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Lot 15

Solid fuel small combustion installations

Task 7: Improvement Potential

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POLITECHNIKA ŚLĄSKA

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7. Task 7 – Improvement Options

Task 7 consists of identifying the design improvement options, quantifying the influence they have on environmental impacts and monetising them in terms of Life Cycle Costs (LCC) for the consumer. Finally, one or more solutions of Best Available Technology (BAT) and with Least Life Cycle Cost (LLCC) needs to be identified.

Key technical improvement options will be identified on the basis of technology development and research to be introduced under Task 6. Such options will be described, listing their environmental improvement potential, feasibility for different types of solid fuel SCIs, and the associated costs.

7.1. DESCRIPTION OF IMPROVEMENT OPTIONS

The options considered in this task are based on the options described in Task 6. All the component options described in Task 6 (see Section 6.2) have undergone a preliminary analysis and screening, so that only the most relevant improvement options are considered (in terms of Least Life Cycle Costs). Thus component options which are clearly not competitive LLCC or BAT candidates are removed from the analysis.

7.1.1. BOILER / HEAT STORAGE

Boiler and heat storage components are already a significant portion of the market for some Member States in Europe like the UK. They represent a mix of products including both wet and dry heat storage and transfer mechanisms.

A ‘wet’ heat storage device, such as a boiler or back-boiler, can be part of the design for almost any direct heating appliance and can improve both the efficiency and heat distribution capacity of the appliance.

A ‘dry’ heat storage device mainly refers to refractory ceramics and other similar thermal masses introduced into the combustion system of an appliance during the design phase and can significantly improve the efficiency of the appliance.

The slow heat release base case and all boiler base cases already have this design component included in their design.

7.1.2. LAMBDA PROBE CONTROL

Two combustion management options were identified in Task 6: lambda probes and room temperature controls. Both options were considered to have limited impacts on the performance of the appliances operating in normal (standard) conditions. However, lambda probes allow a significant reduction of CO emissions.

An additional combustion management option is air staging, or the improved distribution of primary and secondary air. Improved air distribution can significantly improve the performance of appliances, although this improvement has not been explicitly considered in Task 6, since it does not involve any specific component, but rather consists of an overall improvement of the design of the appliances. Another related, and often associated improvement, is the better design of the combustion chamber, which may include ceramic lining to increase its heat storage and insulation capacity (considered under heat recovery options in Task 6). Based on expert opinion and product research, the efficiency of appliances with improved air distribution/combustion chamber can be estimated to increase by 5 – 15%. Emissions to air are reduced accordingly. Therefore, given that the BCs represent rather minimum emissions, the improved air distribution/combustion chamber option was considered to improve the efficiency of appliances by 15%, but to have no further impacts (on the BOM, electricity consumption, price, or product lifetime) compared to the BCs.

Lambda probes were considered as combustion management improvement options and will be included in this analysis. Air staging and distribution is considered an overall design feature of an appliance rather than a specific component which can be introduced to an appliance's design, therefore it will not be included in the analysis. Room control loops were judged to be more a convenience solution for the user than an improvement option for the appliance, and were not considered further.

7.1.3. ESP

Four after-treatment options were considered in Task 6: catalyst, electrostatic precipitator (ESP), high efficiency cyclone and fabric filter. All four options can significantly reduce PM emissions (by up to 90%), and catalysts can also reduce CO and OGC emissions. ESPs, cyclones and fabric filters serve the same function.

All after-treatment options are considered inapplicable to the products in the scope of the Lot 15 study except the ESP (as discussed in Task 6). ESPs are therefore the after treatment option considered in Task 7.

7.1.4. Condensation heat recovery

Improvement to heat recovery products were presented in Task 6 and of the various design upgrades discussed, only condensation heat recovery was considered a valid improvement option under the goals of the eco-design directive.

As described in Task 6, condensation heat recovery heat exchangers are becoming a more feasible solution for improving the heat recovery of the boiler products in the Lot 15 study. These will be considered only for indirect heating products as they are not yet applicable to boiler products for stoves or fireplaces.

7.1.5. Overview of improvement options

An overview of the applicability of the different component options to the each of the Base Cases is shown in Table 7-1.

Table 7-1: Matrix of component options to be considered against Base Cases

		Component			
		1	2	3	4
		Boiler/heat storage	Lambda probe control	ESP *	Condensation heat recovery
BC 1	OPEN FIREPLACE				
BC 2	CLOSED FIREPLACE / INSERT	✓		✓	
BC 3	WOOD STOVE	✓		✓	
BC 4	COAL STOVE	✓		✓	
BC 5	COOKER	✓		✓	
BC 6	SHR STOVE	-		✓	
BC 7	PELLET STOVE	✓		✓	
BC 8	DOM. BOILER - UPPERFIRE	-	✓	✓	
BC 9	DOM. BOILER - DOWNDRAUGHT	-	✓	✓	✓
BC 10	COAL BOILER	-	✓	✓	
BC 11	PELLET BOILER	-	✓	✓	✓
BC 12	CHIP BOILER	-	✓	✓	✓

'-' signifies the base case is assumed to already include this design option
* ESP is available as a retrofit option for stock also

The applicability of the different BAT product options to each of the Base Case is shown in Table 7-2.

Some BATs have been chosen to represent multiple BCs. This is because new products are slow to penetrate the European market, given the long life time of solid fuel SCIs. Thus Base Cases often represent older type appliances, for which better replacement products are already available. There are a few instances where the type, and potential functionality of the appliance, is different between the BCs and the BATs. While these differences are acknowledged, for the purpose of this EU-wide study, replacement of one appliance by the other is a possibility.

Table 7-2: Matrix of Base Cases that are replaceable by Product Cases

		BC 1	BC 2	BC 3	BC 4	BC 5	BC 6	BC 7	BC 8	BC 9	BC 10	BC 11	BC 12
		OPEN FP	CL FP/ INSERT	WOOD STOVE	COAL STOVE	COOKER	SHR STOVE	PELLET STOVE	DOM. BOILER CONV	DOM. BOILER DD GSFY.	COAL BOILER	PELLET BOILER	CHIP BOILER
BAT 1	Closed fireplace, fireplace insert	✓	✓										
BAT 2	Advanced stove			✓									
BAT 3	Advanced cooker					✓							
BAT 4	Slow heat release stove						✓						
BAT 5	Pellet stove							✓					
BAT 6	Pellet boiler											✓	
BAT 7	Downdraught gasifying boiler								✓	✓			
BAT 8	Stoker boiler, coal										✓		
BAT 9	Chips boiler												✓

7.1.6. MODELLING THE ENVIRONMENTAL IMPACTS OF THE OPTIONS

The method of modelling the environmental impacts associated with each option is:

- **Component cases**: for each component option, changes in the BOM, emissions, electricity consumption, and emissions were those estimated in Task 6, Table 6.21.
- **Product cases**: each Product Case was associated to an efficiency, a BOM, emissions representative of CO, PM and OGC, electricity consumption where relevant, and a purchase cost (summarised in Task 6, Table 6.20). These data were developed based on expert opinion, stakeholder questionnaires, and market research. The set of emissions was used to develop an "appliance factor" similar to the method used in Task 5 for the Base Cases. These appliance factors were then multiplied by fuel inventories to estimate the environmental impacts of each product case in a manner which is comparable to the base cases.

7.2. ENVIRONMENTAL IMPACTS

The reduction in environmental impacts obtained by implementing various improvement options (component options) in average EU appliances (Base Cases) is calculated using the EcoReport tool. The results obtained by adding each applicable component option to the Base Cases are listed in the sub-sections below. These results are discussed in Section 7.4. , together with the results of the combined improvement options.

7.2.1. Base case 1: Open Fireplace

The environmental impacts of the improvement options compared to BC1 and applicable BAT options are shown in Table 7-3.

Table 7-3: Life cycle improvements for BC1 - open fireplace with wood logs per GJ of space heat provided

	UNIT	BC1	BAT1
Resources Use			
Total Energy (GER)	MJ	4280	1539
of which, electricity	MJ	13	27
Water (process)*	L	0,7	0,3
Waste, non-haz./ landfill*	g	3533	4816
Waste, hazardous/ incinerated*	g	0,2	0,2
Emissions (Air)			
Greenhouse Gases in GWP100	kg CO2eq.	26	17
Acidifying agents (AP)	g SO2 eq.	562	214
Volatile Org. Compounds (VOC)	g	90	9
Persistent Org. Pollutants (POP)	ng i-Teq	471	214
Heavy Metals (HM)	mg Ni eq.	178	79
PAHs	mg Ni eq.	1103	368
Particulate Matter (PM, dust)	g	545	131
Emissions (Water)			
Heavy Metals (HM)	mg Hg/20	0,97	7,40
Eutrophication (EP)	g PO4	0,02	0,15

7.2.2. BASE CASE 2: CLOSED FIREPLACE/INSERT

The environmental impacts of the improvement options compared to BC2 and applicable BAT options are shown in Table 7-4.

Table 7-4: Life cycle improvements for BC2 - closed fireplace with wood logs per GJ of space heat provided

	UNIT	BC2	BC2 C1 C3	BC2 C1	BC2 C3	BAT1 B
Resources Use						
Total Energy (GER)	MJ	1665	1708	1696	1677	1445
of which, electricity	MJ	15	39	29	25	9
Water (process)*	L	1,8	5,7	1,9	5,6	0,1
Waste, non-haz./ landfill*	g	2169	4130	4064	2235	2211
Waste, hazardous/ incinerated*	g	0,7	5,1	0,7	5,1	0,1
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2eq.	12	16	15	12	10
Acidifying agents (AP)	g SO2 eq.	227	241	236	231	193
Volatile Org. Compounds (VOC)	g	32	31	31	32	9
Persistent Org. Pollutants (POP)	ng i-Teq	195	223	222	195	173
Heavy Metals (HM)	mg Ni eq.	136	147	146	137	65
PAHs	mg Ni eq.	424	418	418	425	367
Particulate Matter (PM, dust)	g	209	97	112	94	76
Emissions (Water)						
Heavy Metals (HM)	mg Hg/20	2,63	8,71	6,38	4,96	2,30
Eutrophication (EP)	g PO4	0,36	0,47	0,43	0,39	0,05

7.2.3. BASE CASE 3: STOVE

The environmental impacts of the improvement options compared to BC3 and applicable BAT options are shown in Table 7-5.

