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Solid fuel small combustion installations

Task 7: Improvement Potential

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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. SUBTASK 7.1 – 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. COMBUSTION MANAGEMENT

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 in 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 BC 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 BOM, electricity consumption, price, or product lifetime) compared to the BC.

Both improved air distribution/combustion chamber and lambda probes were considered as combustion management options. 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.

7.1.2. DRAUGHT MANAGEMENT

Three main draught management options were identified in Task 6: draught limiters, stove regulators and fan assisted draught (see Section 6.2.1). All three options can improve the efficiency of the appliances by 5% and reduce emissions accordingly. The main differences lie in the BOM, and therefore price of these options, with draught limiters being the simplest and cheapest of the three. The full details of the changes in the life cycle parameters that were considered are shown in Section 6.2.1. These options carry out the same function, and are considered interchangeable. However, they will not occur together in a given appliance.

7.1.3. ADVANCED HEAT TRANSFER

Five heat exchange or heat recovery options were identified in Task 6. The lining of the combustion chamber is rather considered part of the improvements to the combustion management, since these improvements usually occur in combination (see Section 7.1.1.). Fan assisted direct heat exchange simply consists in adding a fan to circulate the heat in the room. These fans are cheap options, which can improve the efficiency of appliances by 15%. In contrast, heat recovery by condensation and accumulator tanks have a smaller impacts on the efficiency of the appliances (1 – 5% on average) and are costlier options (see Section 6.2.1), while three-layer heat exchangers have no impact on efficiency at nominal output. Accordingly, fan assisted direct heat exchange will be the only advanced heat transfer option considered in the scope of Task 7.

7.1.4. AFTER-TREATMENT OR ABATEMENT TECHNOLOGIES

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 fulfil the same function and are considered interchangeable. Therefore, the three PM after-treatment options cannot occur together in a given appliance, while catalysts can be considered with them. The details of the associated changes in the life cycle parameters that were considered and are shown in section 6.2.1. Cyclones and bag filters are assumed to both require fan assistance, in the case of cyclones, to maintain the correct velocity for developing the swirling action, and in the case of filters to maintain the necessary pressure differential across the filters.

7.1.5. BURNERS AND GRATES

Three improvement options concerning burners and grate systems were identified in Task 6. Stepped grate and rotary grates are mostly convenience functions, allowing more flexibility to changes of fuel parameters and reducing the maintenance requirements of the appliance, respectively. Self-cleaning bowl burners also reduce the maintenance requirements of the appliance, without substantially improving its performance under normal operating conditions. Therefore, all three options are considered to have limited potential to improve the performance of solid fuel SCIs and are not considered as improvement options in Task 7.

7.1.6. SELF-CLEANING, ASH REMOVAL

Two component options were identified in Task 6 related to the cleaning of the appliance. Automatic ash removal systems are convenience devices, made for ease of use and have a negligible impact on the performance of the appliances. In contrast, self-cleaning heat exchangers can improve the efficiency of the appliances, by improving the conductivity of the heat exchanger and by creating turbulence in the flue ducts, however these changes are negligible for well-maintained appliances. Therefore, both options are considered to have a limited potential to improve the performance of solid fuel SCIs and are not considered as improvement options in Task 7.

7.1.7. 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. The number of options per Base Case ranges from 2-7. In principle, a combination of all applicable options to each Base Case is possible, but this would mean several hundred combinations of options. Therefore, an alternative approach is used: all options are first calculated individually (Base Case + Option1, Base Case + Option2, etc.), then the most realistic add-on scenarios are considered consecutively (Base Case + Option 1 + Option2, Base Case + Option 1 + Option 2 + Option 4, etc.). So for instance this meant that if several options covering the same function were available (e.g. draught limiter and fan assisted draught, which both perform draught control), then based on the first step, the best option was first identified (best environmental improvement to cost ratio) and only that option was used in the add-on scenarios.

The applicability of the different product options to each of the Base Case is shown in Table 7-2. There is 1-3 Product Cases for each Base Case. 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. The type of improvement options included in each of these Product Cases is summarised in Table 7-3.

