion and literature have not shown a high degree of consensus, and therefore are still subject to further refinement and clarification.

  It must be noted that there is no acknowledged or scientifically approved method to determine the real-life efficiency of direct heating appliances. Also stakeholders have noted it is questionable to define a real efficiency for direct appliances, as direct heating appliances produce heat that is immediately available and radiated to the room where the appliance is installed, i.e. it is produced in the same place and at the same time when it is needed. There are no distribution or storage losses.

It has been mentioned during stakeholder consultations that it is industry's experience that part load may even cause an increase in efficiency, due to the lowering of the chimney temperature that compensates for the increased air ratio during combustion. The consortium and technical experts involved in the study acknowledge this possability.

Nevertheless, for the purposes of this study, real-life efficiency must be addressed and has been represented here as a 5% reduction in the test standard efficiency for all direct heating appliances. This is to represent 2.5% for consumer misuse and 2.5% for part load reduction in efficiency. This method is proposed as a first step towards addressing the fact that real-life efficiency is different from test standard efficiency, yet the extent to which it differs is difficult and complex to quantify. It is similar in approach to the estimation method proposed by the UK government's standard assessment procedure for the energy rating of dwellings when a seasonal efficiency is not available for an appliance[3], though it is acknowledged that this procedure was developed for appliances with boiler functions.

It should be noted that this method should not be translated or used for purposes other than estimating the life cycle environmental impacts of these appliances. It was created to this end and should only be used as such.

- The real-life efficiency is used to describe the efficiency of boilers over the entire heating season to help quantify the overall efficiency of the central heating system. Factors affecting this efficiency are most importantly the variations of boiler efficiency at different loads and different hydronic system operating temperatures. These are typically characterised through several test points in which a boiler's heat generator is tested for efficiency, normally at full load with 80/60 water temperature (80°C delivery, 60°C return), partial load 80/60, full load 50/30 and partial load 50/30, however these are unavailable in the case of most solid fuel boilers, especially batch appliances which may not be capable of operation at part load. Several variations of test point sets are used to characterise a boiler's performance in the industry. The performance of the hydronic system including radiator efficiency and the heat-up and cool-down transient periods inherent to boiler cycling during moderate heating periods are also important parameters affecting the seasonal efficiency.

For the Lot 15 boilers, the ECOBOILER tool was used to estimate the seasonal efficiency of the boiler base cases. The ECOBOILER tool was developed as part of the EuP Lot 1 preparatory study on central heating boilers. It is currently under development and is likely to form part of a labelling scheme which is proposed for oil and gas boilers in Europe. It is important that the Lot 15 boilers remain consistent with any implementing measures which occur as a result of the Lot 1 study, hence the ECOBOILER tool has been

[3] The Government's Standard Assessment Procedure for Energy Rating of Dwellings rev. 3, Published on behalf of DECC by BRE, Garston, Watford, 2005

adopted in this study. In the absence of variations in efficiency over the multiple test points required, this study has assumed the following for the indirect base cases (Table 5-4).

Table 5-4: Assumptions used to determine real life efficiency of boilers

Base case	Description	Nominal Load Efficiency [%NCV]	Maximum Turndown [%]	System Buffer	Night Setback	Real-Life (Seasonal) Efficiency - Bin method calculation [%NCV]
BC 8	DOM. CONV. BOILER	66	-	Yes	No	50
BC 9	DOM. DD. GAS. BOILER	88	50	Yes	No	66
BC 10	RETORT COAL BOILER	82	30	Yes	Yes	64
BC 11	PELLET BOILER	88	30	Yes	Yes	69
BC 12	NON-DOM. CHIP BOILER	88	20	Yes	Yes	70

Materials

A complete description of the materials of the BCs is given below, for the purpose of performing a base-case assessment. To this end, estimates from previous tasks on the average EU lifetime and energy use of each appliance, as well as on bill of materials (BOM) are summarised for each BC.

According to the MEEuP, some parameters are common to all BCs:

- Each type of material is associated to a default factory process (e.g. rolling for steel coil or sheet). Therefore, no distinction is made between the impacts of the materials used and the impacts of their processing at plant. This is why only the total impact of production is presented (the columns "Materials" and "Manufacturing" are empty).
- No materials are assumed to be used for the distribution of the SCIs. Indeed, most appliances are transported on wood pallets, which are assumed to be re-used indefinitely. The cardboard packaging is also assumed to be negligible in comparison to the total weight of the appliances.
- Besides the fuel, no other consumable materials are assumed to be used during the use of solid fuel SCIs. The fuel used for SCI is included as a nested LCA for the energy use of the appliance.

As a result, the materials summary obtained for each BC after inputting the BOM data into the Ecoreport tool (developed for the MEEuP) comprises summary information on the total production of materials and the end-of-life disposal methods, but not on the distribution or use phases.

As not every possible type of material is available for use in Ecoreport, simplifications have been made for material types not represented. Close approximations of similar materials with similar environmental impacts have been used to represent materials not available in Ecoreport. The materials used to represent the BOMs of each base case are shown in Table 5-5.

Table 5-5: Materials used in Ecoreport to represent BOMs of base cases

BOM Material	Ecoreport Material Group	Ecoreport Material
All Plastics	1-BlkPlastics	1-LDPE
All grades of steel sheets, tubes, framing and fasteners	3-Ferro	21-St sheet galv.
All grades of cast iron plates, tubes, framing and fasteners	3-Ferro	23-Cast iron
All non ferrous metal components	4-Non-ferro	30-Cu tube/sheet
All coatings on steel (not including zinc)	5-Coating	39-powder coating
All electronics, circuitry and wiring	6-Electronics	98-controller board
Ceramic, rock, and masonry, both for aesthetics and thermal mass	7-Misc.	85-Refractory Ceramics
All glass	7-Misc.	54-Glass for lamps

The associated life cycle impacts per kg of each material in the table above is shown in the Annex in Table 5-40.

The aggregated BOMs (Table 5-6 to Table 5-14), lifetime and energy use for each BC are detailed below for each BC.

➔ DIRECT HEATING APPLIANCES

BC1 – Open fireplace

Appliances represented include those that have natural draft air supply and have no primary or secondary air control mechanisms. Heat transfer is through direct means, mostly through direct radiant energy from the flames. Open fireplaces are integrated into the structure of the household and are mostly composed of masonry and ceramic materials which are represented in the bill of materials (BOM) as 'Miscellaneous – refractory ceramics'. One side of the fuel bed and combustion zone is open to the living environment of the household (open fireplaces).

In the EU, the main fuel used in this appliance is wood logs. Fuel-feeding into the combustion zone is manual.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 35 years. (Task 2, Section 2.2.4)
- The annual use of the product is 42 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-6: BC1 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	Unit				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	31 330	1 567	29 764	31 330
4	Non-ferro	g	0	0	0	0
5	Coating	g	0	0	0	0
6	Electronics	g	0	0	0	0
7	Misc.	g	271 000	13 550	257 450	271 000
	Total weight	**g**	302 330	15 117	287 214	302 330

- **BC2 – Closed fireplace / insert**

BC2 is defined as a combination of a closed fireplace and a fireplace insert appliance applicable under EN 13229. The EN standard has been used to help define the base case so that any environmental impact estimates and associated regulations resulting from this study are in line with existing product testing and measurement standards.

Appliances represented include closed fireplaces that use natural draft and may have primary or secondary air control mechanisms. Heat transfer is through direct means through radiation and natural draught convection from the hot surfaces of the appliances. The appliance is composed of iron, steel and masonry ceramics. The fuel bed and combustion zone are completely enclosed and may be visible from the exterior of the appliance through windows on the door. Fuel-feeding into the combustion zone is manual.

In the EU, the main fuels used in this appliance are wood logs. Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 20 years. (Task 2, Section 2.2.4)
- The annual use of the product is 266 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime.

Table 5-7: BC2 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	unit				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	135 900	6 795	129 105	135 900
4	Non-ferro	g	0	0	0	0
5	Coating	g	500	25	475	500
6	Electronics	g	100	100	0	100
7	Misc.	g	30 600	1 530	29 070	30 600
	Total weight	**g**	167 100	8 450	158 650	167 100

- **BC3 – Wood stoves**

Traditional stoves use natural draft and have no secondary air control mechanism, while modern stoves typically include secondary air control. This base case is a sales weighted mix of modern stoves and traditional stoves. Heat transfer is through direct means of natural draught convection from the hot surfaces of the appliances. The appliance is freestanding and is mainly composed of iron and steel. The fuel bed and combustion zone are completely enclosed and may be visible from the exterior of the appliance through windows on the door. Fuel-feeding into the combustion zone is manual.

BC4 is defined as a (modern) stove with a nominal heat output capacity equal to 7 kW and an efficiency of 70% based on net calorific value. In the EU, the main fuels used in this appliance are wood logs and lignite briquettes.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 27.5 years. (Task 2, Section 2.2.4)
- The annual use of the product is 337 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-8: BC3 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	**unit**				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	152 500	7 625	144 875	152 500
4	Non-ferro	g	0	0	0	0
5	Coating	g	200	10	190	200
6	Electronics	g	0	0	0	0
7	Misc.	g	8 000	400	7 600	8 000
	Total weight	**g**	160 700	8 035	152 665	160 700

BC4 – Coal stoves

Coal stoves are similar to wood stoves in appearance and function, however the environmental impacts associated with combustion of mineral fuels are significantly different and hence justify a new base case. Nevertheless, the materials, hours of use and product lifetime can be assumed to be the same for the purposes of this study and therefore in this section, refer to BC3 – Wood stoves for further information regarding base case LCA assumptions.

BC5 –Cookers

Appliances represented here include those that use natural draft, and may have primary or secondary air control. Heat transfer is through direct means to cooking surfaces through conduction and to the household space through convection of the hot surfaces of the appliances and radiation. The appliance is freestanding and is composed of mostly iron and steel; this is represented in the BOM as 'Ferro – cast iron' and 'Ferro – steel'. The fuel bed and combustion zone are completely enclosed and not visible from the exterior of the appliance. Fuel-feeding into the combustion zone is manual.

In the EU, the main fuels used in this appliance are wood logs and hard coals. Fuel feeding into the combustion zone is manual.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 20 years. (Task 2, Section 2.2.4)
- The annual use of the product is 112 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-9: BC5 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	**unit**				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	140 800	7 040	133 760	140 800
4	Non-ferro	g	0	0	0	0
5	Coating	g	500	25	475	500
6	Electronics	g	0	0	0	0
7	Misc.	g	22 600	1 130	21 470	22 600
	Total weight	**g**	163 900	8 195	155 705	163 900

BC6 – Slow heat release stoves

Appliances represented here include slow heat release stoves and kachelofens that use natural draft. Heat transfer is through direct means through radiation and natural draught convection from the hot surfaces of the appliances including from the large thermal mass which characterises these appliances. The appliance is composed of mostly ceramics and masonry material which are the reason for the large thermal mass. The fuel bed and combustion zone are completely enclosed and may be visible from the exterior of the appliance through windows on the door. Fuel-feeding into the combustion zone is manual.

In the EU, the main fuels used in this appliance are wood logs.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 27.5 years. (Task 2, Section 2.2.4)
- The annual use of the product is 337 hours (Task 3, Section 3.2.4), equivalent to approx 3000 - 4000 hours of slow heat release.

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-10: BC6 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	**unit**				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	55 700	2 785	52 915	55 700
4	Non-ferro	g	0	0	0	0
5	Coating	g	0	0	0	0
6	Electronics	g	0	0	0	0
7	Misc.	g	1 449 100	72 455	1 376 645	1 449 100
	Total weight	**g**	1 504 800	75 240	1 429 560	1 504 800

- **BC7 – Pellet stoves**

Appliances represented here include pellets stoves that use natural draft and may have primary or secondary air control mechanisms. Heat transfer is through direct means through radiation and natural draught convection from the hot surfaces of the appliances. The appliance is composed of mostly iron and steel. The fuel bed and combustion zone are completely enclosed and may be visible from the exterior of the appliance through windows on the door. Fuel-feeding into the combustion zone is automatic with electronic feed hoppers.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 12.5 years. (Task 2, Section 2.2.4)
- The annual use of the product is 403 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-11: BC7 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	**unit**				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	133 300	6 665	126 635	133 300
4	Non-ferro	g	1 200	60	1 140	1 200
5	Coating	g	600	30	570	600
6	Electronics	g	900	900	0	900
7	Misc.	g	11 500	575	10 925	11 500
	Total weight	**g**	147 500	8 230	139 270	147 500

➔ INDIRECT HEATING APPLIANCES - BOILERS

Heat transfer is indirect through a heat exchanger which transfers the combustion heat to water. The accessory heat transfer system (water piping) is not included within the scope of this study and hence does not form part of this BC despite being a necessary component for delivering heat. The appliance is freestanding and is composed of mostly iron and steel; this is represented in the BOM as 'ferro – cast iron' and 'ferro –

steel'. The fuel bed and combustion zone are completely enclosed and typically not visible from the exterior of the appliance.

BC8 – Small domestic boiler: conventional manually fuelled boiler

BC6 is defined as a small domestic boiler. The BC is a boiler using over-fire combustion technology with natural draught, primary air supply and may have secondary air supply.

In the EU, the main fuels used in this appliance are wood logs. Fuel feeding into the combustion zone is manual in batches.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 17.5 years. (Task 2, Section 2.2.4)
- The annual use of the product is 1000 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-12: BC8 - BOM summary

		Life cycle phases	PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	**unit**				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	349 800	17 490	332 310	349 800
4	Non-ferro	g	400	20	380	400
5	Coating	g	400	20	380	400
6	Electronics	g	0	0	0	0
7	Misc.	g	27 400	1 370	26 030	27 400
	Total weight	**g**	378 000	18 900	359 100	378 000

BC9 – Small domestic boiler: downdraught – gasifying boiler

BC7 is defined as a small domestic boiler using downdraught and gasification techniques with forced primary air and forced secondary air supplies.

In the EU, the main fuel used in this appliance is wood logs.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 17.5 years. (Task 2, Section 2.2.4)
- The annual use of the product is 1000 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-13: BC9 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	**unit**				
1	Bulk Plastics	g	500	450	50	500
2	TecPlastics	g	0	0	0	0
3	Ferro	g	457 100	22 855	434 245	457 100
4	Non-ferro	g	6 500	325	6 175	6 500
5	Coating	g	500	25	475	500
6	Electronics	g	3000	3 000	0	3 000
7	Misc.	g	115 000	5 750	109 250	115 000
	Total weight	**g**	582 600	32 405	550 195	582 600

- **BC10 – Small automatic boiler: hard coal retort boiler**

The appliance uses upper fire combustion and forced primary air and secondary air supplies. This BC is a hypothetical mix of appliances with automatic under-feed stoker fuel feeding system and moving grate fuel feeding system. In the EU, the main fuels used in this appliance are hard coals and wood chips.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 20 years. (Task 2, Section 2.2.4)
- The annual use of the product is 1000 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-14: BC10 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	**unit**				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	463 500	23 175	440 325	463 500
4	Non-ferro	g	1 400	70	1 330	1 400
5	Coating	g	0	0	0	0
6	Electronics	g	500	500	0	500
7	Misc.	g	3 800	190	3 610	3 800
	Total weight	**g**	469 200	23 935	445 265	469 200

- **BC11 – Small automatic boiler: pellet boiler**

The appliance uses upper fire combustion and forced primary air and secondary air supplies. In the EU, the main fuels used in this appliance are pellets.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 20 years. (Task 2, Section 2.2.4)
- The annual use of the product is 1000 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-15: BC11 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	unit				
1	Bulk Plastics	g	0	0	0	0
2	TecPlastics	g	0	0	0	0
3	Ferro	g	433 400	21 670	411 730	433 400
4	Non-ferro	g	10 800	540	10 260	10 800
5	Coating	g	2 700	135	2 565	2 700
6	Electronics	g	2 700	2 700	0	2 700
7	Misc.	g	86 700	4 335	82 365	86 700
	Total weight	**g**	536 300	29 380	506 920	536 300

- **BC12 – Non-domestic wood chip boiler**

The appliance uses upper fire combustion and forced primary air and secondary air supplies. This BC is a hypothetical mix of appliances with automatic under-feed stoker fuel feeding system and moving grate fuel feeding system. In the EU, the main fuels used in this appliance are wood chips, however there is a wide variety of other fuels not represented here.