Table 7-5: Life cycle improvements for BC3 – wood stove per GJ of space heat provided

	UNIT	BC3	BC3 C1 C3	BC3 C1	BC3 C3	BAT2
Resources Use						
Total Energy (GER)	MJ	1639	1661	1651	1649	1423
of which, electricity	MJ	4	21	13	12	8
Water (process)*	L	1,0	3,7	1,1	3,7	0,1
Waste, non-haz./ landfill*	g	1510	2792	2747	1555	1842
Waste, hazardous/ incinerated*	g	0,1	3,1	0,1	3,1	0,1
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2eq.	10	13	12	11	9
Acidifying agents (AP)	g SO2 eq.	218	227	223	222	189
Volatile Org. Compounds (VOC)	g	31	31	31	32	8
Persistent Org. Pollutants (POP)	ng i-Teq	184	202	201	185	166
Heavy Metals (HM)	mg Ni eq.	86	92	92	87	62
PAHs	mg Ni eq.	424	418	418	424	363
Particulate Matter (PM, dust)	g	207	94	109	92	66
Emissions (Water)						
Heavy Metals (HM)	mg Hg/20	0,88	4,88	3,34	2,42	1,60
Eutrophication (EP)	g PO4	0,10	0,17	0,15	0,12	0,03

7.2.4. BASE CASE 5: COOKER

The environmental impacts of the improvement options compared to BC5 and applicable BAT options are shown in Table 7-6.

Table 7-6: Life cycle improvements for BC5 – Cooker with wood logs per GJ of space heat provided

	UNIT	BC5	BC5 C1 C3	BC5 C1	BC5 C3	BAT3
Resources Use						
Total Energy (GER)	MJ	1905	2009	1995	1919	1547
of which, electricity	MJ	43	79	71	51	28
Water (process)*	L	1,7	9,3	2,0	9,0	0,4
Waste, non-haz./ landfill*	g	4882	9026	8902	5007	4912
Waste, hazardous/ incinerated*	g	0,7	9,8	0,7	9,8	0,3
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2eq.	19	28	28	20	17
Acidifying agents (AP)	g SO2 eq.	270	300	294	277	215
Volatile Org. Compounds (VOC)	g	41	41	41	41	10
Persistent Org. Pollutants (POP)	ng i-Teq	251	313	312	252	216
Heavy Metals (HM)	mg Ni eq.	227	250	248	229	80
PAHs	mg Ni eq.	461	455	454	461	369
Particulate Matter (PM, dust)	g	304	181	199	174	180
Emissions (Water)						
Heavy Metals (HM)	mg Hg/20	7,84	20,58	15,75	12,67	7,59
Eutrophication (EP)	g PO4	0,80	1,03	0,96	0,87	0,15

7.2.5. BASE CASE 6: SLOW HEAT RELEASE STOVE

The environmental impacts of the improvement options compared to BC6 and applicable BAT options are shown in Table 7-7.

Table 7-7: Life cycle improvements for BC6 – slow heat release stoves with wood logs per GJ of space heat provided

	UNIT	BC6	BC6 C3
Resources Use			
Total Energy (GER)	MJ	1423	1647
of which, electricity	MJ	5	11
Water (process)*	L	0,2	1,4
Waste, non-haz./ landfill*	g	1089	1269
Waste, hazardous/ incinerated*	g	0,0	1,2
Emissions (Air)			
Greenhouse Gases in GWP100	kg CO2eq.	8	10
Acidifying agents (AP)	g SO2 eq.	186	217
Volatile Org. Compounds (VOC)	g	18	31
Persistent Org. Pollutants (POP)	ng i-Teq	156	180
Heavy Metals (HM)	mg Ni eq.	59	68
PAHs	mg Ni eq.	368	424
Particulate Matter (PM, dust)	g	150	81
Emissions (Water)			
Heavy Metals (HM)	mg Hg/20	0,12	0,71
Eutrophication (EP)	g PO4	0,00	0,01

7.2.6. Base case 7: Pellet stove

The environmental impacts of the improvement options compared to BC7 and applicable BAT options are shown in Table 7-8.

Table 7-8: Life cycle improvement options for BC7 – pellet stove with wood pellets per GJ of space heat provided

	UNIT	BC7	BC7 C1 C3	BC7 C1	BC7 C3	BAT5
Resources Use						
Total Energy (GER)	MJ	1562	1603	1591	1574	1441
of which, electricity	MJ	28	50	40	37	18
Water (process)*	L	4,2	8,0	4,4	7,8	0,8
Waste, non-haz./ landfill*	g	1956	3808	3746	2018	1512
Waste, hazardous/ incinerated*	g	4,1	8,3	4,1	8,3	0,3
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2eq.	16	20	19	17	14
Acidifying agents (AP)	g SO2 eq.	150	165	160	155	132
Volatile Org. Compounds (VOC)	g	5	5	5	5	3
Persistent Org. Pollutants (POP)	ng i-Teq	377	401	400	378	348
Heavy Metals (HM)	mg Ni eq.	109	119	118	110	67
PAHs	mg Ni eq.	289	285	285	290	269
Particulate Matter (PM, dust)	g	45	36	38	32	31
Emissions (Water)						
Heavy Metals (HM)	mg Hg/20	4,96	10,66	8,48	7,15	2,31
Eutrophication (EP)	g PO4	0,28	0,38	0,35	0,31	0,05

7.2.7. Base case 8: Conventional domestic boiler

The environmental impacts of the improvement options compared to BC8 and applicable BAT options are shown in Table 7-9.

Table 7-9: Life cycle improvement options for BC8 – Conventional domestic boiler with wood logs per GJ of space heat provided

	UNIT	BC8	BC8 C2 C3	BC8 C2	BC8 C3	BAT 7
Resources Use						
Total Energy (GER)	MJ	2139	2125	2118	2146	1452
of which, electricity	MJ	21	28	21	27	18
Water (process)*	L	1,2	2,3	1,5	2,1	1,4
Waste, non-haz./ landfill*	g	2126	2126	2111	2141	1549
Waste, hazardous/ incinerated*	g	0,4	1,4	0,7	1,1	0,9
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2eq.	13	13	13	13	9
Acidifying agents (AP)	g SO2 eq.	285	284	282	287	194
Volatile Org. Compounds (VOC)	g	38	38	38	38	1
Persistent Org. Pollutants (POP)	ng i-Teq	241	239	239	241	165
Heavy Metals (HM)	mg Ni eq.	98	97	97	98	62
PAHs	mg Ni eq.	551	546	546	551	372
Particulate Matter (PM, dust)	g	201	73	199	74	45
Emissions (Water)						
Heavy Metals (HM)	mg Hg/20	1,24	1,73	1,39	1,59	1,30
Eutrophication (EP)	g PO4	0,06	0,06	0,06	0,06	0,02

7.2.8. Base case 9 : Downdraught gasifying domestic boiler

The environmental impacts of the improvement options compared to BC9 and applicable BAT options are shown in Table 7-10.

Table 7-10: Life cycle improvement options for BC8 – Conventional domestic boiler with wood logs per GJ of space heat provided

	UNIT	BC9	BC9 C2 C3 C4	BC9 C2 C4	BC9 C2	BC9 C3	BC9 C4	BAT7
Resources Use								
Total Energy (GER)	MJ	1633	1403	1396	1617	1639	1410	1452
of which, electricity	MJ	22	28	22	22	28	22	18
Water (process)*	L	2,4	3,4	2,6	2,6	3,2	2,4	1,4
Waste, non-haz./ landfill*	g	1903	1748	1734	1892	1917	1744	1549
Waste, hazardous/ incinerated*	g	2,3	3,2	2,5	2,5	2,9	2,3	0,9
Emissions (Air)								
Greenhouse Gases in GWP100	kg CO2eq.	10	9	9	10	10	9	9
Acidifying agents (AP)	g SO2 eq.	220	191	189	218	221	190	194
Volatile Org. Compounds (VOC)	g	1	0	0	1	1	0	1
Persistent Org. Pollutants (POP)	ng i-Teq	187	161	160	185	187	162	165
Heavy Metals (HM)	mg Ni eq.	78	68	68	77	78	68	62
PAHs	mg Ni eq.	418	356	356	414	418	359	372
Particulate Matter (PM, dust)	g	60	21	33	59	24	33	45
Emissions (Water)								
Heavy Metals (HM)	mg Hg/20	2,43	2,89	2,58	2,57	2,75	2,44	1,30
Eutrophication (EP)	g PO4	0,07	0,08	0,07	0,07	0,08	0,07	0,02

7.2.9. Base case 10: Retort coal boiler

The environmental impacts of the improvement options compared to BC10 and applicable BAT options are shown in Table 7-11.

Table 7-11: Life cycle improvement options for BC8 – Retort coal boiler with coal per GJ of space heat provided

	UNIT	BC10	BC10 C2 C3	BC10 C2	BC10 C3	BAT8
Resources Use						
Total Energy (GER)	MJ	1735	1724	1718	1741	1543
of which, electricity	MJ	17	24	18	24	17
Water (process)*	L	1,1	1,9	1,3	1,8	1,3
Waste, non-haz./ landfill*	g	2314	2307	2296	2325	2036
Waste, hazardous/ incinerated*	g	0,5	1,2	0,7	1,0	0,7
Emissions (Air)						
Greenhouse Gases in GWP100	kg CO2eq.	150	147	147	150	133
Acidifying agents (AP)	g SO2 eq.	904	897	895	906	804
Volatile Org. Compounds (VOC)	g	29	29	29	29	28
Persistent Org. Pollutants (POP)	ng i-Teq	890	881	881	890	791
Heavy Metals (HM)	mg Ni eq.	916	907	907	917	815
PAHs	mg Ni eq.	85	85	84	85	76
Particulate Matter (PM, dust)	g	147	54	145	54	113
Emissions (Water)						
Heavy Metals (HM)	mg Hg/20	1,11	1,44	1,21	1,35	1,05
Eutrophication (EP)	g PO4	0,02	0,02	0,02	0,02	0,02

7.2.10. BASE CASE 11: PELLET BOILER

The environmental impacts of the improvement options compared to BC11 and applicable BAT options are shown in Table 7-12.