Each Product Case may sometimes be applicable to multiple Base Cases. Table 7-2 shows which product cases are applicable with which base cases. There are a few instances where the type, and potential functionality of the appliance, is different between the Base Cases and the Product Cases (e.g. for BC4 traditional stove, one Product Case is a pellet stove). While these differences are acknowledged, for the purpose of this EU-wide study, replacement of one appliance by the other is a possibility.

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

	Combustion Management		Draught control			Advanced heat transfer	After-treatments			
Component option	Improved air distribution / combustion chamber	Lambda Probe	Draught limiter	Stove regulator	Fan assisted draught	Fan assisted direct heat exchange	Catalyst	ESP	High efficiency cyclone	Fabric filter
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
BC1 - Open fireplace			●			●				
BC2 - Closed fireplace	●		●	●	●	●	●	●		
BC3 - Cooker	●						●	●		
BC4 - Traditional stove	●		●	●	●	●	●	●		
BC5 - Modern stove	-		●	●	●	●	●	●		
BC6 - Manual boiler <50kW	-	●	●	●	●		●	●		●
BC7 - Automatic boiler <50kW	-	●	●	●	●		●	●		●
BC8 - Automatic boiler 100kW	-	●	●	●	●		●	●	●	●

- : component already included in base case

Table 7-2: Matrix of components included in the product case definition

Product Cases		Combustion Management		Draught control	Advanced heat transfer
		Improved air distribution / combustion chamber	Lambda probe		Fan assisted direct heat exchange
		C1	C2		C6
Advanced closed fireplace/fireplace insert	P1	✓		✓	✓
Advanced cooker	P2	✓		✓	
Advanced stove	P3	✓		✓	✓
Pellet stove	P4	✓		✓	✓
Downdraught manual boiler <50kW	P5	✓		✓	
Pellet boiler	P6	✓	✓	✓	
Wood chips boiler >50kW	P7	✓	✓	✓	
Downdraught/gasifying boiler >50kW	P8	✓	✓	✓	

Table 7-3: Matrix of Base Cases that are replaceable by Product Cases

Product case		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8
Advanced closed fireplace / fireplace insert	P1	✓	✓						
Advanced cooker	P2			✓					
Advanced stove	P3				✓	✓			
Pellet stove	P4				✓	✓			
Downdraught manual boiler <50kW	P5						✓		
Pellet boiler	P6						✓	✓	
Wood chips boiler >50 kW	P7								✓
Downdraught / gasifying boiler >50 kW	P8								✓

7.1.8. MODELLING THE ENVIRONMENTAL IMPACTS OF THE OPTIONS

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

- **Component cases**: for each component option, changes in BOM, emissions, electricity consumption, and emissions were those estimated in Task 6, Table 6.18.
- **Product cases**: each Product Case was associated to a BOM, representative emissions of CO, NOx, PM and OGC, and electricity consumption where relevant, and a purchase cost (summarise in Task 6, Table 6.17). 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 manner which is comparable to the base cases.

The output and lifetime of the component options and Product cases were assumed to be those of their associated Base Case. While it is likely that more advanced appliances have a shorter lifetime, these appliances are more efficient and need to be used for less time to provide the required heat.

7.2. SUBTASK 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 simple improvement options combinations compared to BC1 and applicable product case options are shown in Table 7-4. It presents BC1 (open fireplaces) and component options C3 (draught limiter) and C6 (fan assisted direct heat exchange). Product case BAT P1 (fireplace insert) is also presented.