Relevant life cycle assumptions based on the analyses performed in previous tasks are:

- The lifetime of the product is 20 years. (Task 2, Section 2.2.4)
- The annual use of the product is 1000 hours. (Task 3, Section 3.2.4)

The table below summarises the materials used for this BC throughout its lifetime:

Table 5-16: BC12 - BOM summary

	Life cycle phases		PROD.	END-OF-LIFE		
				Disposal	Recycl.	Total
	Materials	unit				
1	Bulk Plastics	g	3 500	3 150	350	3 500
2	TecPlastics	g	0	0	0	0
3	Ferro	g	866 700	43 335	823 365	866 700
4	Non-ferro	g	21 700	1 085	20 615	21 700
5	Coating	g	5 400	270	5 130	5 400
6	Electronics	g	5 400	5 400	0	5 400
7	Misc.	g	173 300	8 665	164 635	173 300
	Total weight	**g**	107 6000	61 905	1 014 095	1 076 000

→ Difference between stock and sales

It is well recognised in the industry of direct heating appliances that there is a significant difference between the appliances being sold today and the appliances being used in the stock. This is a direct result from the steady progress that the industry has been making in environmental efficiency and emissions controls, combined with the long lifetimes of products in this study. Older, less efficient products are still being used and are contributing to a great deal of environmental impacts and emissions in Europe that must be taken into accounted. This could lead to an underestimation of the environmental impacts of the products in this study as the base cases all represent products currently sold on the market. The difference between the sales and stock efficiencies is demonstrated with accurate stock data compiled by the European Committee of Heating and Domestic Cooking Manufacturers (CEFACD) for this study. This information has been included below in **Table 5-17**. Using this information, one can discern how many older appliances are currently in use in the European stock. For example, CEFACD has made a distinction between traditional closed fireplaces and modern closed fireplaces (also for wood stoves). This distinction allows the separation between stock and sales and allows for a more accurate picture of the environmental impacts associated with the stock to be estimated. While this information is useful and important for inclusion in the study, it does not mean that the base cases should be based on this data.

Table 5-17: Direct heating industry (CEFACD) compiled data for old appliances

	η %	Particulate mg/m³	CO mg/m³	OGC mg/m³
Open fireplaces	5 – 40	150 – 5 000	6 000 – 37 500	300 – 1 500
Inset fireplaces	40 – 60	90 – 120 (5 000)	6 000 – 17 500 (37.500)	200 – 500 (1 500)
Closed fireplace	40 – 60	90 – 120 (5 000)	6 000 – 17 500 (37.500)	200 – 500 (1 500)
Slow heat release stove	60 – 75	90 – 150 (5 000)	10 000 – 17 500 (37.500)	250 – 750 (1 500)
Kachelofen	60 – 75	90 – 150 (5 000)	10 000 – 17 500 (37.500)	250 – 750 (1 500)
Traditional cookers	50 – 60	100 – 200 (5 000)	8 000 – 20 000 (37.500)	300 – 900 (1 500)
Cookers with water components	50 – 65	100 – 200 (5 000)	10 000 – 20 000 (37.500)	300 – 900 (1 500)
Continuous burning stoves	50 – 70	90 – 150 (5 000)	10 000 – 17 500 (37.500)	250 – 750 (1 500)
Wood burning stoves	50 – 70	90 – 120 (5 000)	4 000 – 15 000 (37.500)	200 – 500 (1 500)

- A further subdivision for other appliances is not convenient or respectively there is no corresponding data available in Germany.
- For Open Fireplaces data is only estimated, there is no certified data available for all the parameters.
- Notice: different values are to be expected for wood based and for coal based fuels.
- Values up to the parenthesis values were observed sporadically.
- CO above 3% is undeterminable due to measuring range.
- Values of NO_x remained roughly the same as in the past, since there is no thermal NOx formation in these wood fired appliances. The NOx emissions result from the nitrogen in the fuel.
- German requirements state 0.3/0.4 % vol. CO since the beginning of the 80s. In the rest of Europe a PM-range of 100-1000 might be more realistic.

In addition to the information provided by CEFACD, the Austrian Bioenergy Centre provided historical data from tests of biomass boiler appliances over the past 20 years. This historical data has shown consistent improvement of boiler efficiencies, however this is not consistent across each type of boiler.

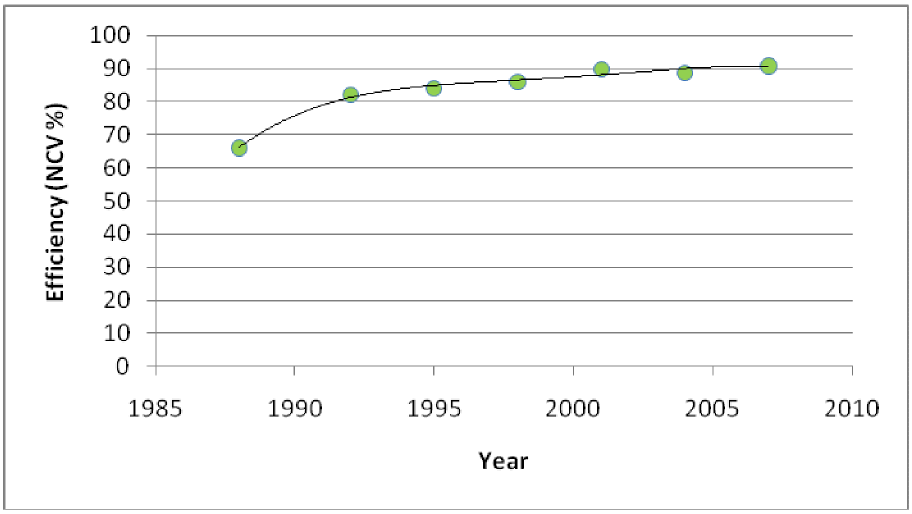

Figure 5-3: Historical efficiency of wood log boilers from the Austrian Bioenergy Centre

This information therefore leads to a preliminary quantification of the efficiencies of the stock of appliances in Europe for Lot 15 products. It is different for each appliance type as it depends both on the amount of 'progress' made in the past years as well as the average life span of the appliances. Based on the information provided, some of the appliances types typical to Lot 15 have sufficient data to estimate the efficiency of the stock and Table 5-18 shows this information.

Table 5-18: The estimated stock test standard efficiency for the base cases

NAME	Base case test standard efficiency	Estimated stock test standard efficiency
	(% NCV)	(% NCV)
OPEN FIREPLACE	30	30
CLOSED FIREPLACE, INSERT	70	54
WOOD STOVE	70	54
COAL STOVE	70	54
DOM. DD. GAS. BOILER	88	80
PELLET BOILER	88	80

It is acknowledged that each emission type from appliances has improved at different rates and this has not been evaluated here. Nevertheless, it is generally accepted that while the efficiency improves, all emissions also tend to be reduced.

5.2. ENVIRONMENTAL IMPACTS FROM FUEL USE

Fuel is of particular importance in the life cycle analysis of solid fuel SCIs. Indeed, solid fuel SCIs burn a large amount of fuel, which is the main sources of pollution of these appliances. Since fuel use is likely to be the most important part of the LCA for solid fuel SCIs, special attention must be given to the environmental impacts of fuels and of their use.

In all preparatory studies in the context of the Eco-design Directive, the LCA is conducted with the Ecoreport tool. The Ecoreport tool was developed to simplify and homogenise the way LCAs are performed in the context of the Eco-design Directive. Any LCA tool is comprised of a series of inventories, for each of the possible components used in the products under study. These inventories quantify the environmental impacts of the use of these components throughout their lifetime. In the Ecoreport tool, this information is summarised in 17 environmental indicators. Compared to standard LCA tools, the Ecoreport tool is based on several assumptions and simplifications to reduce the amount of calculations and data collection normally required in a LCA.

Due to its simplified nature, the Ecoreport tool does not provide inventories for all of the solid fuel types considered in the Lot 15 study. This is because the Ecoreport tool was originally developed for electrical appliances and boilers. As a result, the only solid fuels considered are wood logs and wood chips. Since Ecoreport has neglected the emissions of solid fuels, they must be developed specifically for this study.

The development of environmental inventories for the solid fuels used in solid fuel SCIs was performed according to a strict methodology. The challenge was that the environmental impacts of fuels depend on the appliance in which they were burnt. For example, different BCs will often use the same types of fuel (e.g. wood logs), but will have different emission levels. Therefore, it is necessary to account both for the influence of the fuel and for that of the appliance on the emissions to be able to distinguish the environmental impacts of the different BCs. A four step approach was therefore chosen to solve the problem:

- **Fuel emissions:** estimate the emissions from each solid fuel type in a generic stove appliance.
- **Appliance factor:** determine how the type of appliance affects emission levels, by calculating an 'appliance factor' which is ratio of appliance emissions to stove.
- **Fuel emissions x appliance factor:** estimate the emissions of a specific fuel type in a specific appliance type by multiplying the fuel emissions in a stove by the appliance factor.
- **Real-life efficiency:** multiply the impacts by the ratio of real-life efficiency to test standard efficiency for each appliance.

Figure 5-4 represents this method in a diagram.

Note that the methodology employed here is solely for the purpose of discerning differences between appliances and fuel types, and that it does not represent real emissions of any appliance or fuel type. It is developed for the purpose of analysing the entire market of solid fuel SCIs in an equitable manner and is not representative of any actual appliance performance.

Following this is a description of the information collected and processed during the process to determine the emissions.

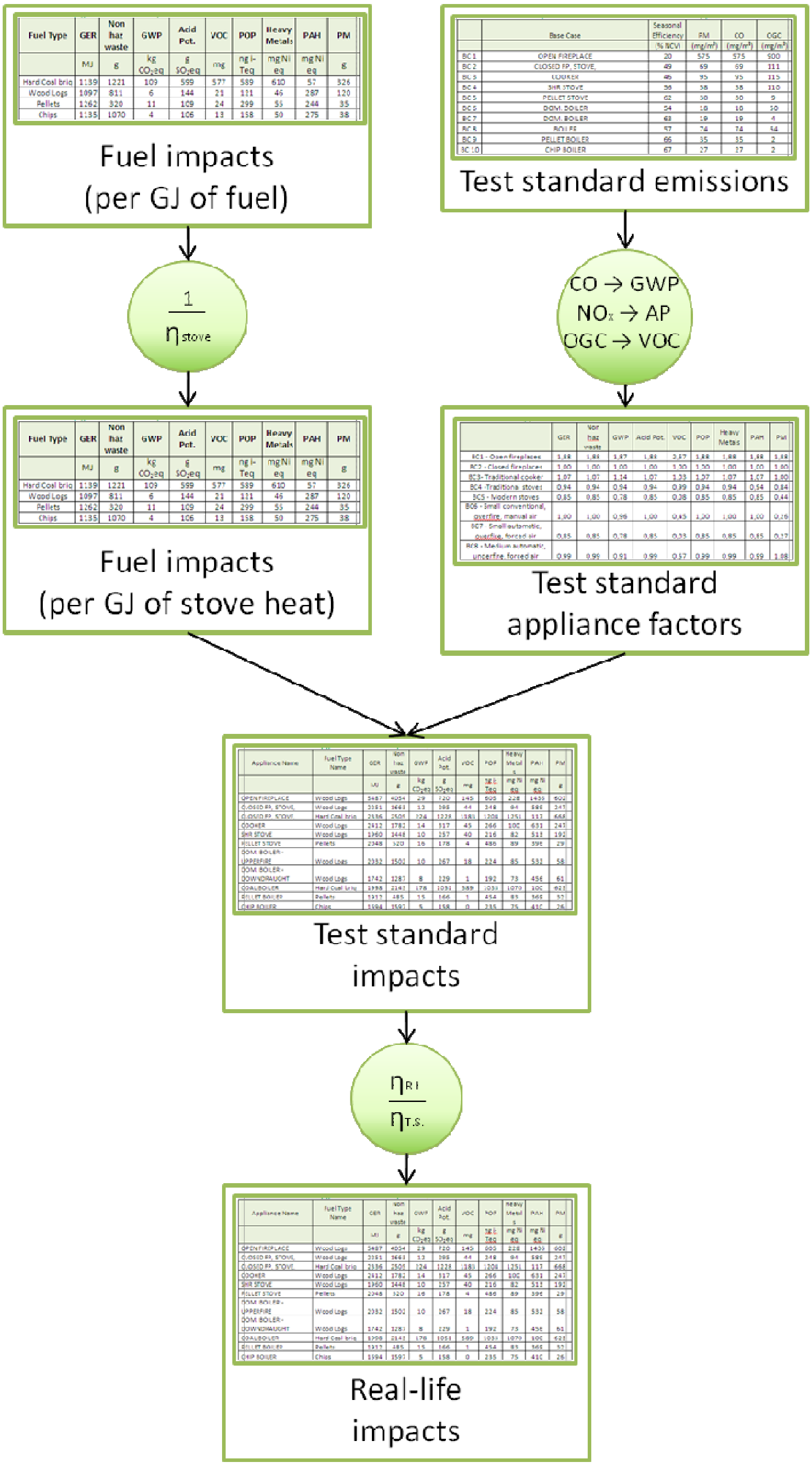

Figure 5-4: Diagram of method to estimate impacts from solid fuel combustion

5.2.1. FUEL IMPACTS

Choice of LCA database

Solid fuel inventories are necessary to be able to determine the impact of solid fuels for nine environmental indicators described below. Several public and private LCA databases were compared so as to determine the one with the most comprehensive and reliable data for the purpose of this study. To date, no satisfying inventories from federations related to the wood or mineral fuel industry could be found. Therefore, the most comprehensive databases available were:

- GEMIS – this database was developed for Germany and Austria, and already used in the MEEuP methodology to estimate the environmental indicators of solid fuels.
- EcoInvent – this is the main LCA database in Europe, and is widely accepted and used by all LCA experts.
- Corinair – this database was elaborated in the context of the national air emission inventories. The emission factors in this database have been determined based on expert opinion for the main domestic appliance and fuel combinations. However, the main limitation from this data source in the context of this study is that it reflects real-life performance rather than standard conditions, which makes it impossible to compare emissions among appliances. Moreover, not all combinations of fuel types and appliances are considered, and only emissions to air are estimated (e.g. not GER).

EcoInvent was chosen over other available life cycle analysis tools (Gemis, Corinair) for two reasons:

- First, EcoInvent has the best representation of fuels applicable to solid fuels SCIs, as it was the largest single information source. Emissions data cannot be cross-referenced or compared between different databases because the testing conditions are not comparable, therefore one single source of data was needed and hence the largest source was most appropriate.
- Second, EcoInvent also provides a detailed network analysis of the processes and products involved in the life cycle of solid fuels. Since solid fuels used in SCIs represent a very specific portion of solid fuels in general, certain aspects of the fuel supply networks were not necessary. The supply chain could be customised to better represent the fuels for solid fuel SCIs.

Environmental indicators in Ecoreport

Seventeen environmental indicators are considered in Ecoreport. Of these, nine are relevant to solid fuel combustion, while others have none to very little impact. The environmental indicators considered for developing fuel inventories are:

- **Gross energy requirement (GER):** the total energy input into the combustion process divided by the energy released by the fuel during combustion. This includes energy spent on processing, manufacturing and transporting the fuel. This does not include energy spent on manufacturing or transporting the appliance. Given in [MJ] per [GJ of useful heat delivered].

- **Non-hazardous waste (Non-haz waste)**: solid waste resulting from the combustion process. Assumed to be entirely composed of the ash resulting from combustion in this methodology. Given in [g] per [GJ of useful heat delivered].
- **Global warming potential (GWP)**: a combination of greenhouse gases resulting from combustion, with weighting factors as described in the MEEuP methodology. Accordingly, biomass derived fuels have a CO_2 weighting of 0 by political default, while CO and CH_4 emitted by biomass fuels have weighing factors as specified in the MEEuP methodology. Given in [g of CO2 equivalent] per [GJ of useful heat delivered].
- **Acidification potential (Acid. Pot.)**: a combination of acid gases resulting from combustion, with weighting factors as described in the MEEuP methodology. Given in [g of SO2 equivalent] per [GJ of useful heat delivered].
- **Volatile organic compounds (VOC)**: a combination of volatile organic compounds resulting from combustion, with weighting factors as described in the MEEuP methodology. Given in [g] per [GJ of useful heat delivered].
- **Persistent organic pollutants (POP)**: toxic pollutants which tend to bio-accumulate. This category typically includes a range of pollutants such as pesticides not relevant to this study, but it is relevant here due to dioxins and furans. Weighting factors are as described in the MEEuP methodology. Given in [ng Teq[4]. TCDD] per [GJ of useful heat delivered].
- **Heavy Metals (Hvy Mtl)**: a series of specific toxic heavy metals released during the combustion process with weighting factors as described. Given in [mg of Ni equivalent] per [GJ of useful heat delivered].
- **Polycyclic aromatic hydrocarbons (PAH)**: specific toxic aromatic hydrocarbons, with weighting factors as described in the MEEuP methodology. Given in [mg of Ni equivalent] per [GJ of useful heat delivered].
- **Total particulate matter (PM tot)** Dust and other particulate matter released during combustion. Given in [g] per [GJ of useful heat delivered].

The rest of the environmental indicators included in the MEEuP methodology are considered null, since they were not considered relevant for solid fuels. Hence no inventory was developed to estimate those indicators. The indicators not considered for solid fuels are listed below with a justification for their exclusion:

- **Electricity energy requirement**: the total electrical energy input into the combustion process. This is applicable for some boilers and pellet stoves which use electrically driven components to sustain the combustion and is accounted for in the use phase section of Ecoreport and is therefore not required as part of the fuel emissions.
- **Feedstock energy**: this factor was included in the MEEuP methodology for recovering energy in plastics and is not applicable to solid fuel combustion.