Table 7-12: Life cycle improvement options for BC8 –Pellet boiler with pellets per GJ of space heat provided

	UNIT	BC11	BC11 C2 C3 C4	BC11 C2 C4	BC11 C2	BC11 C3	BC11 C4	BAT6
Resources Use								
Total Energy (GER)	MJ	1790	1536	1530	1773	1797	1545	1642
of which, electricity	MJ	25	32	26	26	32	25	20
Water (process)*	L	2,3	3,1	2,4	2,4	3,0	2,3	1,5
Waste, non-haz./ landfill*	g	966	916	904	962	978	907	772
Waste, hazardous/ incinerated*	g	1,5	2,2	1,7	1,7	2,0	1,5	0,8
Emissions (Air)								
Greenhouse Gases in GWP100	kg CO2eq.	15	14	13	15	16	14	14
Acidifying agents (AP)	g SO2 eq.	163	142	141	162	165	142	147
Volatile Org. Compounds (VOC)	g	6	1	1	6	6	1	3
Persistent Org. Pollutants (POP)	ng i-Teq	424	362	362	419	424	365	388
Heavy Metals (HM)	mg Ni eq.	108	97	97	107	108	97	72
PAHs	mg Ni eq.	339	289	289	336	339	292	312
Particulate Matter (PM, dust)	g	20	9	12	20	10	12	11
Emissions (Water)								
Heavy Metals (HM)	mg Hg/20	1,90	2,24	2,00	2,00	2,13	1,91	0,97
Eutrophication (EP)	g PO4	0,17	0,17	0,17	0,17	0,17	0,17	0,02

7.2.11. BASE CASE 12: NON DOMESTIC BOILER

The environmental impacts of the improvement options compared to BC12 and applicable BAT options are shown in Table 7-13.

Table 7-13: Life cycle improvement options for BC8 – Non domestic chip boiler with wood chips per GJ of space heat provided

	UNIT	BC12	BC12 C2 C3 C4	BC12 C2 C4	BC12 C2	BC12 C3	BC12 C4	BAT9
Resources Use								
Total Energy (GER)	MJ	1568	1343	1337	1552	1574	1350	1463
of which, electricity	MJ	10	16	10	10	16	10	8
Water (process)*	L	0,8	1,3	0,9	0,9	1,3	0,8	0,5
Waste, non-haz./ landfill*	g	1631	1422	1414	1617	1639	1426	1528
Waste, hazardous/ incinerated*	g	0,8	1,0	0,8	0,8	1,0	0,8	0,2
Emissions (Air)								
Greenhouse Gases in GWP100	kg CO2eq.	5	5	5	5	6	5	5
Acidifying agents (AP)	g SO2 eq.	149	129	128	148	151	129	139
Volatile Org. Compounds (VOC)	g	1	0	0	1	1	0	1
Persistent Org. Pollutants (POP)	ng i-Teq	218	186	186	216	218	188	204
Heavy Metals (HM)	mg Ni eq.	79	69	69	78	79	69	65
PAHs	mg Ni eq.	376	320	320	373	376	324	351
Particulate Matter (PM, dust)	g	18	6	10	18	7	10	11
Emissions (Water)								
Heavy Metals (HM)	mg Hg/20	0,61	0,69	0,62	0,62	0,68	0,61	0,37
Eutrophication (EP)	g PO4	0,05	0,05	0,05	0,05	0,05	0,05	0,01

7.2.12. COMPARISON OF ENVIRONMENTAL IMPACTS BY INDICATOR

Based on the above analyses, the changes observed to each of the environmental indicators for wood stoves and downdraught gasifying domestic boilers is shown in Figure 7-1 and Figure 7-2 respectively.

It can be seen that some environmental indicators change in similar proportions compared to the BCs, and are correlated to GER, Total energy consumption. Other indicators are more closely tied to specific material and increase as material use increases. Since fuel consumption is responsible for most of the significant environmental impacts of solid fuel SCIs (see Task 5) the most significant environmental indicators follow the changes of GER. PM does not always follow GER as closely as ESP specifically targets the reduction of PM.

Therefore the environmental analyses will discuss specifically the impacts on GER and on PM emissions, given the importance of emissions to air for solid fuel SCIs.

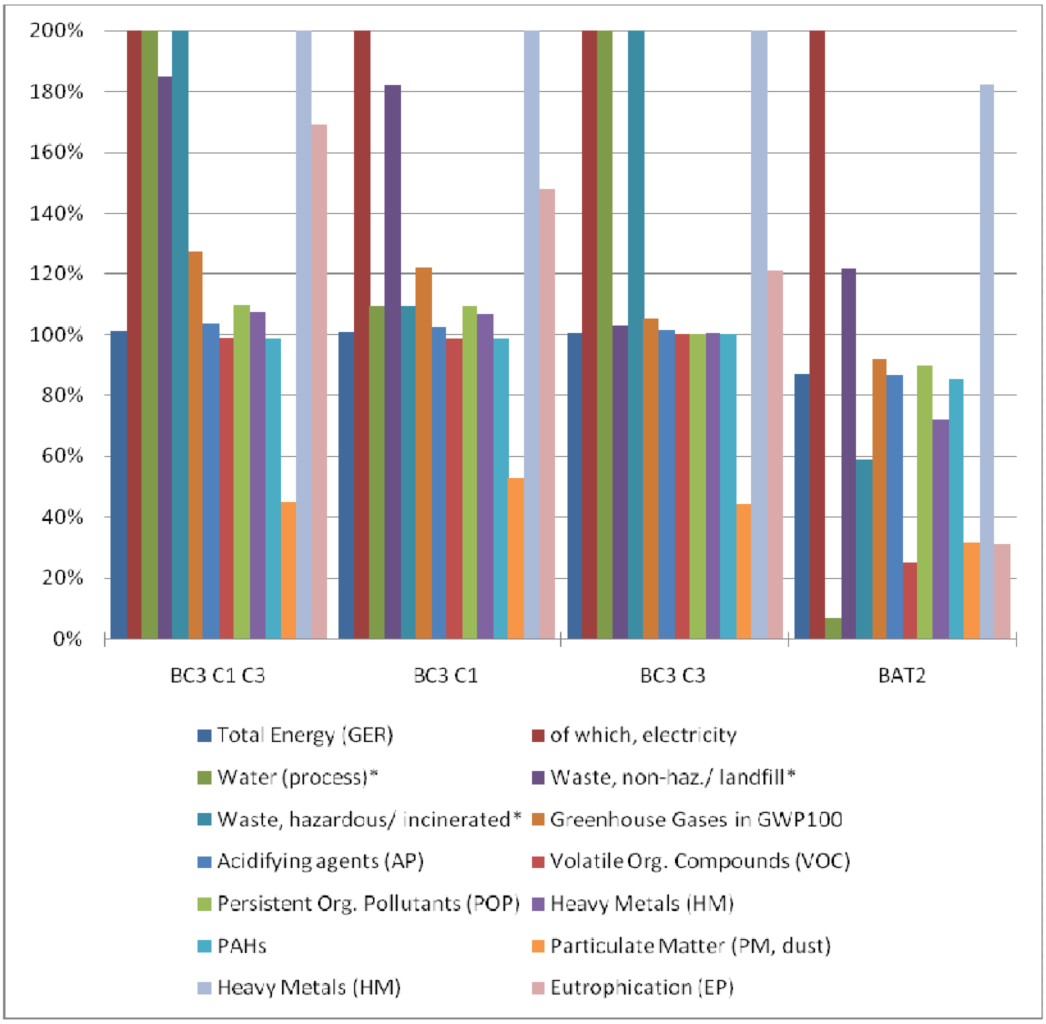

Figure 7-1: Typical changes to environmental impacts for components for wood stove

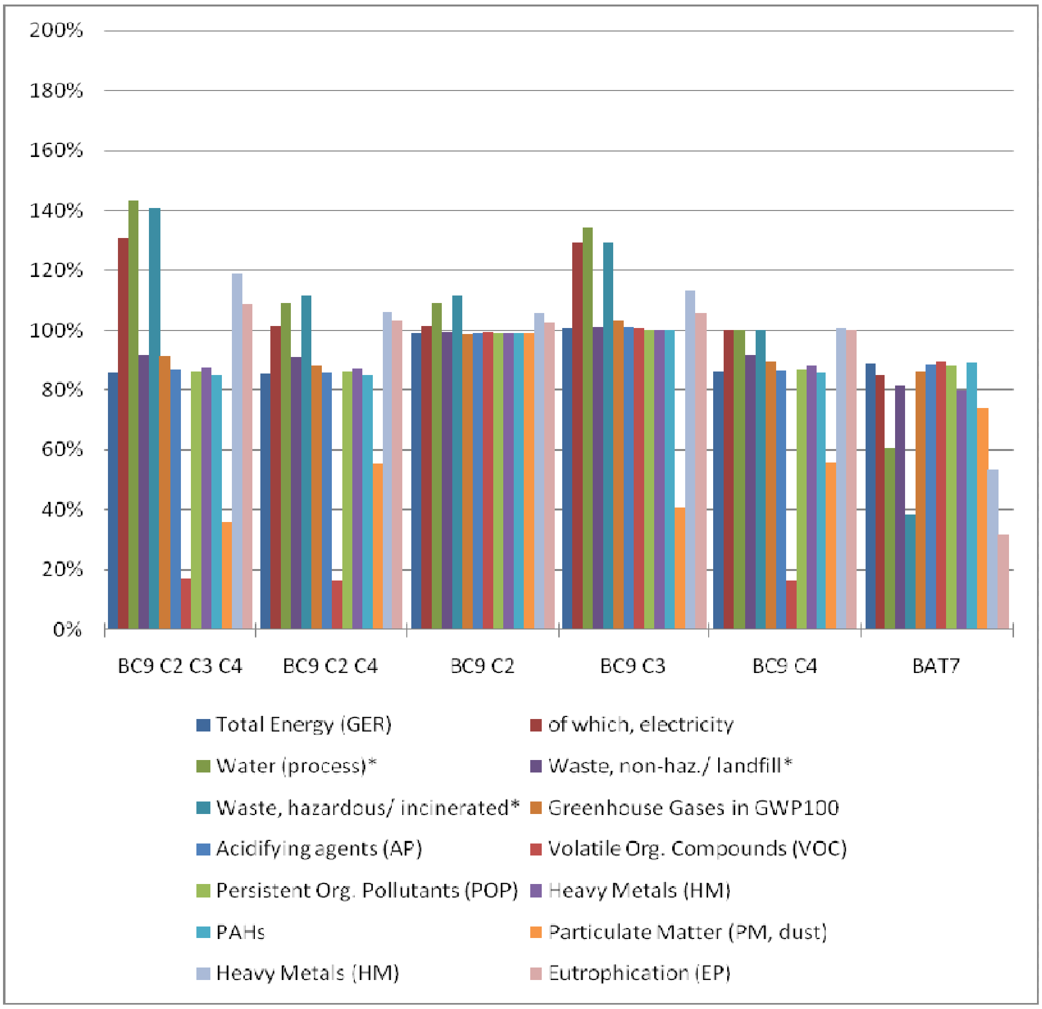

Figure 7-2 Changes to environmental impacts for downdraught gasifying domestic boiler

7.3. LIFE CYCLE COSTS

The impact of implementing various improvement options to average EU products (base cases) were calculated in terms of Life Cycle Cost (LCC) using the EcoReport tool. The resulting LCC per improvement option are listed below for each Base Case.