Table 7-4: Life cycle improvements for BC1 - open fireplace with wood logs (simple improvement options)

	UNIT	BC1	C3	C6	BAT P1
Resources					
GER	MJ	581841	552934	554246	65531
Elec.	MJ	119	138	1390	1264
Water	L	36	36	119	22
Waste, haz.	g	315954	303912	308089	210259
Waste, nh	g	12	12	40	12
Air					
GWP	kg CO2eq.	3167	3009	3083	745
AP	g SO2 eq.	76790	73004	73339	9198
VOC	g	9627	8667	9148	585
POP	ng i-Teq	64298	61145	61196	9370
Hma	mg Ni eq.	24374	23183	23219	3477
PAH	mg Ni eq.	151798	144211	144214	15541
PM	g	67575	61377	64412	8429
Water					
HMw	mg Hg/20	47	52	65	353
EP	g PO4	1	1	1	7

7.2.2. BASE CASE 2: CLOSED FIREPLACE

The environmental impacts of the simple improvement options combinations compared to BC2, as well as applicable product case options are shown in Table 7-5. Improved air distribution/combustion chamber (C1) is considered to be a necessary pre-requisite for other, more elaborated improvement options, such as draught-limiter (C3), fan assisted draught (C5) or heat transfer (C6), catalyst (C7) and ESP (C8). Thus BC2 (closed fireplaces) is compared to BC2 with component options C1+C3 (advanced design and draught limiter), C1+C5 (advanced design and fan assisted draught), C1+C6 (advanced design and fan assisted heat transfer), C1+C7 (advanced design and catalyst), C1+C8 (advanced design and ESP). Product case BAT P1 (fireplace insert) is also presented alone and with after-treatment options C7 (catalyst) and C8 (ESP) (BAT P1 is assumed to already have an improved air distribution/combustion chamber).

Table 7-5: Life cycle improvements for BC2 - closed fireplace with wood logs (simple improvement options)

	UNIT	BC2	C1+C3	C1+C5	C1+C6	C1+C7	C1+C8	BAT P1	BAT P1 C7	BAT P1 C8
Resources										
GER	MJ	389601	271353	274404	273670	285641	291001	257034	257034	257245
Elec.	MJ	2389	2408	5238	4666	2423	8036	1264	1264	1315
Water	L	282	282	960	432	522	656	22	22	23
Waste, haz.	g	330546	272917	278125	278261	290646	291088	307974	307974	315302
Waste, nh	g	274	274	984	325	285	403	12	12	12
Air										
GWP	kg CO2eq.	2591	1933	2084	2044	1949	2272	1670	1670	1686
AP	g SO2 eq.	52505	36993	38017	37587	38920	40291	34334	34334	34382
VOC	g	9084	5961	5968	6290	3988	6621	2362	2362	2362
POP	ng i-Teq	44488	31483	31518	31541	33088	33127	30489	30489	30605
Hma	mg Ni eq.	28397	23487	23604	23540	24076	24187	11448	11448	11487
PAH	mg Ni eq.	100264	69292	69357	69296	73034	72947	65667	65667	65667
PM	g	56435	38792	38829	40584	31250	8857	23377	23377	5784
Water										
HMw	mg Hg/20	373	379	732	398	417	424	353	353	367
EP	g PO4	65	65	70	65	65	65	7	7	7

7.2.3. Base case 3: Traditional cooker

The environmental impacts of the simple improvement options combinations compared to BC3, as well as applicable product case options are shown in Table 7-6. Improved air distribution/combustion chamber (C1) is considered to be a necessary pre-requisite for other, more elaborated improvement options, such as draught-limiter (C3), catalyst (C7) and ESP (C8). Thus BC3 (traditional cooker) is compared to BC3 with component options C1+C3 (advanced design and draught limiter), C1+C7 (advanced design and catalyst), C1+C8 (advanced design and ESP). Product case BAT P2 (advanced cooker) is also presented alone and with after-treatment options C7 (catalyst) and C8 (ESP) (BAT P2 is already assumed to have an improved air distribution/combustion chamber).