[4] Toxic Equivalent

- **Cooling water**: there is typically no cooling water rejected to the environment for solid fuel SCIs because most solid fuel SCIs do not have water-based cooling systems.
- **Process water**: while water in boiler heating hydronic circuits could be considered process water, the amount of rejection from these cycles per GJ of heat delivered is expected to be negligible.
- **Hazardous waste**: the Eco-design Directive concerned itself with restrictions on hazardous substance (RoHS) emissions before 2006. Since these substances are prohibited since 2006, the MEEuP methodology describes the specific cases of applicable hazardous substances which are still applicable to the Eco-design Directive. None of the cases defined in the MEEuP methodology are applicable to solid fuel SCIs (Final MEEuP Methodology Report, Sec 3.14.1[5]). Based on preliminary analysis, the concentration of RoHS substances (heavy metals in ash) are more than six orders of magnitude below the RoHS thresholds and thus considered negligible in this study.
- **Heavy metals to water**: emissions of heavy metals from solid fuel SCI combustion processes to water were estimated to be negligible. All heavy metal emissions were assumed to be released to air or to ash (in a negligible concentration to ash and in a relatively stable and inert state).
- **Eutrophication potential**: inadvertent release of nutrient chemicals to local bodies of water is expected to be negligible from the combustion process of solid fuel SCIs.
- **Ozone depletion potential**: emission of ozone depletion potential chemicals was estimated to be on the order of 10^{-7} g per GJ of heat, hence they were neglected.

Fuel inventories

The data was extracted from the LCA tool “EcoInvent”[6] for the nine environmental indicators described above. The EcoInvent data was filtered such that only the specific chemical emissions relevant for the environmental indicators are included. The environmental weighting factors for different chemicals are applied based on the descriptions given in the MEEuP methodology. The supply chain modelled in EcoInvent is shown in Figure 5-2 for wood fuel types.

The EcoInvent fuels are all roughly based on combustion in conditions similar to a stove (stove, wood-heater or furnace). The word ‘generic’ is used here to describe the combustion of a fuel in an appliance similar to a stove. The emissions from this combustion will then be multiplied by appliance specific factors (based on DIN+ or EN 305-5 type testing results) described in Section 5.2.2.

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[5] http://ec.europa.eu/energy/demand/legislation/doc/2005_11_28_finalreport1_en.pdf

[6] EcoInvent – Simapro v 7.1.6, program copyrighted by PRé Consultants 2008, Netherlands

The generic appliance fuel emissions are calculated for the following fuel types[7]:

- **Fuel type 1 (FT1) – Hard coal briquettes**

This describes the combustion process and includes coal transport and ash disposal. The stove is assumed to fire hard coal briquettes. The heating value (31.4 MJ/kg) and the composition of the briquettes are average values available from the literature. The emission data are also taken from literature reporting measurements. Size distribution of particles has been estimated on the basis of recent information from EPA. Emissions of trace elements were calculated using the ash content in the coal and average transfer coefficients for coal power plants with ash retention of 98 %, as first approximation.

- **Fuel type 2 (FT2) – Wood logs**

This describes the combustion of natural wood logs. Included are the infrastructure, the wood requirements (logs, 72% softwood and 28% hardwood), the emissions to air, the transport of the wood, and the disposal of the ashes. Heat of combustion of wood is based on low heating value. The apparent density of the logs (humidity = 20%) is 607 kg/m^3, the low heating value is 9427 MJ/m^3. Air emission factors from measurements were adjusted based on operation experience of installed heaters. The inventory shall be also considered valid for boilers with nominal capacity up to about 20 kW.

- **Fuel type 3 (FT3) – Wood Pellets**

This describes the combustion of natural wood pellets. Included are the infrastructure, the wood requirements (average pellets), the emissions to air, the transport of the fuel, the electricity needed for operation, and the disposal of the ashes. Heat of combustion of wood pellets is based on low heating value. The apparent density of the pellets (humidity = 10%) is 715 kg/m^3, the low heating value is 12184 MJ/m^3. Air emission factors from measurements were adjusted based on operation experience of installed furnaces. The inventory shall be considered valid also for boilers with nominal capacity in the approximate range of 10 kW to 30 kW.

- **Fuel type 4 (FT4) – Wood Chips**

This describes the combustion of natural wood chips. Included are the infrastructure, the wood requirements (mixed chips from forest, 72% softwood and 28% hardwood), the emissions to air, the transport of the fuel, the electricity needed for operation, and the disposal of the ashes. Heat of combustion of wood is based on low heating value. Characteristics of the available dataset of wood chips as fuel input has been adjusted to actual humidity of 50%, which is achieved after some weeks of drying. The apparent density of the chips is 415 kg/m^3, the bulk density is 189 kg/m^3, and the low heating value is 3299 MJ/m^3. Air emission factors from measurements were adjusted based on operation experience of installed furnaces. The inventory shall be considered valid also for boilers with nominal capacity in the approximate range of 30 to 100 kW.

[7] Specific EcoInvent library information is copyrighted and could not be included here.

- **Life cycle emissions per fuel type**

The resulting emission inventories for each fuel type is given in Table 5-19 and is given on a [per GJ of fuel] basis.

Table 5-19: Compiled environmental indicators for the fuels used in the BCs defined in the Lot 15 study (per GJ of fuel used)

Fuel Type	GER	Non-haz waste	GWP	Acid Pot.	VOC	POP	Heavy Metals	PAH	PM
	MJ	g	kg CO_2eq	g SO_2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g
Hard Coal briq	1139	1221	109	599	577	589	610	57	326
Wood Logs	1097	811	6	144	21	121	46	287	120
Pellets	1262	320	11	109	24	299	55	244	35
Chips	1135	1070	4	106	13	158	50	275	38

From a LCA perspective, the data in Table 5-19 presents the total emissions of solid fuel combustion products over the lifetime of the fuel. This is to say that the emissions are the sum of the emissions from the combustion process as well as emissions from transport and processing of the fuels (e.g. mining). Table 5-19 suggests that while the emissions are highly dependent on many other factors, one could expect to use an average of 1139 MJ per GJ of hard coal, which emits 326 g of particulate matter.

The values in Table 5-19 are based on a 'per GJ of fuel burnt' basis. To include the efficiency of the appliance they must be converted to a 'per GJ of useful heat delivered by the appliance' basis. This is necessary because later in this methodology, an appliance factor is applied to each environmental indicator and this step will require the efficiency of the appliance to be incorporated. This process has been called normalisation here and simply means that more fuel must be burnt to provide a GJ of space heat in any real appliance with less than 100% efficiency.

5.2.2. TEST STANDARD APPLIANCE FACTOR

It is very difficult to predict the emissions of solid fuel SCIs based on empirical or analytical means. It is known that each appliance contributes differently to the production of each type of emission. In order to reflect the differences among appliances, each BC is represented by a series of environmental factors derived from the DIN+ or EN 303-5 test standard results. The factors are expressed as a ratio to that of the stove value.

Table 5-20 gives a summary of the data used to develop the appliance factors.

Table 5-20: Summary of emissions for appliance factors (DIN+ method[1])

	Base Case	Test standard Efficiency	PM	CO	OGC
		(% NCV)	(mg/m³ @ 13% O_2)	(mg/m³ @ 13% O_2)	(mg/m³ @ 13% O_2)
BC 1	OPEN FIREPLACE	30	900	12 500	900
BC 2	CLOSED FIREPLACE / INSERT	70	200	4 500	350
BC 3	WOOD STOVE	70	200[2]	4 500[2]	350[2]
BC 4	COAL STOVE	70	200	4 500	350
BC 5	COOKER	65	225	5 000	450
BC 6	SHR STOVE	80	150	2 500	200
BC 7	PELLET STOVE	86	75	350	50
BC 8	DOM. BOILER - UPPERFIRE	66	180	4 000	350
BC 9	DOM. BOILER - DOWNDRAUGHT	88	50	200	10
BC 10	COAL BOILER	82	50	200	10
BC 11	PELLET BOILER	88	50	350	50
BC 12	NON-DOM. CHIP BOILER	88	50	350	10

Notes:
1 – DIN+ method is used here, however not endorsed as a testing method
2 - Coal stove emissions are differentiated in this calculation by fuel type not appliance factor, hence emission factors which appear similar for wood stove and coal stove base cases in this table will result in different environmental impacts in life cycle calculations

Since DIN+ and EN 303-5 tests only measure up to three emissions, the following assumptions have been made to extrapolate appliance factors for the different Ecoreport environmental indicators:

- PM is the normalised DIN+ or EN 303-5 value, expressed as a ratio to that of the stove.
- VOC is the normalised OGC value expressed as a ratio to that of the stove.
- GER factor is the inverse of efficiency determined for that BC, expressed as a ratio to that of the stove.
- Non-haz waste, Acid Pot. Heavy Metals, POP and PAH are assumed to be equivalent to the GER factor. This is because they can be assumed to depend mostly on the fuel type, and hence their emission levels depend more on the amount of fuel consumed than on any one characteristic of the appliance. Essentially this establishes that the efficiency of the appliance is the basis for these emissions, meaning if the appliance has no influence at all on the production of the emission, it must then depend on the fuel type and of course the amount of fuel consumed.
- GWP: both CO_2 and CO contribute to GWP. It is assumed that efficiency is an indicator of CO_2 emissions (therefore the CO_2 factor is assumed equivalent to the GER factor). CO emissions are taken from DIN+ or EN 303-5 test results. Thus, GWP is estimated with a weighted average of the GER factor and CO factor, with GER given a weight of 90% and CO a weight of 10%. This ratio is based on the contribution to GWP from CO and CO_2 emissions for other similar

combustion processes in EcoInvent[8]. An example of this calculation is given below in Figure 5-5:

Stove efficiency:	70%	Stove CO:	4500
Pellet stove efficiency:	86%	Pellet stove CO:	350
Ratio is GER Factor:	$\frac{70}{86} = 0.814$	Ratio is CO Factor:	$\frac{350}{4500} = 0.078$

90% (0.814) = 0.733
10% (0.078) = 0.008

Sum = 0.74 (GWP Appliance Factor for Pellet stove)

Figure 5-5: Example calculation for GWP factor

This calculation is important because it allows appliances with similar efficiencies to have different GWP factors if they have different CO emissions. This also allows for appliances burning biomass to contribute to GWP through CO emissions. One can see the effect of the CO emissions for each appliance in the GWP indicator category by comparing the GER indicator to the GWP indicator. The difference is a result of the CO emissions.

Each factor is a ratio of the emissions data for an appliance to the equivalent emission of BC2. BC2 was chosen arbitrarily as the base for these ratios. This arbitrary choice remains consistent with the methodology in Task 3 for determining the usage of appliances. The resulting appliance factors are presented below, in Table 5-21.

Table 5-21: Appliance factors for the BCs in the Lot 15 study

Base Case	GER	Non-haz waste	GWP	Acid Pot.	VOC	POP	Heavy Metals	PAH	PM
BC 1	2.33	2.33	2.38	2.33	2.57	2.33	2.33	2.33	2.33
BC 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BC 3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BC 4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BC 5	1.08	1.08	1.08	1.08	1.29	1.08	1.08	1.08	1.13
BC 6	0.88	0.88	0.84	0.88	0.57	0.88	0.88	0.88	0.75
BC 7	0.81	0.81	0.74	0.81	0.14	0.81	0.81	0.81	0.38
BC 8	1.06	1.06	1.04	1.06	1.00	1.06	1.06	1.06	0.90
BC 9	0.80	0.80	0.72	0.80	0.03	0.80	0.80	0.80	0.25
BC 10	0.85	0.85	0.77	0.85	0.03	0.85	0.85	0.85	0.25
BC 11	0.80	0.80	0.72	0.80	0.14	0.80	0.80	0.80	0.25
BC 12	0.80	0.80	0.72	0.80	0.03	0.80	0.80	0.80	0.25

Table 5-21 suggests that to deliver one GJ of useful heat to a space, a hypothetical "Open fireplace" will use 2.33 times the "Gross Energy" used by a stove, while emitting 2.57 times the VOCs emitted by a stove.

[8] The EcoInvent data contains international industrial life cycle inventory data on energy supply, resource extraction, material supply, chemicals, metals, agriculture, waste management services, and transport services.

5.2.3. ENVIRONMENTAL IMPACT OF APPLIANCES

By multiplying a fuel inventory by an appliance factor, an estimate can be obtained for the emission inventory of a given fuel burnt in a given appliance under test standard conditions.

As a final step to this process, to ensure that the environmental impacts are representative of the actual fuel used in the appliances, each impact category is multiplied by the ratio of test standard efficiency to seasonal efficiency for the appliance in question. This compensates the impacts such that they are representative of the real use of appliances throughout the heating seasons, and not just an extrapolation of test standard efficiencies.

This appliance factor is based on test standard emissions data and test standard efficiencies. The difference between test standard emissions and real life environmental impacts are that the real life environmental impacts must be estimated based on the seasonal efficiencies. Hence, a final step is required, multiplying each impact category by the ratio of seasonal efficiency to test standard efficiency, giving the final impacts in terms of seasonal efficiencies for each appliance.

While this method is a crude estimate of the real emissions, it is useful here for several reasons. First, it allows for a reliable comparison between various fuels and appliances on a consistent basis. Second, the methodology highlights the key differences in GER and direct emissions to air between the different fuels and appliances covered in this study.

This methodology does not claim to be representative of any real appliances; it merely allows for relative comparisons in a consistent and transparent manner which can lead to meaningful conclusions in the context of the Lot 15 study.

The resulting emission inventories for the selected BCs and their main fuels are given in Table 5-22 (non-inclusive of non-relevant environmental indicators, which are set to zero by default). These results highlight that for a given appliance, mineral fuels generate more environmental impacts than wood fuels across all indicators except PAH.

Table 5-22: Environmental indicators for use in Ecoreport, for the BCs defined in the Lot 15 study (per GJ of useful heat provided)

Appliance Name	Fuel Type Name	GER	Non-haz waste	GWP	Acid Pot.	VOC	POP	Hvy Mtl	PAH	PM
		MJ	g	kg CO_2eq	g SO_2eq	mg	ng i-Teq TCDD	mg Ni eq	mg Ni eq	g
OPEN FIREPLACE	Wood	4210	3110	23	553	90	464	175	1102	462
CLOSED FIREPLACE / INSERT	Wood	1619	1196	9	213	31	179	67	424	178
WOOD STOVE	Wood	1619	1196	9	213	31	179	67	424	178
COAL STOVE	Hard Coal	1680	1802	161	883	851	869	900	84	480
COOKER	Wood	1754	1296	9	230	40	193	73	459	201
SHR STOVE	Wood	1403	1037	7	184	18	155	58	367	132
PELLET STOVE	Pellets	1494	379	11	129	5	354	65	289	19
DOM. BOILER - UPPERFIRE	Wood	2105	1555	11	276	38	232	88	551	196
DOM. BOILER - DOWNDRAUGHT	Wood	1595	1178	8	209	1	176	66	417	55
COAL BOILER	Hard Coal	1706	1830	148	897	29	882	914	85	143
PELLET BOILER	Pellets	1754	445	13	152	6	416	76	339	15
CHIP BOILER	Chips	1555	1466	5	145	1	216	69	376	16

The data presented in Table 5-22 is implemented into the Ecoreport tool for the complete LCA of the BCs considered in this study. Specifically, the above 12 heating types have been added to the drop-down list in line 220 of the 'Inputs' sheet of Ecoreport, in column 'F', such that for each BC, the appropriate appliance and fuel combination can be selected. The drop-down list then calls the data in the above table and incorporates it into the remainder of the LCA.

It must be highlighted again that the above data does not represent values of real appliances. This data is valid exclusively in the context of this study and has been developed with a strictly theoretical approach that does not represent any real physical process. It was developed for comparison of BCs with BATs and improvement options and hence is valid only to this end.

5.3. BASE CASE ENVIRONMENTAL IMPACT ASSESSMENT

For each BC, the total environmental impacts according to Ecoreport calculations are shown in Table 5-23 to Table 5-34 respectively. The contribution of the different phases of the life cycle to each of the impact categories are illustrated in Figure 5-7 to

Figure 5-18, for each BC respectively. The total impact of a category is shown as 100%, but it does not mean that each of the impacts in each category is equally important. The categories are not comparable. Negative impacts at the end-of-life, i.e. recycling credits which outweigh disposal impacts, are shown in these graphs as a negative percentage.

The environmental impacts of the processing, distribution, use and end-of-life of the fuel are all included under the 'Use' phase of the BC. This is because fuel is used for making the appliances work, and therefore is treated as a nested LCA within the use phase of the appliance LCA.

The main characteristics of the LCA analysis are:

- Use phase: for each BC, the use phase dominated the life cycle impacts for the seven environmental indicators of emissions to air, GWP, Acidification, VOC, POP, Heavy metals, PAH and PM as well as for GER and Non-hazardous waste. For example, the use phase contributed 98% to GER, 87% to PM and 88% to GWP across all base cases.