As already calculated for the base cases in Task 5, the LCC for solid fuel SCIs is equal to: "Product cost + fuel cost +electricity cost" (no repair / installation cost). Therefore, implementing an option which affects the solid fuel SCI's cost, fuel use or electricity use, will affect the LCC.

The results will be discussed in Section 7.4.

7.3.1. BASE CASE 1: OPEN FIREPLACE

Table 7-14 presents the LCC for BC1 (open fireplaces), the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-14: Life cycle costs comparison for open fireplace and fireplace insert (BAT1)

	UNIT	BC1	BAT1
LC Cost	EUR	4111	3384
LC Cost per GJ of space heat	EUR/GJ	86	71
Percent LCC relative to BC	%	100%	82%

7.3.2. Base case 2: Closed fireplace

Table 7-15 presents the LCC for BC2 (closed fireplaces), the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-15: Life cycle costs comparison for closed fireplace/insert, component options and fireplace insert BAT

	UNIT	BC2	BC2 C1 C3	BC2 C1	BC2 C3	BAT1 B
LC Cost	EUR	4538	8529	7018	6050	4290
LC Cost per GJ of space heat	EUR/GJ	30	56	46	39	28
Percent LCC relative to BC	%	100%	188%	155%	133%	95%

7.3.3. Base case 3: Wood stove

Table 7-16 presents the LCC for BC3 (wood stoves) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-16: Life cycle costs comparison for stoves, component options and advanced stove (BAT2)

	UNIT	BC3	BC3 C1 C3	BC3 C1	BC3 C3	BAT2
LC Cost	EUR	4878	8865	7348	6395	4892
LC Cost per GJ of space heat	EUR/GJ	21	38	31	27	21
Percent LCC relative to BC	%	100%	182%	151%	131%	100%

7.3.4. Base case 5: Cookers

Table 7-17 presents the LCC for BC5 (cookers) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-17: Life cycle costs comparison for cookers, component options and advanced cookers (BAT3)

	UNIT	BC4	BC5	BC5 C1 C3	BC5 C1	BC5 C3	BAT3
LC Cost	EUR	5425	4056	8046	6546	5556	4910
LC Cost per GJ of space heat	EUR/GJ	23	56	111	90	77	68
Percent LCC relative to BC	%	100%	100%	198%	161%	137%	121%

7.3.5. Base case 6: Slow heat release stove

Table 7-18 presents the LCC for BC6 (slow heat release stoves) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-18: Life cycle costs comparison for slow heat release stoves, component options and BAT slow heat release stoves (BAT4)

	UNIT	BC6	BC6 C3	BAT4
LC Cost	EUR	11803	14026	11517
LC Cost per GJ of space heat	EUR/GJ	19	22	18
Percent LCC relative to BC	%	100%	119%	98%

7.3.6. Base case 7: Pellet stoves

Table 7-19 presents the LCC for BC7 (pellets stove) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-19: Life cycle costs comparison for slow heat release stoves, component options and BAT for slow heat release stoves (BAT 4)

	UNIT	BC7	BC7 C1 C3	BC7 C1	BC7 C3	BAT5
LC Cost	EUR	5211	9191	7678	6724	5711
LC Cost per GJ of space heat	EUR/GJ	32	56	47	41	35
Percent LCC relative to BC	%	100%	176%	147%	129%	110%

7.3.7. Base case 8: Conventional domestic boiler

Table 7-20 presents the LCC for BC8 (conventional domestic boiler) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-20: Life cycle costs comparison for conventional domestic boiler, component options, and BAT downdraught gasifying boiler (BAT 7)

	UNIT	BC8	BC8 C2 C3	BC8 C2	BC8 C3	BAT 7
LC Cost	EUR	19048	21501	19914	20635	17994
LC Cost per GJ of space heat	EUR/GJ	17	19	18	18	16
Percent LCC relative to BC	%	100%	113%	105%	108%	94%

7.3.8. Base case 9: Downdraught gasifying domestic boiler

Table 7-21 presents the LCC for BC9 (Downdraught gasifying domestic boiler) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-21: Life cycle costs comparison for downdraught gasifying domestic boiler, component options and BAT downdraught gasifying domestic boiler (BAT 7)

	UNIT	BC9	BC9 C2 C3 C4	BC9 C2 C4	BC9 C2	BC9 C3	BC9 C4	BAT7
LC Cost	EUR	18921	20838	19241	19809	20518	18337	19003
LC Cost per GJ of space heat	EUR/GJ	15	17	15	16	16	15	15
Percent LCC relative to BC	%	100%	110%	102%	105%	108%	97%	100%

7.3.9. BASE CASE 10: RETORT COAL BOILER

Table 7-22 presents the LCC for BC10 (retort coal boiler) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-22: Life cycle costs comparison for retort coal boilers, component options and BAT coal boiler (BAT8)

	UNIT	BC10	BC10 C2 C3	BC10 C2	BC10 C3	BAT8
LC Cost	EUR	27562	29989	28353	29198	21760
LC Cost per GJ of space heat	EUR/GJ	15	17	16	16	12
Percent LCC relative to BC	%	100%	109%	103%	106%	79%

7.3.10. BASE CASE 11: PELLET BOILER

Table 7-24 presents the LCC for BC11 (pellet boilers) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-23: Life cycle costs comparison for pellet boilers, component options and BAT pellet boiler (BAT 6)

	UNIT	BC11	BC11 C2 C3 C4	BC11 C2 C4	BC11 C2	BC11 C3	BC11 C4	BAT6
LC Cost	EUR	36090	35740	34104	36823	37726	33334	34760
LC Cost per GJ of space heat	EUR/GJ	20	20	19	20	21	19	19
Percent LCC relative to BC	%	100%	99%	94%	102%	105%	92%	96%

7.3.11. BASE CASE 12: NON DOMESTIC CHIP BOILER

Table 7-24 presents the LCC for BC12 (non domestic boilers) the improvement options and BAT option assuming identical use patterns and lifetime.

Table 7-24: Life cycle costs comparison for nondomestic boiler, component options and nondomestic chip boiler (BAT 9)

	UNIT	BC12	BC12 C2 C3 C4	BC12 C2 C4	BC12 C2	BC12 C3	BC12 C4	BAT9
LC Cost	EUR	99860	95170	92798	100254	102232	92319	100793
LC Cost per GJ of space heat	EUR/GJ	9	8	8	9	9	8	9
Percent LCC relative to BC	%	100%	95%	93%	100%	102%	92%	101%

7.4. ANALYSIS LLCC AND BAT

The Least Life Cycle Costs (LLCC) analysis and BAT analysis assess the improvements on consumer expenditure and environmental impacts respectively, when implementing individual improvement or combinations of options. This analysis allows the identification of the lowest life cycle cost (LLCC) appliance, as well as of the appliance which has the lowest environmental impact.

The BAT analysis is based on the two main environmental indicators impacted by solid fuel SCIs, GER (Total energy) and PM. Typically, most environmental indicators are correlated to Total Energy (since fuel consumption is responsible for most of the environmental impacts). PM emissions are considered one of the most important emissions to air for solid fuel SCIs (at least in terms of health impacts), and they may often differ from total energy given that some after-treatment options specifically target PM abatement. Therefore, two sets of graphs are presented for each Base Case, GER (Total energy) and PM, each along with the LLCCs.

7.4.1. ENVIRONMENTAL IMPACTS SUMMARY

A summary of the gross energy requirement change for the improvement options on the Base Cases is presented in Table 7-25. Not every combination of components which has been calculated is shown below for the sake of presentation. Comparisons can only be made horizontally on this table as each base case has different life cycle parameters attributed to it for generation this information.

Table 7-25: Summary of the effects on gross energy requirement (GER) change for the improvement options on base cases

	Boiler / Heat Storage	Lambda probe control	ESP	Condensation heat recovery	Boiler / Heat Storage with ESP	Lambda probe control with ESP	Lambda probe control with Condensation heat recovery	Lambda probe control with ESP and Condensation heat recovery	Respective BAT product for each BC
	C1	C2	C3	C4	C1 C3	C2 C3	C2 C4	C2 C3 C4	BAT
BC 1 - Open Fireplace									36%
BC2 - Closed Fireplace / Insert	102%		101%		103%				87%
BC3 - Wood Stove	101%		101%		101%				87%
BC5 - Cooker	105%		101%		105%				81%
BC6 - Slow heat relase stove			116%						96%
BC7 - Pellet stove	102%		101%		103%				92%
BC 8 - Dom. Conventional boiler		99%	100%			99%			68%
BC 9 - D.D. Gasfy. Dom. Boiler		99%	100%	86%			86%	86%	89%
BC 10 - Coal Boiler		99%	100%			99%			89%
BC 11 - Pellet Boiler		99%	100%	86%			85%	86%	92%
BC 12 - Non Dom. Chip Boiler		99%	100%	86%			85%	86%	93%

Table 7-25 shows that the energy savings potential of many components is negligible or in fact increases the energy consumption. This is because ESP components are intended not to increase appliance efficiency, but to reduce the production of specific air emissions, specifically, PM, VOC and CO. Other components actually add energy consumption throughout the lifetime of the product because of the energy consumed during materials and manufacturing is not offset through energy savings.