Table 7-6: Life cycle improvements for BC3 –traditional cooker with wood logs (simple improvement options)

	UNIT	**BC3**	**C1+C3**	**C1+C7**	**C1+C8**	**BAT P2**	**BAT P2 C7**	**BAT P2 C8**
Resources								
GER	MJ	207459	138494	165874	177397	122380	146341	157864
Elec.	MJ	2982	6058	26531	38306	1968	25517	37292
Water	L	122	326	1929	2474	30	1837	2382
Waste, haz.	g	360141	329644	367334	374921	338444	379082	386669
Waste, nh	g	49	120	603	862	22	575	835
Air								
GWP	kg CO2eq.	1773	1528	2450	2982	1290	2323	2845
AP	g SO2 eq.	28709	20051	26280	29238	16987	23161	26119
VOC	g	3865	2347	1595	2613	1260	792	1274
POP	ng i-Teq	25831	17943	18870	18950	16793	17061	17141
Hma	mg Ni eq.	18884	15950	16584	16801	6243	6672	6888
PAH	mg Ni eq.	51577	32711	34566	34491	29425	29570	29494
PM	g	29066	20490	17711	9129	25938	20544	9496
Water								
HMw	mg Hg/20	565	590	760	807	551	746	792
EP	g PO4	55	56	56	57	11	12	12

7.2.4. Base case 4/5: Traditional/Modern stove

The environmental impacts of BC4 and BC5 compared to each component option as well as applicable product case options are shown in Table 7-7. BC5 is already an improvement option of BC4, and essentially corresponds to BC4+C1 (traditional stove with improved design). Improved air distribution/combustion chamber (C1) is considered to be a necessary pre-requisite for other, more elaborated improvement options, such as draught-limiter (C3), fan assisted draught (C5) or heat transfer (C6), catalyst (C7) and ESP (C8). Thus BC4 is compared to BC5 and BC4 with component options C1+C3 (advanced design and draught limiter), C1+C5 (advanced design and fan assisted draught) C1+C6 (advanced design and fan assisted heat transfer), C1+C7 (advanced design and catalyst), C1+C8 (advanced design and ESP). BAT P3 (advanced stove) and BAT P4 (pellet stove) are presented alone and BAT P3 is also shown with options C7 (catalyst) and C8 (ESP) (BAT P3 is already assumed to have an improved air distribution/combustion chamber).

Table 7-7: Life cycle improvements for BC4 - traditional stove with wood logs (simple options)

	UNIT	BC4	BC4 C1	BC5	C1+C3	C1+C5	C1+C6	C1+C7	C1+C8	BAT P3	BAT P4	BAT P3 C7	BAT P3 C8
Resources													
GER	MJ	654570	437667	492589	416055	420759	420025	438112	447604	264185	168477	359702	369194
Elec.	MJ	614	614	824	633	5116	4543	647	10392	2196	2378	2229	11974
Water	L	220	220	226	220	1008	480	460	869	32	72	272	681
Waste, haz.	G	383911	273235	323694	264916	272040	272175	286609	291842	443360	272810	505243	510476
Waste, nh	G	22	22	24	22	771	112	34	247	17	32	28	241
Air													
GWP	kg CO2eq.	3727	2582	3003	2462	2685	2649	2467	3022	1992	817	2378	2890
AP	g SO2 eq.	86510	58041	65335	55212	56661	56232	58159	60594	35668	15859	48264	50699
VOC	G	12621	8430	12623	7592	7600	8012	5077	8434	2408	78	1997	3294
POP	ng i-Teq	72717	48797	55136	46448	46495	46517	48910	48976	32921	41861	43518	43585
Hma	mg Ni eq.	30312	21284	23977	20396	20542	20478	21309	21491	12302	8702	16285	16466
PAH	mg Ni eq.	170395	113620	127815	107943	108011	107950	113719	113640	66442	30391	91425	91346
PM	G	78324	54515	78326	49878	49925	52167	40257	11728	45038	6374	43581	10970
Water													
HMw	mg Hg/20	159	159	204	164	527	194	202	236	615	479	658	692
EP	g PO4	18	18	21	18	23	19	18	19	12	10	12	13

7.2.5. BASE CASE 6: SMALL MANUAL BOILER

The environmental impacts of the simple improvement options combinations compared to BC6 as well as applicable product case options are shown in Table 7-8. Among the options presented, both lambda probes (C2) and fabric filters (C10) are assumed to require a fan assisted draught (C5). Accordingly, BC6 (small manual boilers) is compared to BC6 with component options C5 (fan assisted draught), C2+C5 (lambda probe and fan assisted draught), C7 (catalyst), C8 (ESP) and C5+C10 (fan assisted draught and fabric filter). Product case BAT P5 (downdraught boiler) and product case BAT P6 (pellet boiler) are also presented. BAT P5 is also shown with after-treatment options C7 (catalyst), C8 (ESP) and C10 (fabric filter - product case BAT P5 is assumed to already have a fan assisted draught).