  The processes included in the use phase are fuel use (fuel combustion, distribution and processing), electricity use and maintenance of the appliance. Overall, the fuel combustion and fuel processing and transportation contribute 98% of the environmental impacts to the use phase (i.e. the fuel life cycle contribute 98% of impacts). Within the fuel life cycle, fuel combustion is responsible for most of these impacts.

  Electricity consumption varied: most direct heating appliances (BC1-BC6) had no electricity consumption, whereas other appliances have a small amount. Thus overall, electricity was not a significant contributor to total energy consumption of all solid fuel SCIs, amounting to less than 0.5% of the GER. Reduction of electricity consumption would therefore not be an effective means of improving the energy efficiency of these appliances.

  Overall, fuel combustion contributes 88% of the energy use per year. Figure 5-6 summarises the GER of solid fuel SCIs in Europe. The use phase is divided to show the source of environmental impacts arising there.

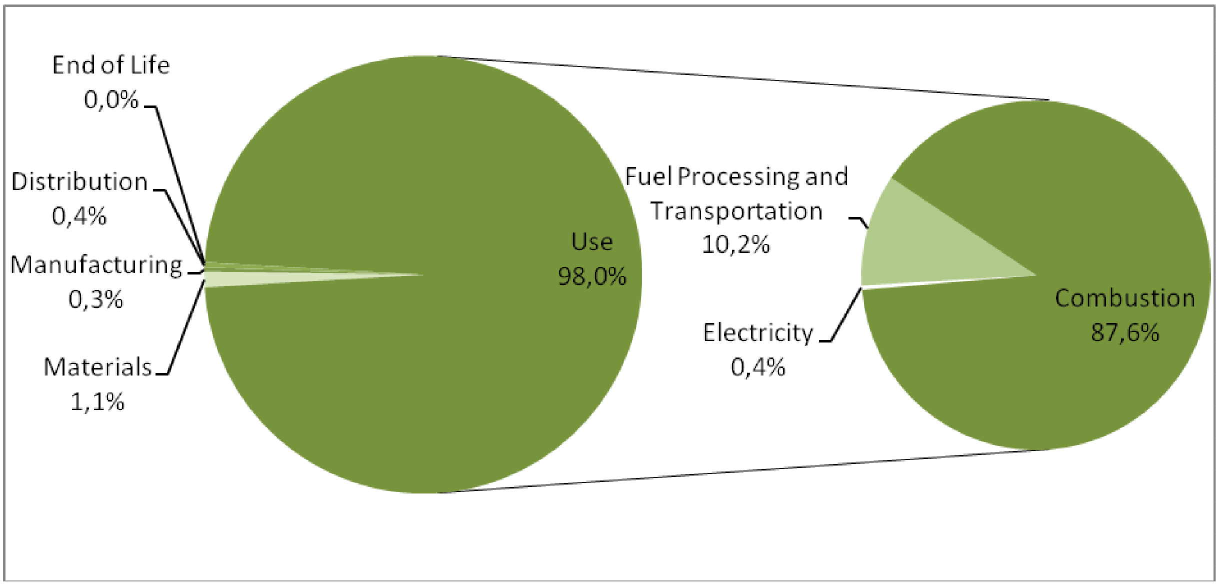

Figure 5-6: Energy consumption for BCs by life cycle phase (use phase expanded) per year

- Materials and Manufacturing: the contribution of environmental impacts of the materials and manufacturing phase was greatest for water consumption indicators (water, heavy metals to water and eutrophication), electricity use (only for appliances which did not directly use electricity during the operation phase – BC1 through BC5) and hazardous waste. However, from a life cycle perspective, the materials and manufacturing phase contributed a very small portion to the overall environmental impacts associated with solid fuel SCIs. The most significant contribution from materials and manufacturing to the environmental indicators in this study was to the non-hazardous waste indicator. It contributed 26% of all the non-hazardous waste across all the BCs.

  In general, steel and cast-iron are responsible for most of the environmental impacts of the materials and manufacturing phase. Production of steel is more energy intensive than cast-iron and hence steel appliances require twice as much energy to manufacture, and causes approximately twice the environmental impacts of cast-iron appliances. For appliances containing electronics, electronic components generate most of the environmental impacts to water, hazardous waste and PAHs of this life cycle phase.

- Distribution: the distribution phase only contributed significantly to the hazardous waste indicator and particulate matter, and this contribution was only notable for some appliances. For hazardous waste, the contribution is because they contain electronics or bulk plastics. Pellet appliances have very low overall PM emissions and hence receive a larger portion of the life cycle PM emissions from truck and ship emissions during distribution. Overall, from a life cycle perspective, the distribution phase contributed a very small portion to the overall environmental impacts associated with solid fuel SCIs.

  The distribution phase only includes the distribution of the appliance, not of the fuel. The distribution of the fuel is included in the use phase of the LCA.

- End-of-life: the end-of-life phase has very little impact on most of the environmental indicators in the BCs. The end-of-life phase only contributes marginally to the hazardous waste indicator for appliances found to contain plastics (bulk or technical plastics).

5.3.1. Base case 1: Open fireplace

Table 5-23: Base case 1, fuel type 2 (wood logs) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1973	169	2142	1162	200521	36	-1	37	203862
9	of which, electricity (in primary MJ)	MJ	521	98	619	3	6	0	0	0	628
10	Water (process)	ltr	34	1	35	0	0	0	0	0	36
11	Water (cooling)	ltr	92	43	134	0	1	0	0	0	136
12	Waste, non-haz./ landfill	g	18691	752	19443	505	148320	0	0	0	168268
13	Waste, hazardous/ incinerated	g	0	0	0	10	0	0	0	0	10
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	85	10	94	70	1080	3	0	3	1247
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	178	41	220	212	26318	3	0	3	26753
17	Volatile Organic Compounds (VOC)	g	4	0	4	21	4270	1	0	1	4295
18	Persistent Organic Pollutants (POP)	ng i-Teq	313	17	330	3	22114	0	0	0	22447
19	Heavy Metals	mg Ni eq.	72	40	111	26	8347	8	0	8	8491
	PAHs	mg Ni eq.	1	0	1	47	52481	8	0	8	52536
20	Particulate Matter (PM, dust)	g	373	6	379	3418	22012	133	0	133	25943
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	45	0	45	1	0	0	0	0	46
22	Eutrophication	g PO4	1	0	1	0	0	0	0	0	1
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

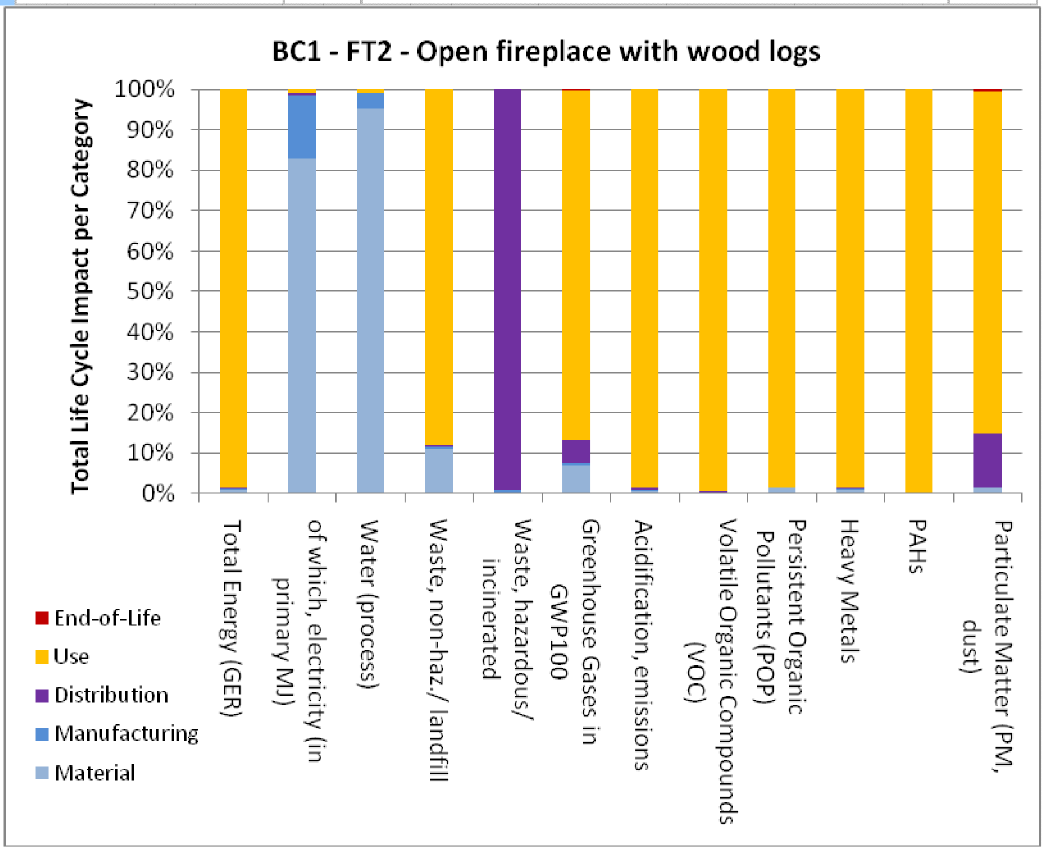

Figure 5-7: Life cycle impacts of base case 1 with fuel type 2

5.3.2. BASE CASE 2: CLOSED FIREPLACE / INSERT

Table 5-24: Base case 2 – fuel type 2 (wood logs) - Life cycle impacts

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	4501	1292	5794	1162	248132	20	0	20	255108
9	of which, electricity (in primary MJ)	MJ	1577	742	2319	3	23	0	0	0	2345
10	Water (process)	ltr	256	10	266	0	3	0	0	0	269
11	Water (cooling)	ltr	1151	314	1464	0	15	0	0	0	1479
12	Waste, non-haz./ landfill	g	140793	6275	147067	505	184743	0	0	0	332316
13	Waste, hazardous/ incinerated	g	95	1	96	10	1	0	0	0	107
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	327	74	401	70	1314	2	0	2	1787
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	1596	320	1916	212	32580	2	0	2	34709
17	Volatile Organic Compounds (VOC)	g	19	1	21	21	4794	0	0	0	4836
18	Persistent Organic Pollutants (POP)	ng i-Teq	2262	168	2430	3	27382	0	0	0	29815
19	Heavy Metals	mg Ni eq.	10050	393	10443	26	10430	4	0	4	20903
	PAHs	mg Ni eq.	14	0	14	47	64934	4	0	4	64999
20	Particulate Matter (PM, dust)	g	1227	49	1276	3418	27243	74	0	74	32012
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	398	0	398	1	4	0	0	0	403
22	Eutrophication	g PO4	54	0	54	0	1	0	0	0	55
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

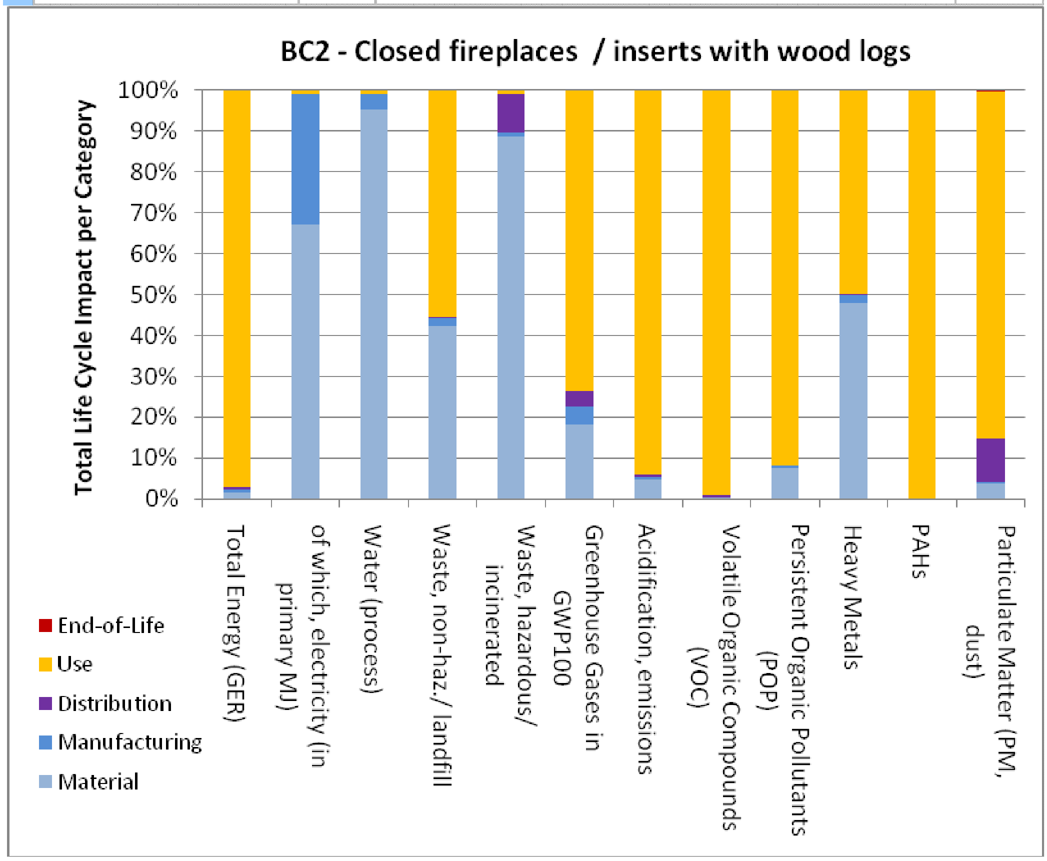

Figure 5-8: Life cycle impacts of base case 2 with fuel type 2

5.3.3. Base case 3: Wood stove

Table 5-25: Base case 3 – fuel type 1 (hard coal) – Life cycle impacts

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2430	534	2964	1606	378159	19	-7	26	382755
9	of which, electricity (in primary MJ)	MJ	588	314	902	4	9	0	0	0	915
10	Water (process)	ltr	226	4	231	0	2	0	0	0	233
11	Water (cooling)	ltr	861	141	1002	0	10	0	0	0	1012
12	Waste, non-haz./ landfill	g	69680	2119	71798	687	280073	0	0	0	352558
13	Waste, hazardous/ incinerated	g	12	0	12	14	0	0	0	0	26
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	210	30	240	96	1999	1	0	2	2337
15	Ozone Depletion, emissions	mg R-11 eq.				negligible					
16	Acidification, emissions	g SO2 eq.	885	130	1015	292	49641	1	-1	2	50950
17	Volatile Organic Compounds (VOC)	g	19	0	19	29	7307	0	0	0	7355
18	Persistent Organic Pollutants (POP)	ng i-Teq	1244	34	1278	4	41713	0	0	0	42995
19	Heavy Metals	mg Ni eq.	4192	79	4271	35	15782	4	0	4	20092
	PAHs	mg Ni eq.	4	0	4	64	98976	4	0	4	99048
20	Particulate Matter (PM, dust)	g	2005	20	2025	4786	41527	71	0	71	48408
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	202	0	202	1	2	0	0	0	205
22	Eutrophication	g PO4	23	0	24	0	0	0	0	0	24
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