A summary of the particulate matter change for the improvement options on the Base Cases is presented in Table 7-26. Not every combination of components which has been calculated is shown below for the sake of presentation. Comparisons can only be made horizontally on this table as each base case has different life cycle parameters attributed to it for generation this information.

Table 7-26: Summary of the effects on particulate matter (PM) change for the improvement options on base cases

	Boiler / Heat Storage C1	Lambda probe control C2	ESP C3	Condensation heat recovery C4	Boiler / Heat Storage with ESP C1 C3	Lambda probe control with ESP C2 C3	Lambda probe control with Condensation heat recovery C2 C4	Lambda probe control with ESP and Condensation heat recovery C2 C3 C4	Respective BAT product for each BC BAT
BC 1 - Open Fireplace									24%
BC2 - Closed Fireplace / Insert	54%		45%		46%				37%
BC3 - Wood Stove	53%		44%		45%				32%
BC5 - Cooker	65%		57%		60%				59%
BC6 - Slow heat relase stove			54%						46%
BC7 - Pellet stove	84%		73%		81%				69%
BC 8 - Dom. Conventional boiler		99%	37%			36%			22%
BC 9 - D.D. Gasfy. Dom. Boiler		99%	40%	56%			55%	36%	74%
BC 10 - Coal Boiler		99%	37%			36%			77%
BC 11 - Pellet Boiler		99%	49%	62%			62%	45%	57%
BC 12 - Non Dom. Chip Boiler		99%	40%	55%			55%	35%	61%

7.4.2. LEAST LIFE CYCLE COST SUMMARY

A summary of the life cycle cost change for the improvement options on the Base Cases is presented in Table 7-27. Not every combination of components which has been calculated is shown below for the sake of presentation. Comparisons can only be made horizontally on this table as each base case has different life cycle parameters attributed to it for generation this information.

Table 7-27: Summary of the effects on life cycle cost (LCC) change for the improvement options on base cases

	Boiler / Heat Storage	Lambda probe control	ESP	Condensation heat recovery	Boiler / Heat Storage with ESP	Lambda probe control with ESP	Lambda probe control with Condensation heat recovery	Lambda probe control with ESP and Condensation heat recovery	Respective BAT product for each BC
	C1	C2	C3	C4	C1 C3	C2 C3	C2 C4	C2 C3 C4	BAT
BC 1 - Open Fireplace									82%
BC2 - Closed Fireplace / Insert	155%		133%		188%				95%
BC3 - Wood Stove	151%		131%		182%				100%
BC5 - Cooker	161%		137%		198%				121%
BC6 - Slow heat relase stove			119%						98%
BC7 - Pellet stove	147%		129%		176%				110%
BC 8 - Dom. Conventional boiler		105%	108%			113%			94%
BC 9 - D.D. Gasfy. Dom. Boiler		105%	108%	97%			102%	110%	100%
BC 10 - Coal Boiler		103%	106%			109%			79%
BC 11 - Pellet Boiler		102%	105%	92%			94%	99%	96%
BC 12 - Non Dom. Chip Boiler		100%	102%	92%			93%	95%	101%

7.4.3. Base case 1: Open fireplace

The LLCC and BAT for BC1 is BAT 1, a fireplace insert (Figure 7-3).

Life cycles costs for BAT 1 at the LLCC are lower than for BC1 (82%) and Total energy consumption (GER) is much lower (36%). PM emissions for BAT 1 are also lower than for BC1, at 24% (Figure 7-4). These results can be explained by the fact that BAT 1 has a better overall combustion design than BC1, including improved air distribution and combustion zone, which both increase the efficiency and reduce the emissions of the appliance. The fundamental difference is that BC 1 (open fireplace) has an efficiency of 30% while BAT 1 (fireplace insert) has an efficiency of 78%.

The figures are based on per GJ of space heat provided over the lifetime of each appliance, and the appliances on the same figure have been taken to have the same power, lifetime and hours of use.

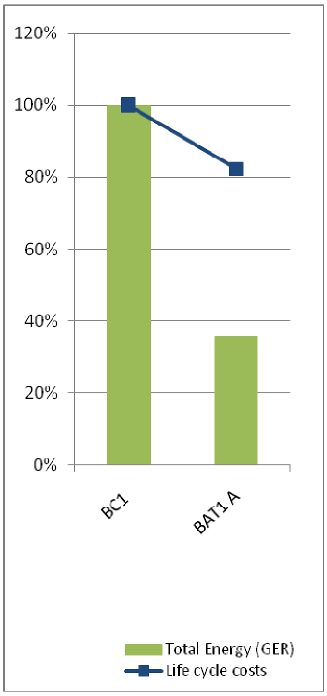

Figure 7-3: BC1: open fireplace – Total life cycle cost (LCC) and BAT (in terms of GER) per option

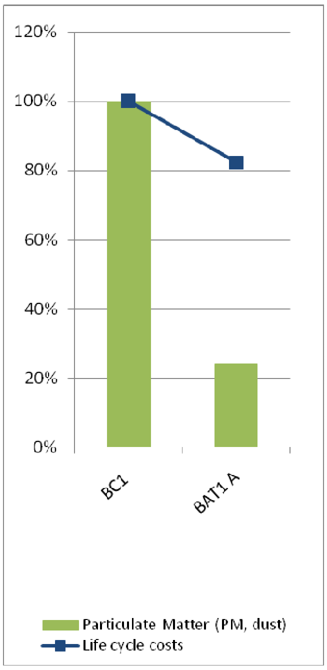

Figure 7-4: BC1: open fireplace – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.4. BASE CASE 2: CLOSED FIREPLACE

The LLCC and BAT for BC2 is BAT 1, an advanced fireplace insert (Figure 7-5). As can be seen from Figure 7-5, C1 and C3 with a closed fireplace make no overall improvements to the energy consumption of the appliance over the lifetime and significantly increase the costs to the consumer. This is because heat storage was found to reduce the energy consumption of the appliance during use, however, this was offset by the energy consumption during the manufacturing of the materials (steel). ESP does not significantly affect energy consumption.

Life cycle costs for BAT 1 at the LLCC point are 95% of BC2. Total energy consumption (GER) of BAT 1 is 87% of BC2. Significant reductions were found to be available for PM, the BAT 1 PM was 34% of BC2 PM (Figure 7-6).

A combination of BC2 with more than two improvement options makes the LCC increase significantly (Figure 7-5 and Figure 7-6).

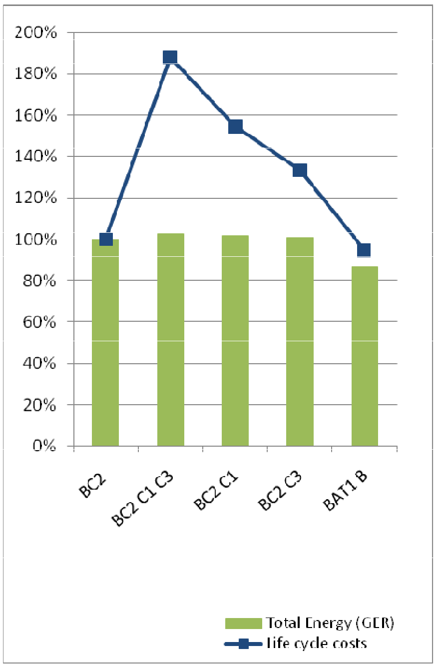

Figure 7-5: BC2: closed fireplace – Total life cycle cost (LCC) and BAT (in terms of GER) per option

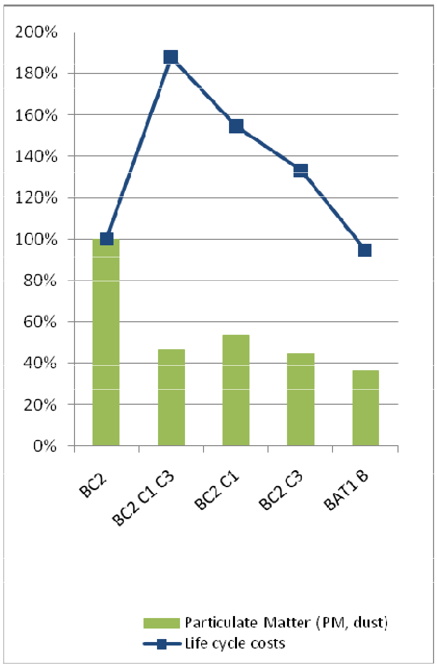

Figure 7-6: BC2: closed fireplace – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.5. BASE CASE 3: WOOD STOVE

The lowest energy consumption for BC3 improvement options was the BAT product which had 87% of the GER of the BC. The LCC of the BAT was approximately equivalent to the LCC of the BC meaning that there was no significant cost savings between the BAT and BC. Components C1 and C3 as with BC2 had no significant impact on the energy consumption and significantly increased the costs (Figure 7-7). This is because heat storage was found to reduce the energy consumption of the appliance during use, however this was offset by the energy consumption during manufacturing of the materials (steel). ESP does not significantly affect energy consumption.