Table 7-8: Life cycle improvements for BC6 - small manual boilers with wood logs (simple options)

	UNIT	**BC6**	**C5**	**C5+C2**	**C5+C10**	**C7**	**C8**	**BAT P5**	**BAT P6**	**BAT P5 C7**	**BAT P5 C8**	**BAT P5 C10**
Resources												
GER	MJ	1154344	1158671	1147256	1158963	1213753	1222305	919517	1056098	925172	933724	925018
Elec.	MJ	16893	20999	21292	21085	16907	25712	8030	13009	13494	22299	13546
Water	L	2400	3163	3427	3270	2640	2986	334	1155	936	1282	803
Waste, haz.	g	1217241	1223928	1218751	1229185	1257992	1262135	986710	725745	1006290	1010433	998174
Waste, nh	g	2243	2983	3313	3447	2255	2446	119	879	254	445	706
Air												
GWP	kg CO2eq.	7538	7745	7655	7764	7491	8251	5689	2753	5659	6312	5931
AP	g SO2 eq.	156166	157518	156189	157614	164015	166208	122811	95547	124288	126480	124265
VOC	g	8320	8328	8240	8329	5582	9237	483	264	319	485	481
POP	ng i-Teq	133735	133779	132480	133851	140316	140376	107382	254326	107531	107591	107490
Hma	mg Ni eq.	58028	58167	57713	58200	60495	60661	40355	50540	40468	40634	40476
PAH	mg Ni eq.	293932	294000	290939	294000	309485	309404	235278	196264	235379	235298	235281
PM	g	272705	272749	269951	19968	212842	35441	44336	12867	32188	9180	9183
Water												
HMw	mg Hg/20	2362	2723	2891	2828	2400	2427	1053	1418	1131	1159	1193
EP	g PO4	76	81	83	87	76	76	21	26	21	21	27

7.2.6. BASE CASE 7: SMALL AUTOMATIC BOILER

The environmental impacts of the simple improvement options combinations compared to BC7 as well as applicable product case options are shown in Table 7-9. Among the options presented, both lambda probes (C2) and fabric filters (C10) are assumed to require a fan assisted draught (C5). BC7 (small automatic boilers) is compared to BC7 with component options C5 (fan assisted draught), C5+C2 (lambda probe and fan assisted draught), C7 (catalyst), 8 (ESP) and C5+C10 (fan assisted draught and fabric filter). Product case BAT P6 (pellet boiler) is also presented alone and with after-treatment options C7 (catalyst), C8 (ESP) and C10 (fabric filter - product case BAT P6 is assumed to already have a fan assisted draught).

Table 7-9: Life cycle improvement options for BC7 - small automatic boiler with wood pellets (simple option)

	UNIT	BC7	C2+C5	C5	C5+C10	C7	C8	BAT P6	BAT P6 C7	BAT P6 C8	BAT P6 C10
Resources											
GER	MJ	1411043	1333366	1346803	1347094	1411489	1421296	1204479	1205889	1215696	1205734
Elec.	MJ	16442	21362	21069	21155	16475	26535	14264	15483	25543	15535
Water	L	1284	2345	2081	2188	1524	1954	1239	1558	1988	1425
Waste, haz.	G	735362	730863	732576	737833	748735	754334	754443	769101	774699	760985
Waste, nh	G	615	1696	1366	1830	626	846	908	945	1165	1398
Air											
GWP	kg CO2eq.	3181	3329	3333	3352	3122	3635	2966	2962	3459	3023
AP	g SO2 eq.	127396	121939	122914	123010	127514	130030	108597	108981	111497	108958
VOC	G	3305	2962	2991	2991	2016	3309	290	205	291	287
POP	ng i-Teq	337752	318026	321326	321398	337865	337934	289476	289596	289665	289555
Hma	mg Ni eq.	81077	77456	78056	78089	81103	81290	57338	57379	57566	57387
PAH	mg Ni eq.	263467	247767	250370	250370	263566	263487	224280	224372	224293	224274
PM	G	50748	46073	46482	8678	37488	10955	13858	10846	6164	6160
Water											
HMw	mg Hg/20	1278	1816	1648	1753	1322	1357	1426	1477	1513	1539
EP	g PO4	93	101	98	105	93	94	26	26	26	32