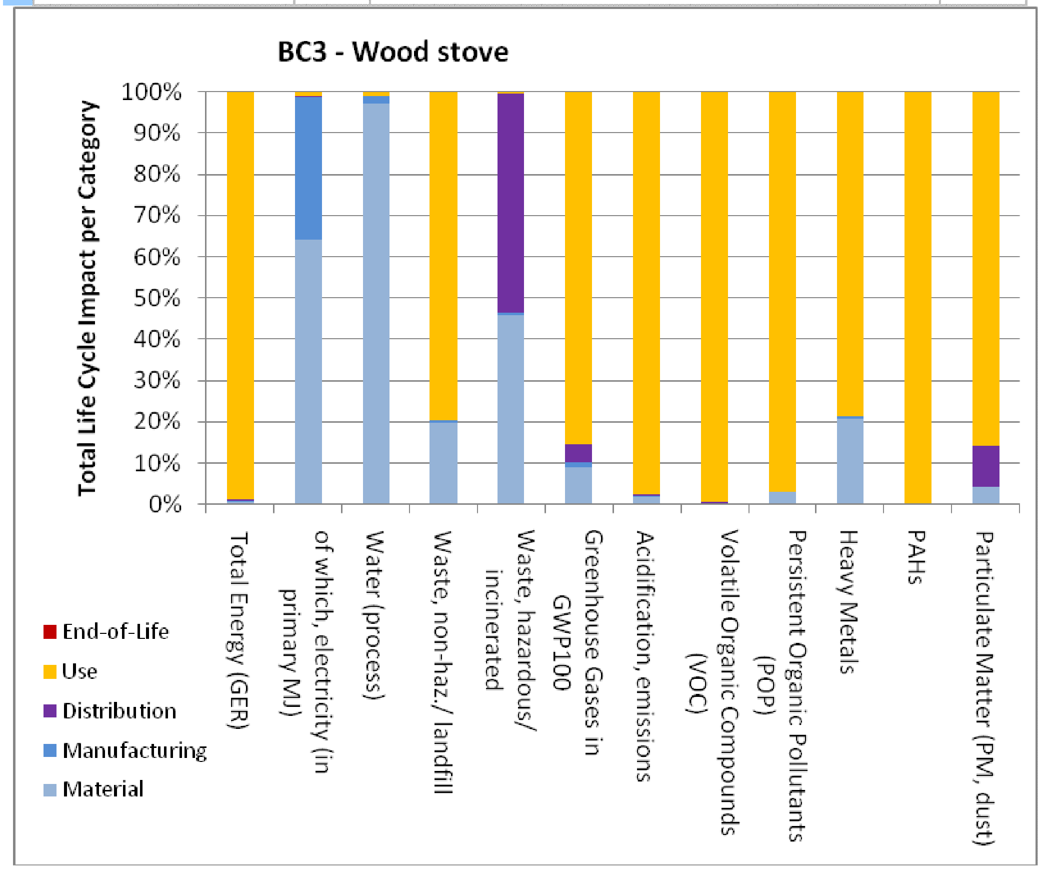

Figure 5-9: Life cycle impacts of base case 3 with fuel type 2

5.3.4. BASE CASE 4: COAL STOVE

Table 5-26: Base case 4, fuel type 1 (hard coal) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2324	534	**2858**	**1606**	**392377**	19	-7	**26**	**396867**
9	of which, electricity (in primary MJ)	MJ	489	314	**803**	**4**	**8**	0	0	**0**	**815**
10	Water (process)	ltr	219	4	**223**	**0**	**2**	0	0	**0**	**225**
11	Water (cooling)	ltr	795	141	936	0	9	0	0	0	945
12	Waste, non-haz./ landfill	g	68919	2119	**71038**	**687**	**421539**	0	0	**0**	**493263**
13	Waste, hazardous/ incinerated	g	10	0	**10**	**14**	**0**	0	0	**0**	**24**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	205	30	**235**	**96**	**37605**	1	0	**2**	**37938**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	821	130	**951**	**292**	**206331**	1	-1	**2**	**207576**
17	Volatile Organic Compounds (VOC)	g	19	0	**19**	**29**	**198714**	0	0	**0**	**198762**
18	Persistent Organic Pollutants (POP)	ng i-Teq	1229	34	**1263**	**4**	**202899**	0	0	**0**	**204166**
19	Heavy Metals	mg Ni eq.	3457	79	**3536**	**35**	**210127**	4	0	**4**	**213701**
	PAHs	mg Ni eq.	4	0	**4**	**64**	**19595**	4	0	**4**	**19667**
20	Particulate Matter (PM, dust)	g	2003	20	**2023**	**4786**	**112188**	71	0	**71**	**119067**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	196	0	**196**	**1**	**2**	0	0	**0**	**199**
22	Eutrophication	g PO4	20	0	**20**	**0**	**0**	0	0	**0**	**20**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

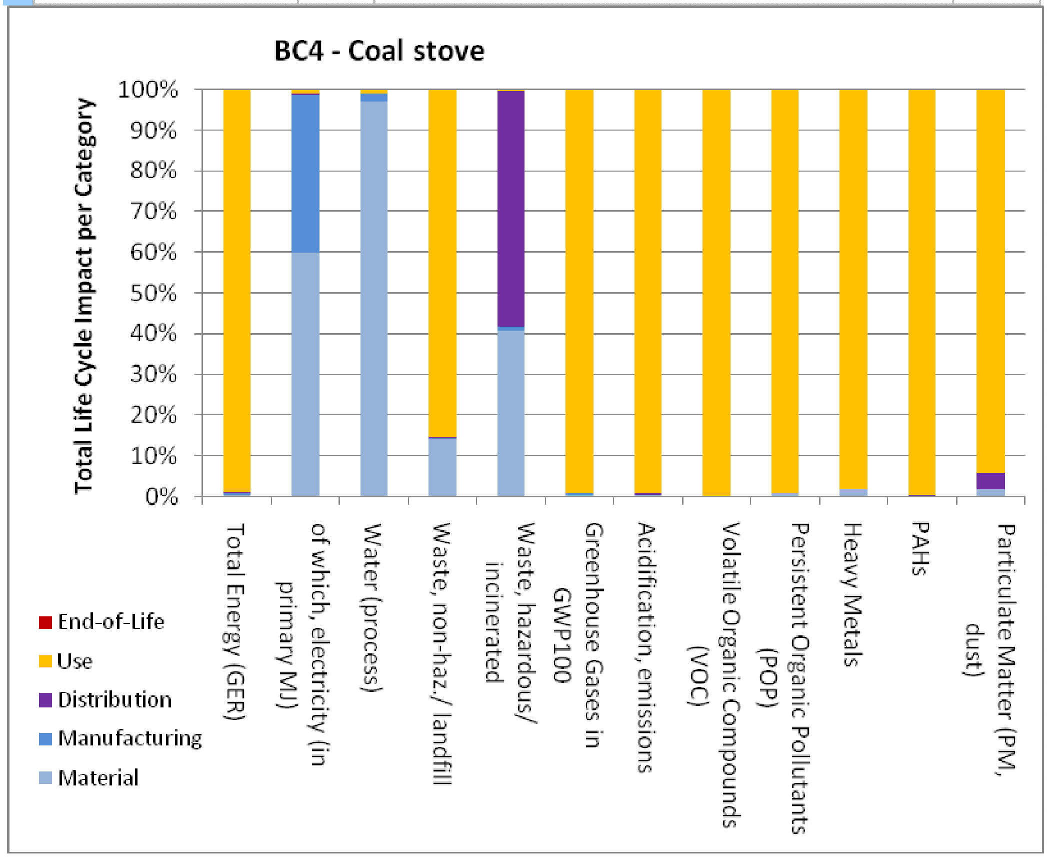

Figure 5-10: Life cycle impacts of base case 4 with fuel type 1

5.3.5. Base case 5: Cooker

Table 5-27: Base case 5, fuel type 2 (wood logs) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	6158	2459	**8618**	**2273**	**127387**	20	9	**11**	**138289**
9	of which, electricity (in primary MJ)	MJ	1648	1403	**3051**	**6**	**31**	0	0	**0**	**3088**
10	Water (process)	ltr	106	19	**125**	**0**	**1**	0	0	**0**	**126**
11	Water (cooling)	ltr	892	584	1476	0	15	0	0	0	1491
12	Waste, non-haz./ landfill	g	244242	12521	**256763**	**959**	**96615**	0	0	**0**	**354337**
13	Waste, hazardous/ incinerated	g	29	2	**31**	**19**	**0**	0	0	**0**	**51**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	454	141	**595**	**135**	**680**	2	1	**1**	**1411**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	1871	613	**2483**	**412**	**16733**	2	1	**1**	**19630**
17	Volatile Organic Compounds (VOC)	g	21	3	**24**	**41**	**2937**	0	0	**0**	**3002**
18	Persistent Organic Pollutants (POP)	ng i-Teq	3743	363	**4107**	**5**	**14080**	0	0	**0**	**18192**
19	Heavy Metals	mg Ni eq.	10165	851	**11016**	**49**	**5409**	4	0	**4**	**16478**
	PAHs	mg Ni eq.	12	0	**12**	**91**	**33321**	4	0	**4**	**33428**
20	Particulate Matter (PM, dust)	g	474	93	**567**	**6836**	**14603**	72	0	**72**	**22079**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	561	0	**562**	**2**	**6**	0	0	**0**	**569**
22	Eutrophication	g PO4	56	1	**57**	**0**	**1**	0	0	**0**	**58**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

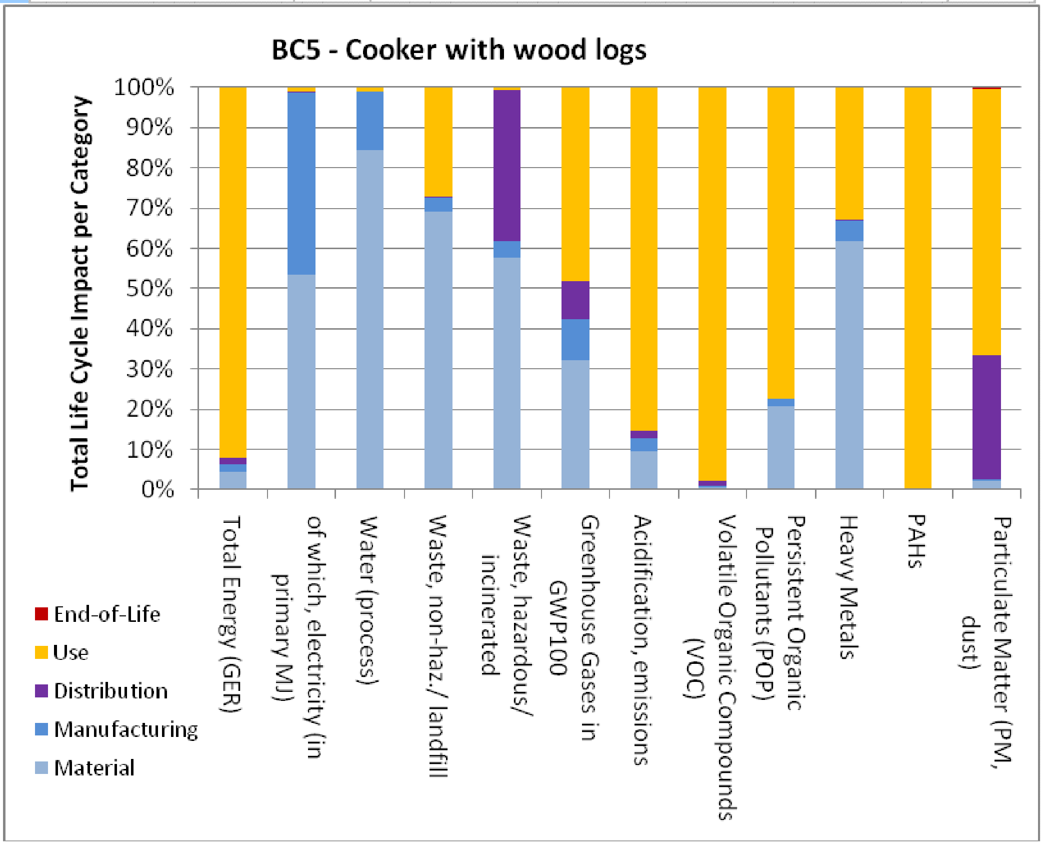

Figure 5-11: Life cycle impacts of base case 5 with fuel type 1

5.3.6. BASE CASE 6: SLOW HEAT RELEASE STOVE

Table 5-28: Base case 6, fuel type 2 (wood logs) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	8856	266	9122	3383	893852	181	-2	183	906540
9	of which, electricity (in primary MJ)	MJ	2742	155	2897	9	29	0	0	0	2934
10	Water (process)	ltr	94	2	96	0	1	0	0	0	97
11	Water (cooling)	ltr	171	68	239	0	2	0	0	0	241
12	Waste, non-haz./ landfill	g	30263	1153	31416	1413	660608	0	0	0	693437
13	Waste, hazardous/ incinerated	g	1	0	1	28	0	0	0	0	29
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	293	15	308	200	4552	14	0	14	5075
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	501	65	566	612	117314	14	0	14	118506
17	Volatile Organic Compounds (VOC)	g	7	0	7	62	11279	3	0	3	11351
18	Persistent Organic Pollutants (POP)	ng i-Teq	515	24	539	8	98569	0	0	0	99116
19	Heavy Metals	mg Ni eq.	127	57	183	72	37203	39	0	39	37497
	PAHs	mg Ni eq.	1	0	1	135	233942	39	0	39	234117
20	Particulate Matter (PM, dust)	g	704	10	714	10254	84098	664	0	664	95730
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	75	0	75	2	1	0	0	0	78
22	Eutrophication	g PO4	2	0	2	0	0	0	0	0	2
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

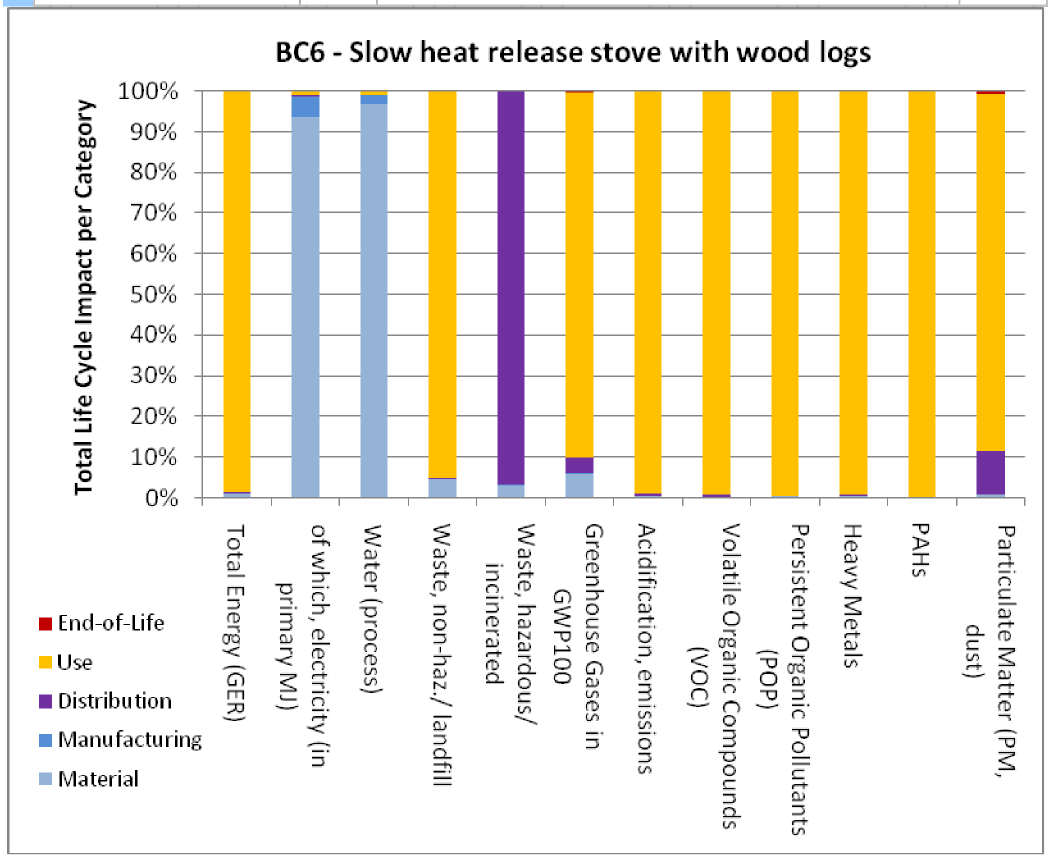

Figure 5-12: Life cycle impacts of base case 6 with fuel type 2

5.3.7. BASE CASE 5: PELLET STOVE

Table 5-29: Base case 7, fuel type 3 (pellets) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	6065	2191	8256	1162	245492	18	21	-3	254907
9	of which, electricity (in primary MJ)	MJ	1628	1251	2878	3	1616	0	0	0	4497
10	Water (process)	ltr	560	17	576	0	112	0	0	0	688
11	Water (cooling)	ltr	784	521	1305	0	4245	0	0	0	5550
12	Waste, non-haz./ landfill	g	241347	11117	252464	505	66240	0	0	0	319209
13	Waste, hazardous/ incinerated	g	612	2	613	10	43	0	0	0	666
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	452	126	577	70	1939	1	2	0	2586
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	2219	546	2765	212	21565	1	2	-1	24541
17	Volatile Organic Compounds (VOC)	g	25	3	28	21	805	0	0	0	853
18	Persistent Organic Pollutants (POP)	ng i-Teq	3313	321	3634	3	57904	0	0	0	61541
19	Heavy Metals	mg Ni eq.	6390	752	7142	26	10633	4	0	4	17804
	PAHs	mg Ni eq.	71	0	71	47	47099	4	0	4	47221
20	Particulate Matter (PM, dust)	g	565	83	648	3418	3169	65	0	65	7300
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	790	0	790	1	18	0	0	0	809
22	Eutrophication	g PO4	44	1	45	0	0	0	0	0	45
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