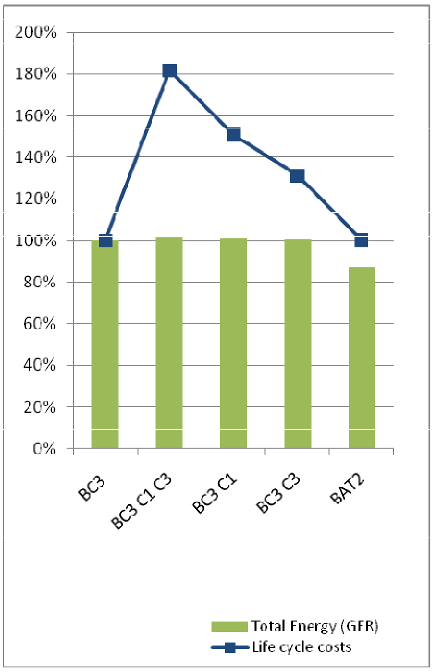

Figure 7-7: BC3: Stove – Life cycle cost (LCC) and BAT (in terms of GER) per option

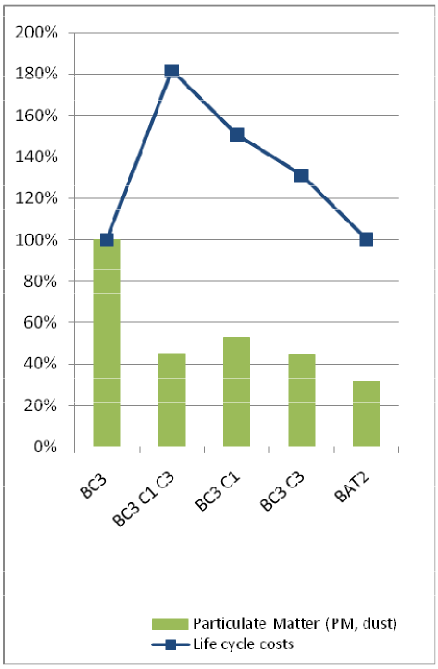

Figure 7-8: BC3: Stove – Life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.6. BASE CASE 5: COOKER

The best improvement option in terms of GER for BC5 is BAT 3, the advanced cooker (Figure 7-9). Life cycle costs for base case 5 at the BAT point are 21% more than for BC5 and therefore represent an increase in costs to the consumer The LLCC for the cooker improvement options was the base case itself meaning that all improvement options represent an increase in costs to the consumer. This is due to the increase in costs of the appliance purchase, and this increase is not offset in fuel costs savings over its lifetime. The total energy consumption (GER) of BAT 4 is 81% of BC5.

Components C1 and C3, as with BC2, had no significant impact on the energy consumption of BC5 and significantly increased the costs (Figure 7-9). This is because heat storage was found to reduce the energy consumption of the appliance during use, however this was offset by the energy consumption during manufacturing of the materials (steel). ESP does not significantly affect energy consumption.

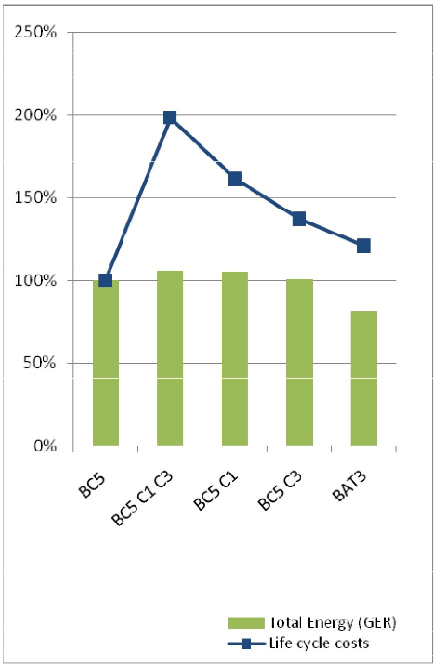

Figure 7-9: BC4: Cooker – Total life cycle cost (LCC) and BAT (in terms of GER) per option

All improvement options significantly improved the PM emissions of the BC through its life cycle and the ESP (C3) had the lowest PM emissions for this appliance at 57% of the BC.

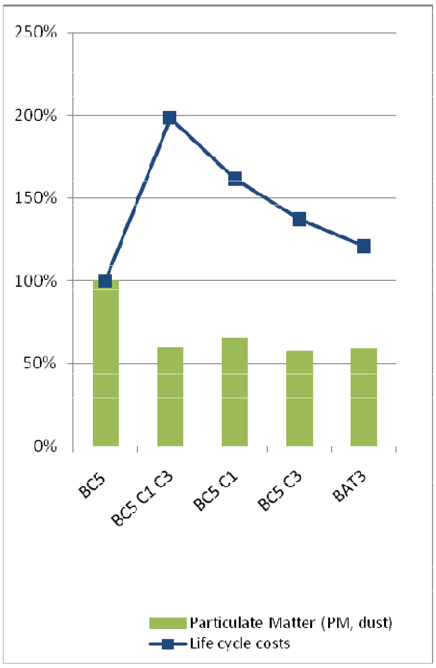

Figure 7-10: BC5: Cooker – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.7. BASE CASE 6: SLOW HEAT RELEASE STOVE

The LLCC and best improvement option for BC6 is BAT 4, (Figure 7-11). Life cycle costs for BAT 5 at the LLCC point are 2% lower than for BC6, while it uses 4% less energy over its lifetime than for BC6. BAT 5 is also the best performing appliance in terms of PM emissions, with approximately half the emissions throughout its lifetime compared to BC6 (Figure 7-12). The ESP component (C3) was found to increase energy consumption and costs while not being as effective for reducing PM as the BAT 4.

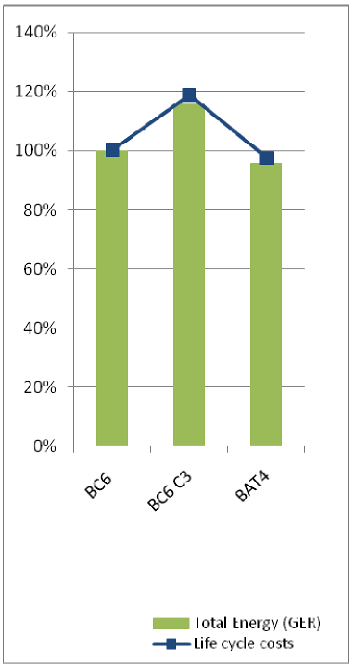

Figure 7-11: BC6: SHR stove – Total life cycle cost (LCC) and BAT (in terms of GER) per option

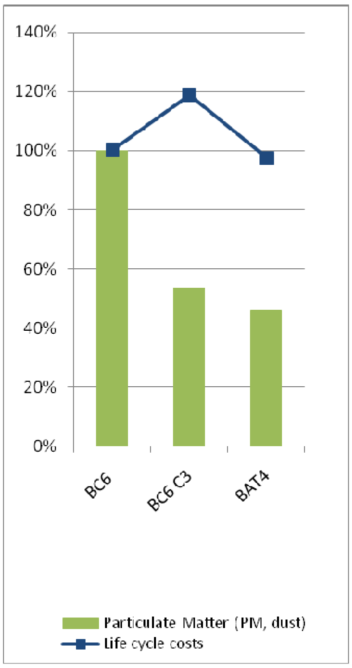

Figure 7-12: BC6: SHR stove – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.8. BASE CASE 7: PELLET STOVE

The lowest energy consumption for BC7 is BAT 6 (Figure 7-13). Life cycle costs for BAT 6 are higher for all improvement options meaning the LLCC point is the base case. All improvement options therefore represent a life cycle cost increase to consumers. The BAT option consumed 92% of the energy of the BC and produced 31% less particulates compared to the base case (Figure 7-14).

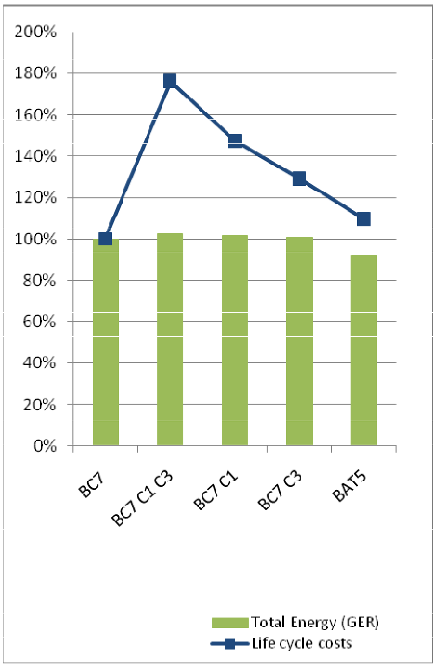

Figure 7-13: BC7: Pellet stove – Total life cycle cost (LCC) and BAT (in terms of GER) per option

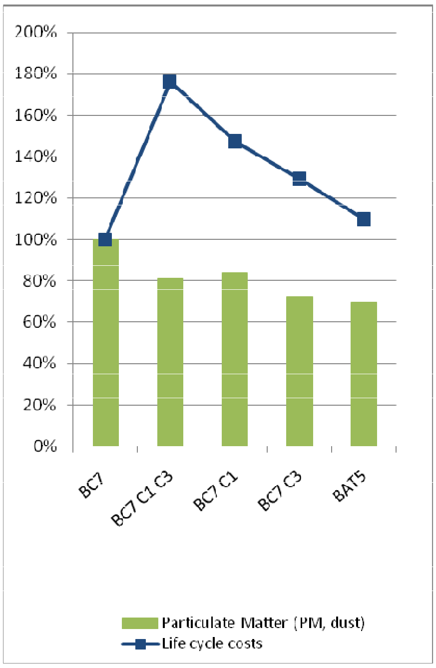

Figure 7-14: BC7: Pellet stove – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.9. BASE CASE 8: CONVENTIONAL DOMESTIC BOILER

The LLCC and BAT for BC8 is BAT 7, a downdraught gasifying boiler (Figure 7-15). Life cycle costs for BC8 at the BAT and LLCC point are 94% of the BC, while using 68% of the energy of the BC. In terms of PM, the BAT 7 is the most effective improvement option and the LLCC also (Figure 7-16). The figures are per GJ of space heat provided, and each figure was assumed to have the same power, lifetime and hours of use.