7.2.7. BASE CASE 8: MEDIUM AUTOMATIC BOILER

The environmental impacts of the simple improvement options combinations compared to BC8 as well as applicable product case options are shown in Table 7-10. Among the options presented, lambda probes (C2), high efficiency cyclones (C9) and fabric filters (C10) are assumed to require a fan assisted draught (C5). BC8 (medium automatic boilers) is compared to BC8 with component options C5 (fan assisted draught), C5+C2 (lambda probe and fan assisted draught), C7 (catalyst), C8 (ESP), C5+C9 (fan assisted draught and cyclone) and C5+C10 (fan assisted draught and fabric filter). Product case BAT P8 (downdraught gasifying boiler) is presented alone and with after-treatment options C9 (high efficiency cyclone; BAT P8 is assumed to already have a fan assisted draught).

Table 7-10: Life cycle improvement options for BC8 - medium automatic boilers with lignite (simple options)

	UNIT	BC8	C5	C2+C5	C7	C8	C5+C9	C5+C10	BAT P8	BAT P8 C7	BAT P8 C8	BAT P8 C9	BAT P8 C10
Resources													
GER	MJ	9132118	8684895	8594572	9132564	9145997	8691940	8685187	8433540	8440515	8453948	8447114	8440361
Elec.	MJ	41164	47242	47535	41197	54883	54127	47328	31559	38121	51807	44973	38174
Water	L	3739	4633	4897	3979	4651	5089	4740	1868	2543	3215	2760	2411
Waste, haz.	g	13842517	13192627	13061157	13855890	13865692	13207879	13197884	12864365	12885308	12895111	12887187	12877192
Waste, nh	g	4044	4829	5158	4055	4359	4987	5293	696	857	1161	1004	1310
Air													
GWP	kg CO2eq.	702551	664387	650427	653645	703163	664701	664405	642612	598164	643509	643211	642915
AP	g SO2 eq.	1299109	1236844	1224237	1299227	1302677	1238652	1236939	1197567	1199366	1202816	1201056	1199343
VOC	g	446557	401932	397471	268020	446563	401935	401932	42760	25739	42768	42766	42763
POP	ng i-Teq	574269	546081	540426	574382	574475	546241	546153	532488	532644	532736	532692	532603
Hma	mg Ni eq.	2132012	2026654	2005582	2132037	2132286	2026811	2026687	1954221	1954358	1954608	1954490	1954366
PAH	mg Ni eq.	234229	222618	220312	234327	234256	222632	222618	216260	216372	216301	216287	216274
PM	g	1858580	1679776	1662360	1308255	207613	808438	111338	567557	404553	78481	132799	78457
Water													
HMw	mg Hg/20	2373	2752	2920	2416	2475	2810	2857	1366	1451	1510	1466	1512
EP	g PO4	117	122	125	117	118	123	129	25	25	26	25	31

7.2.8. COMPARISON OF ENVIRONMENTAL IMPACTS BY INDICATOR

Based on the above analyses, the typical changes that can be expected to each of the environmental indicators for both direct and indirect appliances are shown in Figure 7-1 and Figure 7-2 respectively.

It can be seen that typically, most environmental indicators change in similar proportions compared to the BCs, and are correlated to GER, Total energy consumption. This is expected, since fuel consumption is responsible for most of the environmental impacts of solid fuel SCIs (see Task 5). However, the change in impacts on water (process and eutrophication) and hazardous waste are unrelated to and much more important than those of GER. Finally, changes in PM and VOC are not always correlated to those in GER.

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.