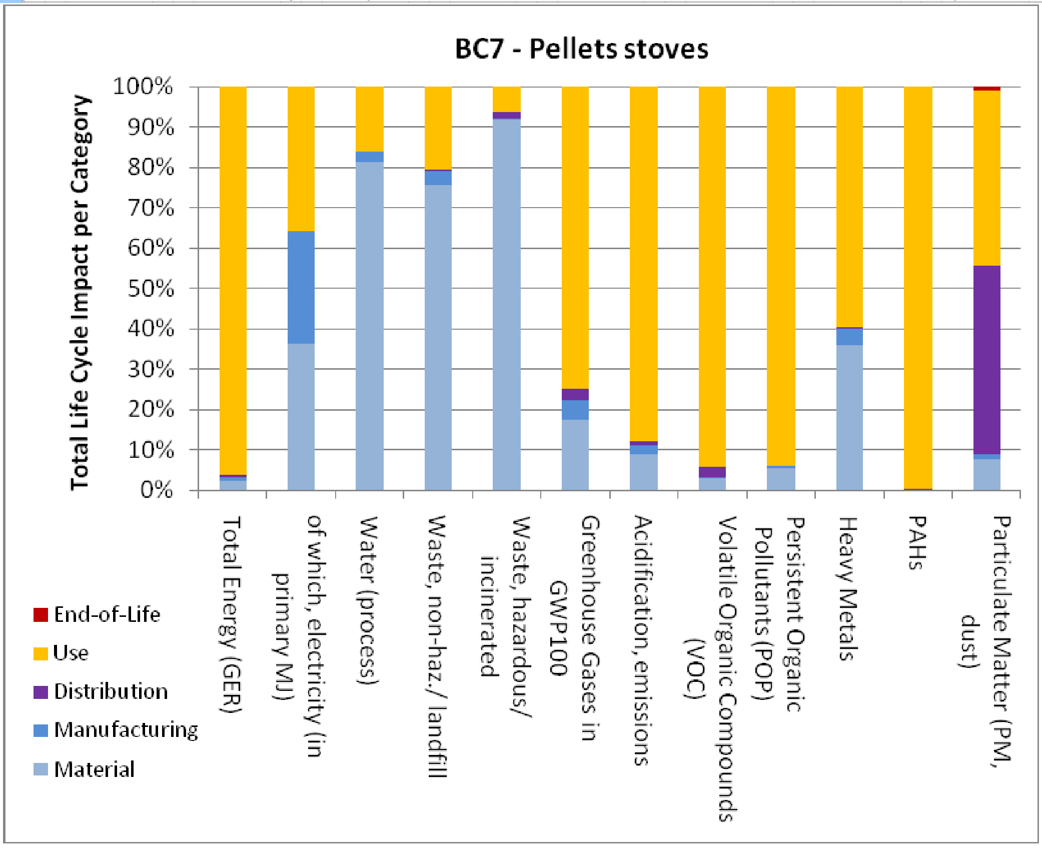

Figure 5-13: Life cycle impacts of base case 7 with fuel type 3

5.3.8. BASE CASE 8: CONVENTIONAL SMALL DOMESTIC BOILER

Table 5-30: Base case 8, fuel type 2 (wood logs) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total			Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	12763	6063	18826	1384	2405461	45	21	24	2425696
9	of which, electricity (in primary MJ)	MJ	1864	3459	5324	3	18428	0	0	0	23755
10	Water (process)	ltr	114	46	160	0	1227	0	0	0	1387
11	Water (cooling)	ltr	762	1439	2201	0	49022	0	0	0	51223
12	Waste, non-haz./ landfill	g	588389	30853	619242	596	1790893	0	0	0	2410731
13	Waste, hazardous/ incinerated	g	24	5	29	12	424	0	0	0	464
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	1014	348	1362	83	13218	4	2	2	14665
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	3242	1511	4752	252	318066	4	2	2	323072
17	Volatile Organic Compounds (VOC)	g	49	8	56	25	43495	1	0	1	43577
18	Persistent Organic Pollutants (POP)	ng i-Teq	8902	895	9796	3	263445	0	0	0	273245
19	Heavy Metals	mg Ni eq.	8966	2096	11062	30	99776	10	0	10	110878
	PAHs	mg Ni eq.	27	1	28	55	624808	10	0	10	624901
20	Particulate Matter (PM, dust)	g	1170	230	1400	4102	222446	167	0	167	228114
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	1271	1	1272	1	131	0	0	0	1404
22	Eutrophication	g PO4	60	2	62	0	1	0	0	0	63
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

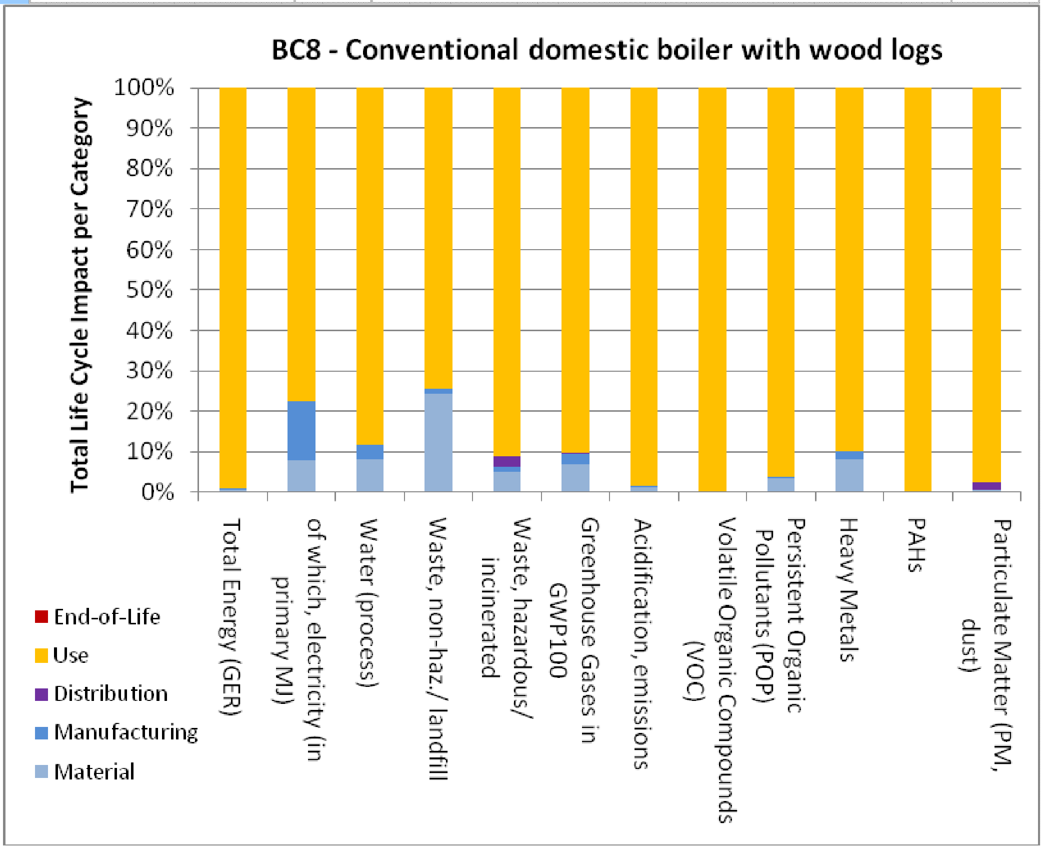

Figure 5-14: Life cycle impacts of base case 8 with fuel type 2

5.3.9. BASE CASE 9: GASIFYING DOWNDRAUGHT DOMESTIC BOILER

Table 5-31: Base case 9, fuel type 2 (wood logs) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	19928	8284	28211	1384	2027830	98	61	37	2057463
9	of which, electricity (in primary MJ)	MJ	4144	4725	8869	3	18464	0	0	0	27336
10	Water (process)	ltr	1667	63	1730	0	1242	0	0	0	2972
11	Water (cooling)	ltr	1153	1965	3118	0	49031	0	1	-1	52148
12	Waste, non-haz./ landfill	g	840972	42181	883153	596	1514477	0	1	-1	2398225
13	Waste, hazardous/ incinerated	g	1985	7	1992	12	443	405	0	405	2852
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	1524	475	1999	83	10439	7	4	3	12524
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	5874	2064	7938	252	268520	10	6	4	276714
17	Volatile Organic Compounds (VOC)	g	83	10	94	25	1402	1	0	1	1522
18	Persistent Organic Pollutants (POP)	ng i-Teq	11977	1225	13202	3	221824	0	0	0	235029
19	Heavy Metals	mg Ni eq.	10750	2869	13619	30	84079	23	0	23	97751
	PAHs	mg Ni eq.	249	1	250	55	525940	15	0	15	526261
20	Particulate Matter (PM, dust)	g	1438	314	1752	4102	69432	293	0	292	75579
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	2914	2	2915	1	148	2	0	2	3066
22	Eutrophication	g PO4	87	3	89	0	1	0	0	0	91
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

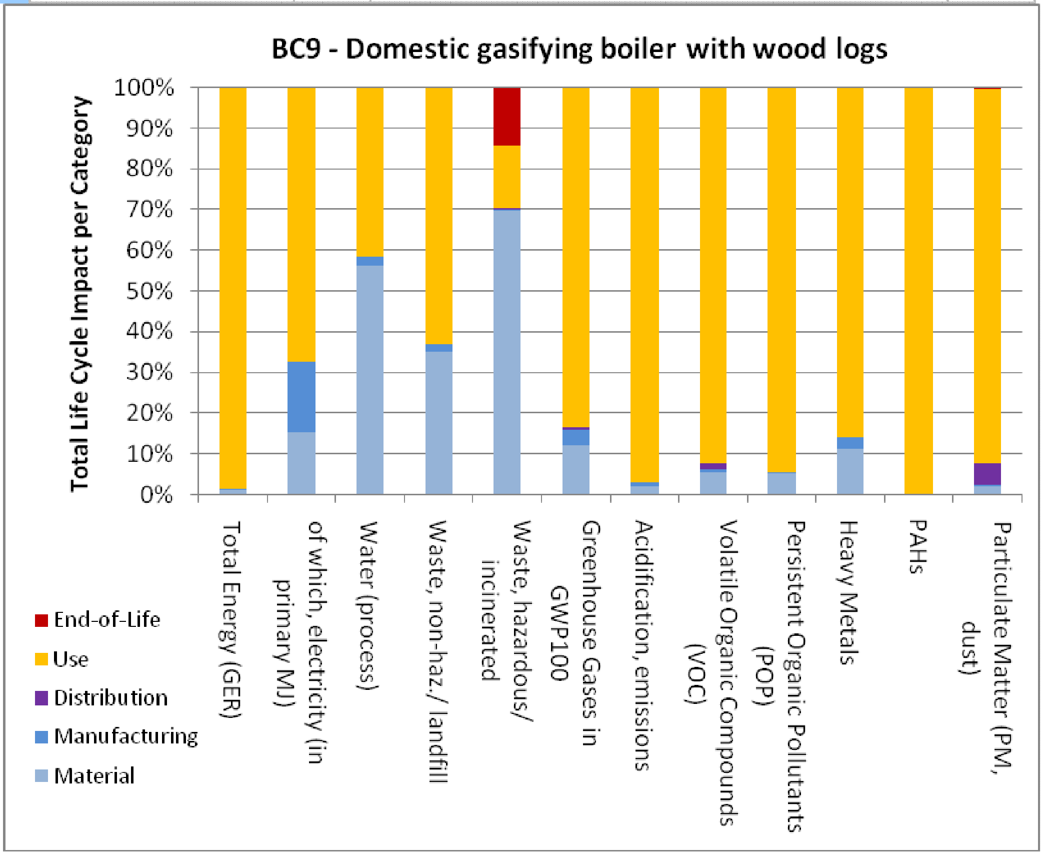

Figure 5-15: Life cycle impacts of base case 9 with fuel type 2

5.3.10. Base case 10: Retort boiler

Table 5-32: Base case 10, fuel type 1 (hard coal) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	15883	8201	**24083**	**1717**	**3096685**	56	31	**26**	**3122511**
9	of which, electricity (in primary MJ)	MJ	1307	4678	**5985**	**4**	**25260**	0	0	**0**	**31249**
10	Water (process)	ltr	266	62	**328**	**0**	**1683**	0	0	**0**	**2011**
11	Water (cooling)	ltr	102	1945	**2047**	**0**	**67220**	0	0	**0**	**69268**
12	Waste, non-haz./ landfill	g	790206	41771	**831977**	**732**	**3331722**	0	0	**0**	**4164432**
13	Waste, hazardous/ incinerated	g	309	7	**315**	**15**	**584**	0	0	**0**	**914**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	1314	470	**1785**	**102**	**267816**	4	2	**2**	**269705**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	3697	2043	**5740**	**312**	**1621601**	4	3	**2**	**1627655**
17	Volatile Organic Compounds (VOC)	g	66	10	**76**	**31**	**52072**	1	0	**1**	**52180**
18	Persistent Organic Pollutants (POP)	ng i-Teq	11786	1213	**12999**	**4**	**1588459**	0	0	**0**	**1601463**
19	Heavy Metals	mg Ni eq.	1703	2842	**4545**	**37**	**1645043**	12	0	**12**	**1649638**
	PAHs	mg Ni eq.	67	1	**68**	**69**	**153435**	12	0	**12**	**153584**
20	Particulate Matter (PM, dust)	g	1428	311	**1739**	**5127**	**257295**	207	0	**207**	**264368**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	1819	2	**1821**	**1**	**181**	0	0	**0**	**2003**
22	Eutrophication	g PO4	32	3	**35**	**0**	**1**	0	0	**0**	**36**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

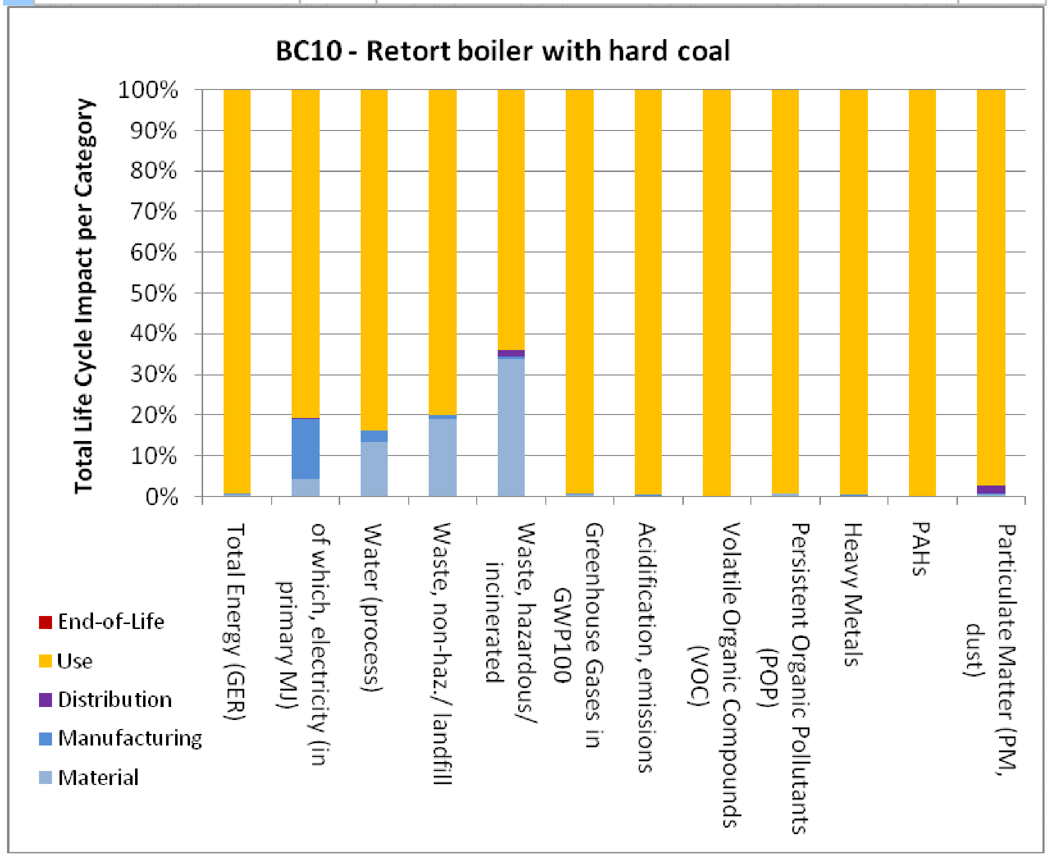

Figure 5-16: Life cycle impacts of base case 10 with fuel type 1

5.3.11. BASE CASE 11: PELLET BOILER

Table 5-33: Base case 11, fuel type 3 (pellets) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	24677	7619	32296	1717	3188447	65	33	31	3222492
9	of which, electricity (in primary MJ)	MJ	9631	4347	13978	4	31640	0	0	0	45622
10	Water (process)	ltr	1954	58	2011	0	2120	0	0	0	4131
11	Water (cooling)	ltr	5088	1809	6897	0	84069	0	0	0	90966
12	Waste, non-haz./ landfill	g	853086	38747	891833	732	846502	0	0	0	1739067
13	Waste, hazardous/ incinerated	g	1918	6	1925	15	745	0	0	0	2684
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	1696	437	2132	102	25536	5	2	3	27774
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	9519	1898	11417	312	281768	5	3	2	293499
17	Volatile Organic Compounds (VOC)	g	85	10	94	31	10664	1	0	1	10790
18	Persistent Organic Pollutants (POP)	ng i-Teq	11925	1123	13048	4	749374	0	0	0	762426
19	Heavy Metals	mg Ni eq.	54295	2630	56925	37	137494	14	0	14	194470
	PAHs	mg Ni eq.	263	1	264	69	609775	14	0	14	610121
20	Particulate Matter (PM, dust)	g	1700	289	1989	5127	28046	237	0	236	35399
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	3187	1	3188	1	235	0	0	0	3424
22	Eutrophication	g PO4	297	3	300	0	4	0	0	0	304
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