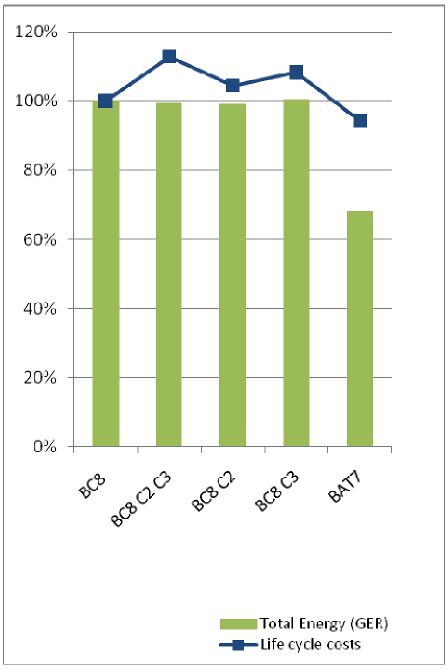

Figure 7-15: BC8: Conv. domestic boiler – Total life cycle cost (LCC) and BAT (in terms of GER) per option

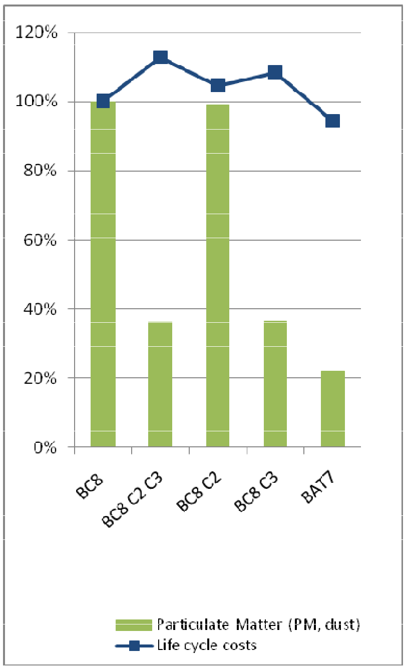

Figure 7-16: BC8: Conv. domestic boiler - Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.10. BASE CASE 9: DOWNDRAUGHT GASIFYING DOMESTIC BOILER

The best improvement option for BC9 is condensation boiler technology with lambda probe control (C2 and C4 in Figure 7-17). While the LLCC is condensation boiler technology without the lambda probe. BAT 7 had a similar life cycle cost as the BC and provided less improvement in terms of energy consumption. PM is most effectively reduced with condensation boiler and ESP technologies (Figure 7-18).

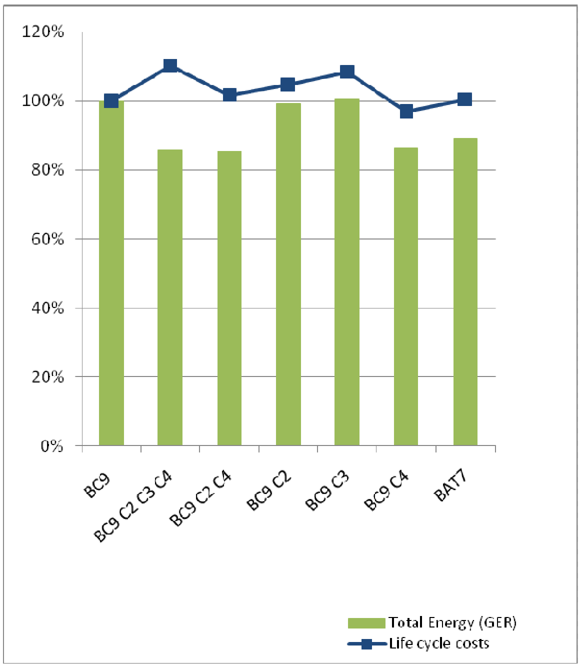

Figure 7-17: BC8: D.D. gasifying domestic boiler - Total life cycle cost (LCC) and BAT (in terms of GER) per option

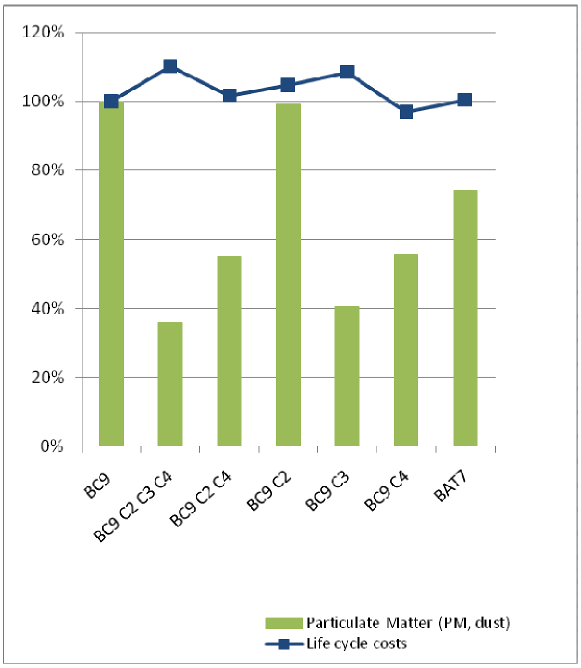

Figure 7-18: BC8: D.D. gasifying domestic boiler - Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.11. BASE CASE 10: RETORT COAL BOILER

The LLCC and BAT for BC10 is BAT 8, a stoker boiler (Figure 7-19). Life cycle costs for BAT 8 at the LLCC point are 79% that of BC8, while energy consumption is 89% that of the BC. However, BAT 8 is not the best improvement option in terms of PM emissions, the improvement option of ESP was found to provide the greatest life cycle reduction in PM (C3 in Figure 7-20).

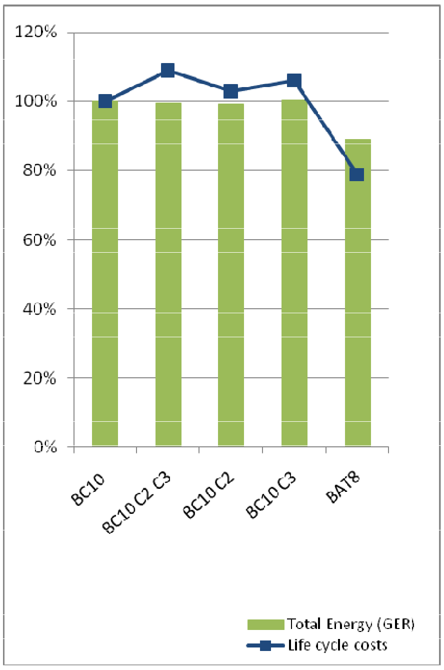

Figure 7-19: BC10: Retort coal boiler - Total life cycle cost (LCC) and BAT (in terms of GER) per option

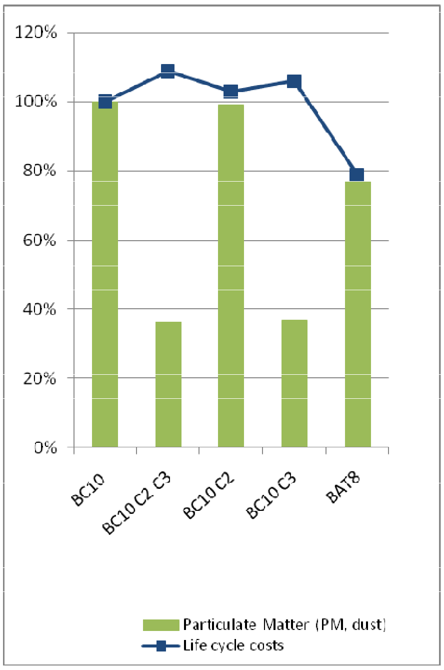

Figure 7-20: BC10: Retort coal boiler - Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.12. BASE CASE 11: PELLET BOILER

The LLCC and best improvement option for BC11 is the condensing heat exchanger with lambda probe control (Figure 7-21). While the LLCC is the condensation boiler technology without the lambda probe. Life cycle costs for this component were 92% that of the BC and energy consumption was 86% of the base case. PM was significantly reduced, however not as effectively as with ESP (C3 and C4 in Figure 7-22).

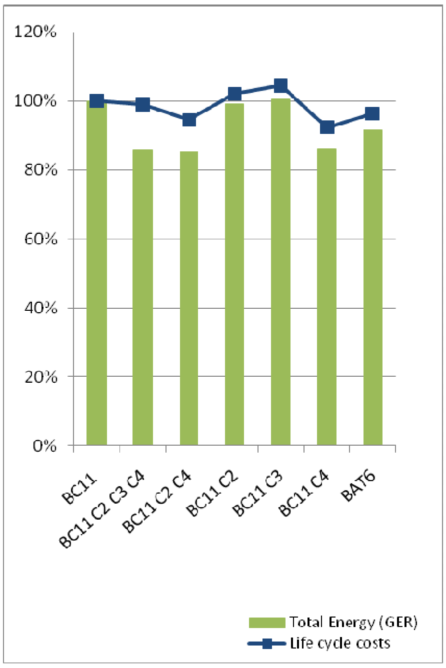

Figure 7-21: BC11: Pellet boiler - Total life cycle cost (LCC) and BAT (in terms of GER) per option

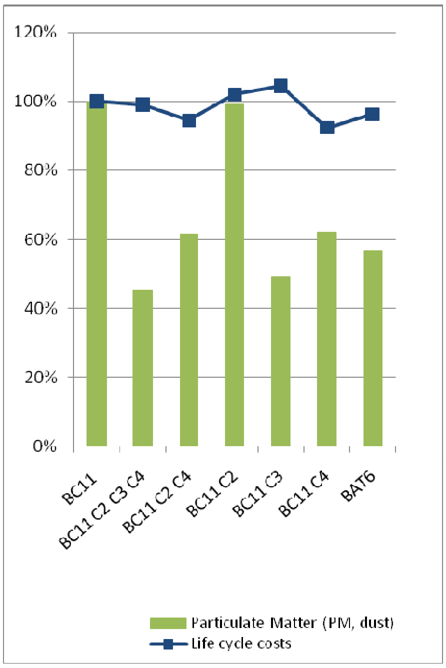

Figure 7-22: BC11: Pellet boiler - Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.13. BASE CASE 12: NON DOMESTIC CHIP BOILER

The LLCC and best improvement option for BC12 is condensation heat recovery with lambda probe control (C3 and C4 in Figure 7-23). While the LLCC is condensation boiler technology without the lambda probe. Life cycle costs for this combination of components were 95% that of the BC and GER was 85% of the BC.