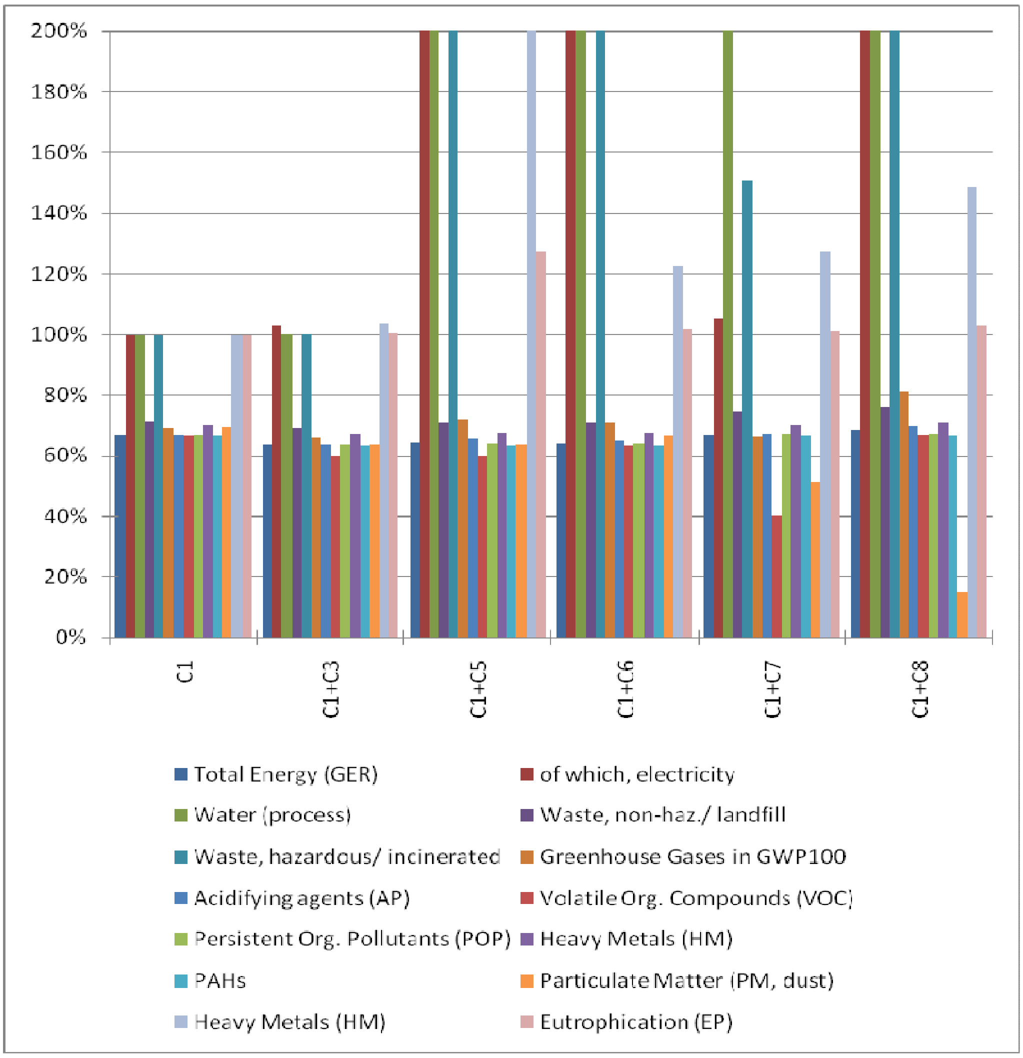

Figure 7-1: Typical changes to environmental impacts for components applicable to direct heating base cases (wood logs in traditional stove shown)