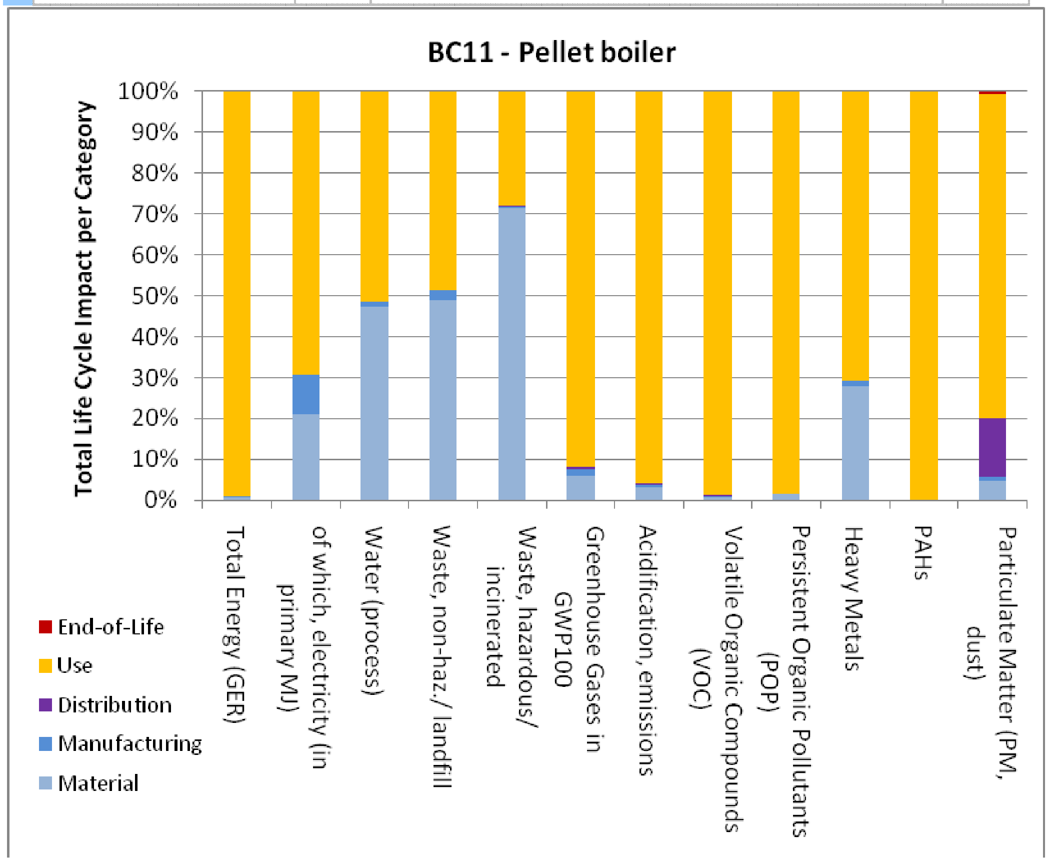

Figure 5-17: Life cycle impacts of base case 9 with fuel type 3

5.3.12. BASE CASE 12: NON-DOMESTIC BOILER

Table 5-34: Base case 12, fuel type 4 (chips) – Life cycle impact

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	49628	15381	**65009**	**3383**	**17993391**	344	246	**98**	**18061880**
9	of which, electricity (in primary MJ)	MJ	19309	8780	**28089**	**9**	**84281**	0	1	**-1**	**112377**
10	Water (process)	ltr	3918	117	**4034**	**0**	**5640**	0	1	**-1**	**9674**
11	Water (cooling)	ltr	10333	3658	**13991**	**0**	**224140**	0	7	**-7**	**238124**
12	Waste, non-haz./ landfill	g	1706956	77942	**1784898**	**1413**	**17005460**	1	5	**-4**	**18791766**
13	Waste, hazardous/ incinerated	g	3852	13	**3865**	**28**	**1974**	3150	1	**3149**	**9016**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	3398	882	**4279**	**200**	**57525**	26	17	**9**	**62014**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	19069	3830	**22899**	**612**	**1694756**	42	22	**20**	**1718287**
17	Volatile Organic Compounds (VOC)	g	171	19	**190**	**62**	**7645**	3	0	**2**	**7899**
18	Persistent Organic Pollutants (POP)	ng i-Teq	23849	2246	**26095**	**8**	**2487430**	0	0	**0**	**2513533**
19	Heavy Metals	mg Ni eq.	108592	5260	**113852**	**72**	**797578**	85	0	**85**	**911587**
	PAHs	mg Ni eq.	527	2	**529**	**135**	**4334200**	28	0	**28**	**4334891**
20	Particulate Matter (PM, dust)	g	3403	583	**3986**	**10254**	**189015**	752	0	**752**	**204006**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	6377	3	**6380**	**2**	**605**	18	0	**18**	**7005**
22	Eutrophication	g PO4	594	5	**599**	**0**	**9**	1	0	**1**	**609**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

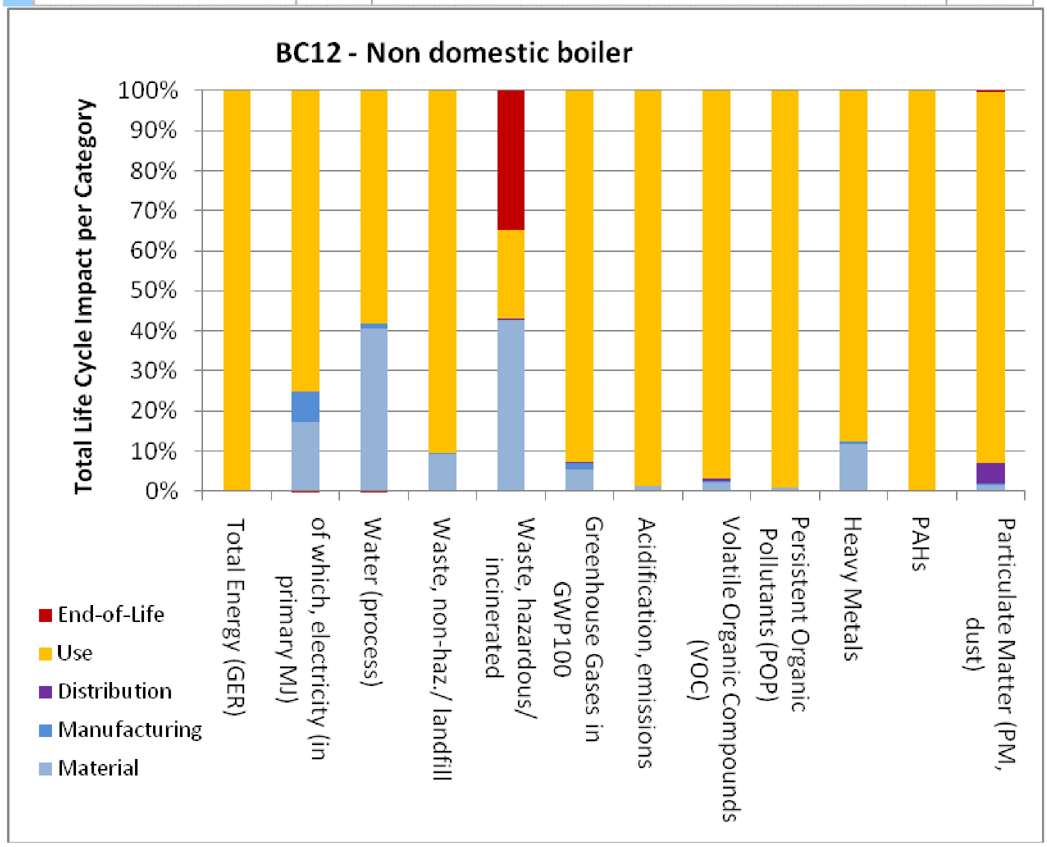

Figure 5-18: Life cycle impacts of base case 12 with fuel type 4

5.4. BASE CASE LIFE CYCLE COSTS

The life cycle costs refer to **2007 data** as they are based on information collected and complied throughout the study (2007-2009). Table 5-35 shows the costs for each BC according the EcoReport calculations.

Table 5-35: Base case life cycle costs

	UNIT	OPEN FIREPLACE	CLOSED FIREPLACE / INSERT	WOOD STOVE	COAL STOVE	COOKER	SLOW HEAT RELEASE STOVE	PELLET STOVE	SMALL DOM. MAN. BOILER	SMALL DOM. DD GASIFYING BOILER	RETORT BOILER	PELLET BOILER	CHIP BOILER
Product price	**EUR**	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00	3000.00	5000.00	4000.00	6000.00	30000.00
Installation/ acquisition costs (if any)	**EUR**	700.00	700.00	500.00	500.00	500.00	5000.00	500.00	1500.00	1500.00	1500.00	2000.00	3500.00
Fuel (gas, oil, wood)	**EUR**	991.99	1370.66	1975.86	2523.27	704.75	4421.95	2194.07	13439.13	11312.40	20885.17	26832.22	61011.51
Electricity	**EUR**	0.00	0.00	0.00	0.00	0.00	0.00	21.76	242.54	242.54	326.41	408.01	1090.18
Repair and maintenance cost	**EUR**	418.64	467.52	401.95	401.95	851.70	380.58	494.92	866.21	866.21	850.03	850.03	4258.50
Totals	**EUR**	**4110.63**	**4538.17**	**4877.81**	**5425.22**	**4056.45**	**11802.54**	**5210.75**	**19047.88**	**18921.15**	**27561.61**	**36090.26**	**99860.18**

5.5. EU TOTALS

5.5.1. Life Cycle Environmental Impacts

The total life cycle impacts summarising the BCs are calculated based on stock estimates in Task 2. Since each appliance has a different lifetime, it is more relevant to compare the yearly impacts of appliances rather than their total life cycle impacts, hence Table 5-36 (reference year: 2009) gives the yearly life cycle impacts for each appliance based on its calculated life cycle impacts divided by its respective life span.

Total Energy (GER) consumption of the EU stock (produced, in use, discarded) for the reference year 2009 is **1734 PJ/year.**

Total PM emissions (PM) of the EU stock for the reference year 2009 is **148 kt/year**, while **Global Warming Potential (GWP)** reached **37.6 mt CO_2eq/year**.

BC8 – conventional domestic boilers are estimated to have the largest GER of solid fuel SCIs. They are also the most important contributors at the EU level to PM emissions. This can be attributed to the fact that they are estimated to be used more throughout the year than the direct heating appliances (i.e. they are more likely to be the primary heat source), have a higher power output and the lowest efficiency among boilers. They also are considered to have the largest presence in the stock of boilers.

For all BCs, the Use phase has been identified as the main contributor to all nine environmental indicators of emissions to air: GER, non-haz waste, GWP, Acidification, VOC, POP, Heavy metals, PAH and PM. For example, the use phase contributed 98% of the GER indicator, 86% of the PM indicator and 88% of GWP across all base cases. This is mostly due to fuel combustion. Materials, Manufacturing and Distribution contributed less than 1% each for many of the indicators. Materials contributed 31% to the non-hazardous waste indicator.

It is estimated that the boiler portion of the study (base cases 8 – 12) represent 70% of the energy use in the study, while the direct heating appliances represent 30%. On the contrary, when consider the volume of sales, direct heating appliances represent 92% of the appliances sold, while indirect heating appliances represent 8%. This can be explained by the large difference found in power output and use patterns found between the two groups of appliances.

5.5.2. Life Cycle Costs

Due to the nature of the market of solid fuel SCIs, the 12 combinations of BCs and fuel types were not able to represent the entire EU market. Based on market stock estimates, the twelve BCs presented in this report represent 77% of the total sales of appliances in Europe which are described in the scope of the study. This must be remembered when analysing the total life cycle costs of the appliances.

As each BC has a different estimated lifetime, the LCC have been divided by their BC's respective lifespan and are given on a per year basis here.

Table 5-36: Life cycle indicators (per year) – totals for Europe stock (2009)

Main life cycle indicators	unit	Open fireplace	Closed fireplace / insert	Wood stove	Coal stove	Cooker	Slow heat release stove	Pellet stove	Small dom. Man. Boiler	Small dom. DD gasifying boiler	Retort boiler	Pellet boiler	Non doemstic boiler	Total
Total Energy (GER)	PJ	83.17	93.64	97.60	34.31	39.78	157.05	14.17	416.89	152.46	300.72	33.20	310.64	1733.63
Electricity	TWh	0.04	0.17	0.03	0.01	0.12	0.08	0.06	0.34	0.20	0.23	0.06	0.14	1.49
Water (process)*	mln.m3	0.03	0.20	0.08	0.03	0.05	0.03	0.11	0.22	0.23	0.16	0.06	0.10	1.31
Waste, non-haz./ landfill	kton	74.59	177.46	96.61	44.85	135.46	123.11	48.02	360.35	185.06	324.90	26.49	294.77	1891.68
Waste, hazardous/ incinerated	kton	0.01	0.08	0.01	0.00	0.02	0.01	0.11	0.08	0.23	0.06	0.05	0.04	0.69
Emissions (Air)														
Greenhouse Gases in GWP100	mt CO2eq.	0.56	0.83	0.63	3.28	0.50	0.94	0.21	2.40	0.94	26.01	0.31	1.00	37.59
Acidifying agents (AP)	kt SO2eq.	10.91	13.21	13.06	17.91	5.84	20.47	1.62	55.32	20.54	157.46	3.11	29.27	348.73
Volatile Org. Compounds (VOC)	kt	1.74	1.74	1.87	17.11	0.84	1.96	0.05	7.51	0.11	5.06	0.11	0.13	38.23
Persistent Org. Pollutants (POP)	g i-Teq.	9.15	11.59	11.04	17.62	5.62	17.06	3.59	46.28	17.50	154.25	7.90	42.95	344.57
Heavy Metals (HM)	ton Ni eq.	3.47	11.64	5.52	18.51	6.17	6.47	1.81	18.14	7.35	159.73	2.54	13.85	255.19
PAHs	ton Ni eq.	21.15	23.17	25.15	1.70	9.25	40.16	2.42	107.86	38.93	14.90	6.23	74.81	365.73
Particulate Matter (PM, dust)	kt	11.80	13.31	12.96	10.48	7.19	17.91	0.89	38.87	5.64	24.99	0.43	3.27	147.75
Emissions (Water)														
Heavy Metals (HM)	ton Hg/20	0.03	0.30	0.07	0.02	0.24	0.02	0.14	0.13	0.25	0.02	0.07	0.01	1.32
Eutrophication (EP)	kt PO4	0.00	0.04	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.11

Table 5-37: Total annual consumer expenditure - totals for base cases in millions of euros per year

	Open Fireplace	Closed Fireplace / Insert	Wood Stove	Coal Stove	Cooker	Slow Heat Release Stove	Pellet Stove	Small Dom. Man. Boiler	Small Dom. Dd Gasifying Boiler	Retort Boiler	Pellet Boiler	Non-domestic Boiler	Total
Appliance purchase	1496.00	1513.45	704.29	238.83	844.12	601.08	353.00	247.90	413.16	6.76	120.00	20.66	6559.25
Installation costs	523.60	529.71	176.07	59.71	211.03	1502.71	88.25	123.95	123.95	2.54	40.00	2.41	3383.92
Fuel costs	524.28	574.22	623.86	270.17	228.53	995.90	124.25	2678.08	966.12	2385.63	321.98	1236.52	10929.53
Electricity Costs	0.00	0.00	0.00	0.00	0.00	0.00	1.23	48.33	20.71	37.28	4.90	22.09	134.55
Repair and maintenance	221.26	195.86	126.91	43.04	276.19	85.71	28.03	172.61	73.98	97.10	10.20	86.31	1417.19
Total	2765.13	2813.23	1631.13	611.74	1559.87	3185.41	594.76	3270.87	1597.92	2529.31	497.07	1367.99	22424.44

In total, the life cycle costs of solid fuel SCis are estimated to be 22 billion Euros in the EU 27 (Table 5-37), of which fuel costs are the largest contributor, representing 49% of the yearly expenditures (discounted to 2009 EUR) and appliance purchase costs representing 29% overall. There is a large difference between the expenditures between mineral fuel and biomass fuel appliances due to the differences in fuel costs. Figure 5-19 and Figure 5-20 compares the life cycle costs for solid fuel SCIs for mineral fuelled appliances versus biomass fuelled appliances (the total annual consumer expenditure for products in the reference year 2007). For both types of appliances, the fuel is largest portion of the costs.