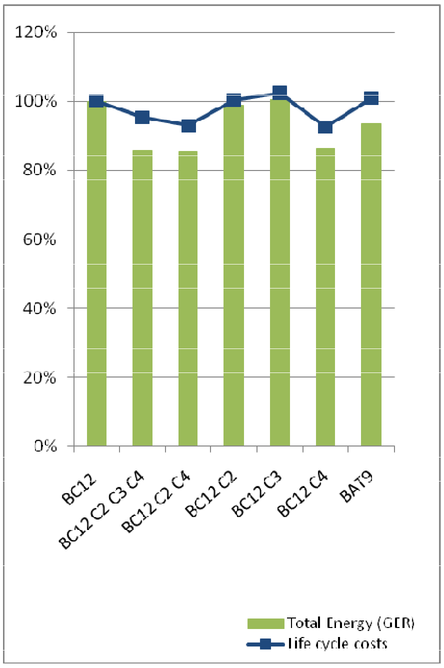

Figure 7-23: BC8: medium automatic boiler with lignite – Total life cycle cost (LCC) and BAT (in terms of GER) per option

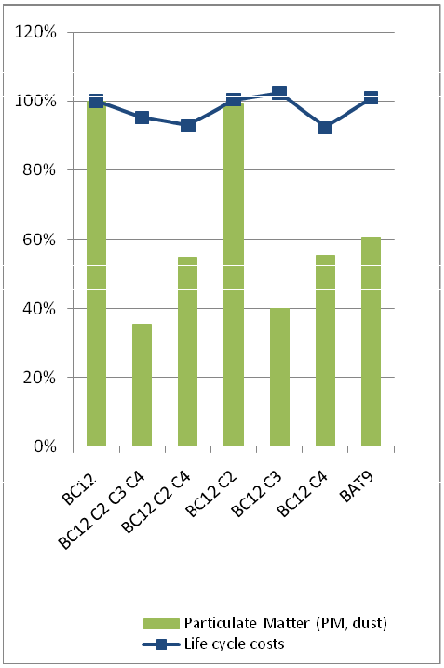

Figure 7-24: BC8: medium automatic boiler with options - Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.14. SUMMARY

Table 7-28 and Table 7-29 summarise the best energy reduction potential and LLCC option for each base case (relative to the base case life cycle energy requirement and costs).

Table 7-28: Overview of the BAT options for each base case

Base Case	Best Improvement Option	Reduction of GER from BC	LCC at BAT
BC 1 - Open Fireplace	Fireplace Insert BAT	36%	82%
BC2 - Closed Fireplace / Insert	Fireplace Insert BAT	87%	95%
BC3 - Wood Stove	Advanced Stove BAT	87%	100%
BC5 - Cooker	Advanced Cooker BAT	81%	121%
BC6 - Slow heat relase stove	SHR Stove BAT	96%	98%
BC7 - Pellet stove	Pellet Stove BAT	92%	110%
BC 8 - Dom. Conventional boiler	DD Gasify Boiler BAT	68%	94%
BC 9 - D.D. Gasfy. Dom. Boiler	Lambda probe control with Condensation heat recovery	86%	102%
BC 10 - Coal Boiler	Coal Boiler BAT	89%	79%
BC 11 - Pellet Boiler	Lambda probe control with Condensation heat recovery	85%	94%
BC 12 - Non Dom. Chip Boiler	Lambda probe control with Condensation heat recovery	85%	93%

➔ Energy savings potential

Based on the tables above, the technologies with the largest potential energy savings impact in Europe which are available today on the market are:

- Downdraught gasifying boilers
- Condensation heat exchanger technology with lambda probe control
- High efficiency fireplace inserts
- High efficiency advanced stoves

The energy savings potential for the entire industry based on differences between current sales and BAT technologies is in the order of **5-15%** depending on the product type.

Conventional domestic boilers have the most potential to reduce energy consumption by approximately **32%** if conventional domestic boiler products are replaced by downdraught gasifying boilers.

It must be noted that far more significant energy savings for all products could be realised if the currently available technologies (either in base cases or in improvement options) are used to replace **the stock of appliances** in Europe. While this may fall outside the intended scope of the Eco-design Directive, it should still be addressed as a means to improving the environmental impacts associated with products in the Lot 15 study. In general, the solid fuel industry has recognised the benefits of efficiency improvements and steadily improved product efficiency on its own accord for most products represented by the base cases. This results in a set of products (and a set of representative base cases) which have a relatively high efficiency compared to the installed stock in Europe. It is strongly recommended that the renewal of stock in Europe is considered during the implementation phase of any policy measures as the potential improvements on emissions in Europe would be realised much more quickly and also to a greater extent.

➔ Environmental performance for other environmental indicators

Energy consumption is the strongest correlation to all other environmental indicators in this study because air emissions are a direct result of fuel consumption. Fuel consumption was shown in Task 5 to be the strongest contribution to overall energy consumption for all base cases. Of the other types of environmental indicators which are of concern in this study, particulate matter could be argued as the most important.

The ESP performed consistently well in terms of removing particulate matter, minimising other environmental impacts (through material usage, disposal, etc.) and in terms of life cycle costs. Energy consumption related to the use of ESP was not significant in the entire life cycle of the products. However, increasing the efficiency of appliances was often found to be as effective or slightly more effective as the ESP component in reducing PM emissions throughout the lifetime.

➔ **LEAST LIFE CYCLE COSTS SAVINGS POTENTIAL**

Table 7-29: Overview of the LLCC options for each base case

Base Case	Improvement Option	LLCC Improvement Option	GER Reduction at LLCC
BC 1 - Open Fireplace	Fireplace Insert BAT	82%	36%
BC2 - Closed Fireplace / Insert	Fireplace Insert BAT	95%	87%
BC3 - Wood Stove	Advanced Stove BAT	100%	87%
BC5 - Cooker	BC	100%	100%
BC6 - Slow heat release stove	SHR Stove BAT	98%	96%
BC7 - Pellet stove	BC	100%	100%
BC 8 - Dom. Conventional boiler	DD Gasify Boiler BAT	94%	68%
BC 9 - D.D. Gasfy. Dom. Boiler	Condensation Heat Recovery	97%	86%
BC 10 - Coal Boiler	Coal Boiler BAT	79%	89%
BC 11 - Pellet Boiler	Condensation Heat Recovery	92%	86%
BC 12 - Non Dom. Chip Boiler	Condensation Heat Recovery	92%	86%

Based on Table 7-29, the appliances which had the best life cycle costs savings potential were:

- High efficiency coal stoker boilers
- High efficiency fireplace inserts
- Condensation heat exchanger technology

The life cycle cost savings potential is less pronounced than the energy savings potential. Most appliances can realise a life cycle cost savings of less than **5%.** This is because the cost savings of fuel are offset by increased purchasing costs of higher efficiency appliances. In general, the solid fuel industry enjoys a low fuel cost relative to other heating types. Though this has traditionally been one of the central benefits to using solid fuel as a heating source, here it proves to be an obstacle in that the cheaper the fuel, the less financial incentive there is to improve efficiency.

Despite this, coal boilers and open fireplaces can reduce their life cycle costs by **18%** and **21%** respectively. This is because coal has a higher fuel cost and savings are proportionately higher. Open fireplaces are also much less efficient than fireplace inserts and therefore the fuel savings do outweigh any increase in purchase costs by a significant amount (assuming similar usage and lifetime).

Overall it was found that a **net life cycle cost savings** can be realised by consumers who choose more efficient products for most product types. This includes all products represented by base cases except pellet stoves, cookers, and stoves, where the base cases were themselves the cheapest life cycle option or had negligible life cycle cost savings. Furthermore it can be noted that the lambda probe appears as a BAT but not as a LLCC improvement option for boiler products.

Across most product types in the study, there was not a significant difference between the BAT cases and the LLCC cases.

7.5. SYSTEM ANALYSIS

➔ CHIMNEYS

Regarding chimneys, it has to be stressed that efficient solid fuel SCIs require a suitable chimney in order to be installed at all. In other words, the improvement potential for product cases 4 and 6 can only be realised if a connection to a suitable chimneys exists. To this end, local building regulations are considered as a crucial part, both in terms of requiring chimneys in buildings as well as requirements for the products as such.

In general, for solid fuel heating systems, efficiencies above 80% require that the flue and chimney system be adequately designed to accommodate condensation. For condensation heat exchangers, the installation costs required to upgrade or retrofit the flue and chimney system are typically the constraining cost.

For very efficient natural draught appliances, back draught in the chimney can be a safety concern arising from the lower flue temperatures which generate weaker draughts. This supports the need for trained and certified installers to install appliances.

➔ POWER MODULATION

Another key parameter of boilers which should receive attention is the ability of the boiler to modulate its power output (further background information in Task 6). This is not always a simple task for solid fuel boilers in this lot as modulating fuel supply is not always easy in these appliances and modulating air supply is not recommended as a means for modulating power output. This is especially difficult for batch loaded appliances which have very little possibility to modulate the rate at which fuel is consumed. The conventional boiler (BC8) was assumed to not have the ability to modulate power output, while all of the BAT boilers were assumed to have varying abilities of power modulation. This is an absolutely key parameter for the eco-design of solid fuel boilers and should be given attention when making eco-design requirements. Boilers should have the ability to modulate to 30% of their nominal rated power, while still operating at a sufficiently high efficiency, while BAT technologies can modulate to 10% of nominal rated power and often have higher efficiencies at lower power output.

➔ INSTALLERS

Properly trained and certified technicians are required for upgrading or installing solid fuel heating systems with high efficiencies. The installation into the dwelling is as influential on the system efficiency as the product itself. It must therefore be acknowledged that any and all improvements to existing or new systems be properly suited to their application including sizing, frequency of use, fuel availability, condensation in the chimney, and the potential for back draught. Only trained and certified personnel should be charged with sizing and installing a heating system for safety reasons as well as for optimising the system performance.

7.6. CONCLUSIONS

As presented in this task, the improvement potential of each of the 12 base cases is significant. The EcoReport analysis shows that most of the environmental indicators decrease thanks to the implementation of one or several improvement options, mainly due to the increase in efficiency, which results in lower fuel consumption and lower air emissions through the use phase of the appliance.

The assessment of the improvement potential of each base case will be further investigated in Task 8 when defining several scenarios until the year 2020. These scenarios, based on relevant assumptions, will evaluate the energy savings potential for the whole EU market of solid fuel SCIs which are within the scope of this study.