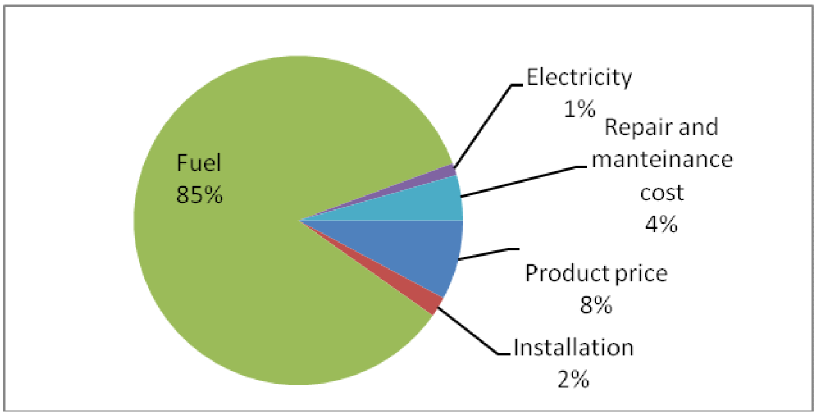

Figure 5-19: Summary of yearly life cycle costs of mineral fuelled base cases

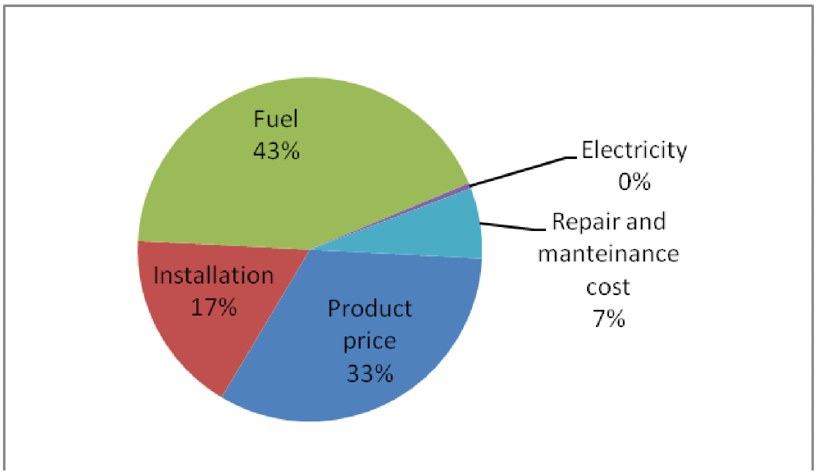

Figure 5-20: Summary of yearly life cycle costs of biomass fuelled base cases

As biomass fuelled appliance have a larger representation in the stock of Europe, they have had a heavier representation in the base cases in this study, and hence the overall life cycle costs calculated here more closely represent the biomass appliance life cycle costs.

5.6. EU-25 TOTAL SYSTEM IMPACT

For direct heating appliances, the appliance typically represents the entire heating system except for the chimney. The chimney is often built with the dwelling which the appliance heats and thus it is difficult to estimate the life cycle impacts related to this portion of the system. For direct heating appliances, the contribution of the chimney to the life cycle impacts has not been quantified in this study.

As elaborated in Tasks 3 and 4, chimneys are an integral part of the heating system. The overall contribution of a suitable chimney to the efficiency of the heating system is difficult to quantify, yet nevertheless recognised as a key factor in optimising the installed system. It has to be stressed that only suitable chimneys allow efficient appliances to operate properly. Considerations towards this must be incorporated when considering improvement options and implementing measures for any appliance type.

For indirect heating appliances, the total heating system impact depends on chimneys as with direct heating appliances, but also depends strongly on the hydronic system connected to the boilers to distribute heat. A good heating system will have a properly sized buffer tank. The degree with which this system impacts the total system of heating is again difficult to estimate because the water piping and pumps are designed and installed in the dwelling and are not sold as 'products'. The real-life efficiency used for estimating the environmental impacts of the boiler base cases attempted to quantify this figure through the seasonal efficiency calculations developed for use in the Lot 1 preparatory study for central heating boilers. The efficiency in which these systems deliver the heat generated by the boiler is also a significant factor which varies depending on the design, the materials chosen and operational demands/behaviour of the user. For indirect heating systems, the contribution of the chimney to the life cycle impacts has not been taken into account. The effect that the hydronic system has on the 'useful heat delivered' to indirect heating systems has been taken into account, however the life cycle impacts of manufacturing, construction, and end-of-life has not been considered for the materials used for the hydronic systems.

5.7. CONCLUSIONS

The BCs will serve as point of reference when evaluating the improvement potential (Task 7) of various design options explored in BATs (Task 6).

The **use phase** is of primary relevancy when analysing the environmental impacts of solid fuel small combustion installations, and will be analysed in following tasks regarding improvement potentials. Specifically the combustion of the fuels used in solid fuels SCIs impact the indicators for GER, Non-hazardous waste, GHG, Acidification potential, VOC, POP, Heavy Metals, PAH and Particulate Matter. In terms of magnitude of environmental impacts, the air emissions from fuel use are of primary concern for these appliances especially particulate matter and global warming potential, while the emissions to water and soil are of less concern. The gross energy requirement (GER), particulate matter (PM) and global warming potential (GWP) indicators are of primary concern for this study.

The **use phase,** specifically the fuel costs, is of primary relevance when analysing the total life cycle costs of solid fuel small combustion installations and will be analysed in the following tasks regarding improvement potentials.

The other life cycle phases of the BCs of solid fuel SCIs which include materials, manufacturing, distribution and end-of-life have much smaller impacts relative to the impacts of the use phase.

Table 5-38 summarises the key results from the Task 5 base case analysis.

Table 5-38: Summary of main environmental indicators for solid fuel SCI stock in Europe per year

Indicator (all Solid Fuel SCIs)	Unit	Value
Total Gross Energy Requirement	PJ / year	1734
Particulate Matter Emissions	kt / year	148
Global Warming Potential (100)	mt CO2eq. / year	38

5.7.1. VALIDITY OF RESULTS

As many important aspects of the small scale solid fuel combustion installations are difficult to determine (i.e. the real life user behaviours) or difficult to characterise in just a few base cases (i.e. the large variety of appliances) the results of the base case analysis must be considered from a very pragmatic perspective.

The results presented are the best estimation of environmental impacts and energy use for a broad and complicated mix of products and processes in Europe, given the scope of the study. However, some base cases are more representative of real products and potential improvement areas than others due to the nature of the products and their market. Below, three base cases are discussed and the limitations of their applicability to further analysis towards implementing measures.

→ BASE CASE 1: OPEN FIREPLACE

The open fireplace base case represents a significant proportion of the total energy use and presents significant emissions and improvement potential. However the information collected and used regarding the open fireplace is not robust enough, nor is it always applicable or appropriate to truly represent the broad range of products which can be considered 'open fireplaces' under circumstances outside of this simplified LCA. Nevertheless, the results obtained for estimating the energy use, emissions and other environmental impacts from this base case are useful insofar as was the intent of this simplified LCA to estimate environmental impacts from a product type.

As such, the open fireplace base case is **not recommended** as a product grouping in which significant improvement options should be identified.

BATs or component improvement options will not be applied to open fireplaces in Task 6. Rather, a replacement option (fireplace inserts) for this product will be evaluated for informational purposes only in Task 7. It is debatable as to whether one can compare the performance of one appliance type to another in this lot due to the wide range of appliances and different functions of the appliances considered in the scope. Indeed, it opens the door to considerations towards replacing one appliance type with another which may be considered to have different functions. As a consequence, relative energy savings or emissions reductions potentials of the improvement options will be performed in Task 7 for open fireplaces by analysing the replacement of an open fireplace by fireplace insert, however the savings potential will not be analysed in the stock model or policy and impact scenarios of Task 8.

➔ **BASE CASE 4: COAL STOVE**

The base case representing coal stoves is included in the task 5 document because it represents a significant environmental impact, significant sales and even a promising improvement potential. However, this base case addresses products used in only a few countries (for example the United Kingdom) and as such it is **not recommended** that improvements to this product are addressed at the European level, but rather at a national level in the countries where this product has a strong presence to be of concern. As a result, this product shall not be considered in Task 6 for improvement options or in Task 7 for improvement potential.

This base case represents significant GHG emissions in countries where this product type is popular. It is recommended that the relevant national bodies look to promote the phasing out of coal based room heating appliances while favouring renewable fuel alternatives as a mechanism to reduce their national GHG emissions. This should be done with prudence and in a manner that the 'renewability' of biomass fuels is maintained. It has been estimated that each coal stove emits **over 15 times more CO_2 eq**. throughout its lifetime than an equivalent wood stove (estimated at 38 tonnes of CO_2 eq. for a coal stove, while an equivalent wood stove emits only 2.3 tonnes of CO_2 eq.) with equivalent lifetime estimates and usage. Furthermore, it was found that the life cycle costs of heating with mineral fuels is greater than that for biomass fuels, and as such switching to biomass fuels from mineral fuels will likely result in a reduction of LCC for the consumer.

➔ **BASE CASE 12: NON-DOMESTIC WOOD CHIP BOILER**

The base case for the non-domestic wood chip boiler also represents significant energy use, significant emissions and improvement potential. Nevertheless, the industrial chip boiler base case represents such a diverse product group that the results are only considered relevant and useful in the context of a simplified LCA for estimating environmental impacts on a European scale.

As a result, the non domestic chip boiler base case is **not recommended** for considerations towards implementing measures as a direct result of this study. However, this base case will be considered for improvement options in Task 6 and estimates for the improvement potential will be considered in Task 7 as it is still useful to understand the magnitude of energy savings potentially available.

The problem comes in translating the energy savings potentials into real, enforceable regulations. A more detailed, specific study is required to create a substantial and useful technical base from which regulations can be developed for these products, for example, on a national basis. Their application is different than the rest of the products in the scope of this study (specifically non-domestic) and hence justifies this. For example, these boilers have a much more diverse range of fuels than those chosen to be represented in this study including waste, straws and other agricultural by-products, all coal types, and even mixtures of coals, wastes, biomass etc. The most common fuels used by these products are regionally specific. Regulations on a European scale for such localised diversity is not reasonable given the scope of this study and can be better addressed outside of the Eco-design Directive. Moreover, the Eco-design Directive is oriented towards improving mass produced products for consumers. This base case represents products which exist in the grey area between 'products' which are mass produced for the general public and 'systems' which are specifically designed to be built and operated at a particular site by trained individuals.

5.7.2. SUPPLEMENTARY COMMENTS

The analysis in Task 5 does not represent real appliances and was never intended to, and no conclusions about actual appliances' performance can be drawn based on the data above. It is valid exclusively in the context of this study (European wide averages across multiple appliance types applied in multiple climates, cultures and geographies) and has been developed with a strictly theoretical approach that does not represent any real physical processes. It was developed for comparison of BCs with BATs and improvement options and hence is valid only to this end.

→ MANAGING PRODUCT DIVERSITY IN LOT 15

Furthermore, it should be noted that due to the wide variety of appliances available in the solid fuel SCI market and to the diversity in their use, a very diverse spectrum of base cases was required for effective representation. This could be considered a deviation from other EuP Eco-design studies, where a much narrower market scope is analysed, and the base cases are correspondingly less diverse. A key consequence of this point is that the base cases are not to be considered interchangeable in this study. Replacing one base case with another is not an effective means for reducing the environmental impacts associated with these appliances, as the base cases often serve different purposes. This poses extra challenges in the subsequent tasks which look towards potential improvement options and should be kept in mind at all times.

One possible means by which one could address the extraordinary diversity of products included in the scope of this study is by splitting the remaining legislative work after this preparatory study into further refined and narrow sub-lots, based mainly on their functionality. One proposition based on the technical and market expertise accumulated throughout this study is as follows:

- **Lot 15 A** – Solid fuel small domestic boilers (Base cases 8 -12)

  The technical constraints of products under these base cases and the industry itself are different than those of the direct heating industry. As more work has occurred towards regulation of central heating (CH) boilers under the EuP Lot 1 study, it would be convenient for the remaining legislative work to proceed for Lot 15 A products in manner which is parallel to the Lot 1 products. The harmonised standard for this product group is EN 303-5. Care must be taken to ensure that this integration between Lot 15 and Lot 1 occurs in a manner which does not neglect existing or concurrent work in the Lot 15 industry, and acknowledges the sometimes different product characteristics and intended function of products under the respective scopes of Lot 15 and Lot 1 (ie. Lot 15 extends beyond domestic heating which was the limit of scope for Lot 1).

- **Lot 15 B** – Solid fuel direct heating appliances (Base cases 2 – 7)

  These products are typically smaller and simpler in their construction and design and hence justify being analysed and regulated separately from the Lot 15 indirect heating products. This product group includes appliances covered under EN 13229, EN 13240, EN 12815, EN 15250 and EN 14875. This product grouping includes direct heating appliances and direct heating appliances with a boiler for central heating or hot water heating functions (as described in the respective EN standards). Open fires are not included in this grouping for reasons discussed in section 0

- **Lot 15 C** – Open fired solid fuel direct heating appliances (Base case 1)

  Open fire appliances (without fire doors as defined in EN 13229) not covered in Lot 15 B have been studied in this Task 5 document. However, they have been found unsuitable for improvement analysis and are not recommended as a product group for regulation under the Eco-design Directive. Other legislative tools may be better suited to address improving the environmental performance of open fire appliances (promoting fireplace inserts as a replacement for open fireplaces).

This is merely a suggestion, which may be useful for the impact assessment study, based on what is currently considered feasible. It does not impact the preparatory study or any of the remaining tasks within.

➔ MANAGING MEASUREMENT DISCREPANCIES

It is not the task of this study to judge, nor recommend solutions to the discrepancies found between different measurement methods for emissions (e.g. particulate matter). This study has applied one method of measurement for self-consistency and simplicity but does not endorse this method as the solution to all the measurement problems currently experienced in the industry.

In the hopes of making as much quick progress as possible towards reducing emissions of solid fuel combustion systems, it is recommended that the most widespread and readily available measurement method is adopted on a temporary basis. This does not imply the that same measurement method should be applied for all regulations or product types, but that each policy should take into account the measurement method that is most appropriate in the short term for each product type applicable.

Once a harmonised, scientifically accurate, and commercially acceptable method has been adopted, all standards and policies should then be realigned to this method.

5.8. ANNEX – TASK 5

Table 5-39: Organisation of appliance groups relevant to Lot 15 in Tasks 1 to Task 4 with sales representation (2007 data)

Task 1	Tasks 2-3	Task 4	Stock (2006) # units	Market share total (2006)	Sales
Fireplace	Open fireplace	Open fireplace	16 000 000	50%	849 000
	Insert/closed fireplace	Insert Insert + IIary air Closed fireplace Closed fireplace + IIary air	16 000 000	25% <1% 25% <1%	849 000
Cookers	Cookers	Traditional cooker Advanced cooker	7 594 000	>80% <20%	464 200
Stoves	Slow heat release stove	Kachelofen Slow heat release stove	6 000 000	5% 18%	300 000
	Stove	Traditional stove Modern stove Continuous burning stove Advanced stove	19 266 000	40% 20% <5% 10%	737 200
	Pellet stove	Pellet stove	634 900	< 2.5%	176 500
Boilers <50kW	Hand stoked	Conventional, overfeed Conventional + Iary air Advanced, gravity feed (x4) Downdraught (gasifying) x4	7 217 492	15%	187 800
	Automatically stoked	Stoker Push-down Pellet		20%	46 950
Boilers 50-500kW	Hand stoked	Advanced, gravity feed (x4) Conventional + IIary air Downdraught (gasifying) x4	628 608	5%	62 600
	Automatically stoked	Stoker, underfeed boilers Pellet boiler Moving grate (overfeed stoker) Underfeed rotating grate		60%	15 650

Table 5-40: Material environmental impacts as used for the bill of materials in Eco-report per gram of material

		Gross Energy [MJ]	Elec [MJ]	Feedstock Energy [MJ]	Process Water (L)	Cooling Water [L]	Haz Waste [g]	Non-Haz Waste [g]	GWP [kg CO2 eqv]	Acidification Pot. [g SO2 eq]	VOC [g]	POP [ng I-Teq]	HM [mg Ni eq]	PAH [mg Ni eq.]	PM [g]	HMw [mg Hg/20]	EP [g PO4]
1	LDPE	77.8	13.3	51.5	3.0	45.0	4.4	44.2	1.9	7.4	0.5	0.0	0.0	0.1	0.9	0.0	26.6
21	St sheet galv.	34.0	2.3	0.1	0.0		0.0	1721.5	2.8	7.5	0.1	26.0	3.5	0.1	2.7	3.6	65.2
23	Cast iron	10.0	0.1	-0.1	1.3	3.7	0.0	315.4	1.1	3.2	0.1	6.0	2.0	0.0	14.0	0.9	26.2
30	Cu tube/sheet	50.9	0.0	0.0	0.0		0.0	8014.0	2.7	62.6	0.0	10.3	33.1	5.4	1.5	37.7	61.9
39	powder coating	357.2	61.3	42.6	19.0	384.0	20.7	491.8	17.8	63.0	0.0	0.5	1.3	0.3	15.4	0.5	9652.1
98	Avg. controller board	781.5	579.5	3.0	523.4	105.6	652.4	1679.7	51.5	437.4	6.5	6.4	73.5	60.4	22.4	333.3	4702.1
85	Refractory Ceramics	5.6	1.9	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
54	Glass for lamps	16.2	12.9	0.0	8.5	0.0	0.3	13.5	0.8	3.0	0.0	0.1	0.2	0.0	0.1	0.0	0.4