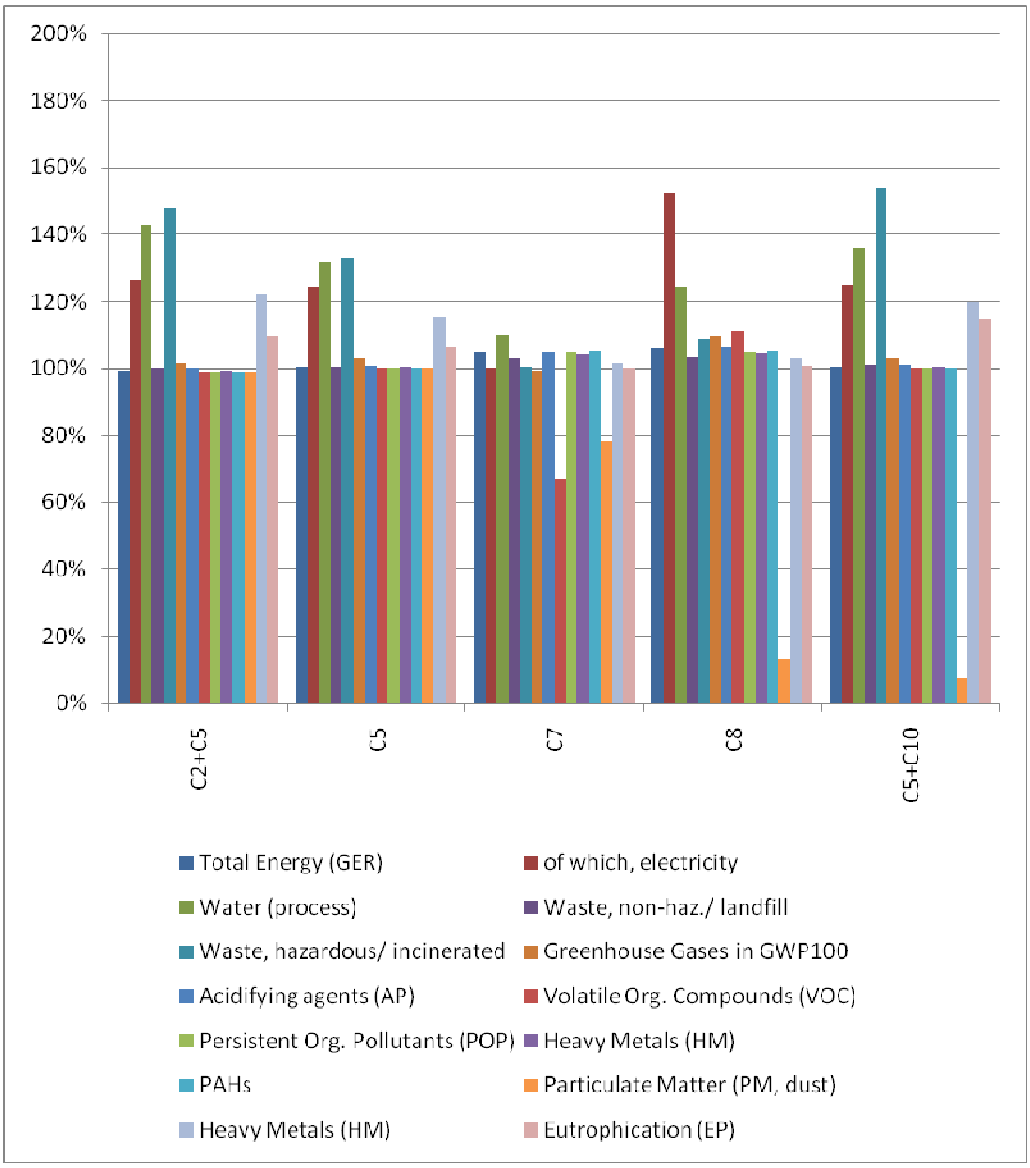

Figure 7-2 Typical changes to environmental impacts for components applicable to indirect heating base cases (wood logs in small manual boiler shown)

7.2.9. COMPARISON OF ENVIRONMENTAL IMPACTS BY FUEL TYPE

While there are small variations from case to case, the overal improvements made by each component are very similar across the various different fuel types as can be seen in Figure 7-3. Most of the components in this study have similar cross applicability due to the nature in which they have been implemented. Cyclones are assumed to only be applicable to coal fuels and have been modeled as such. While this is not entirely correct in reality, it is representative enough of the actual performance for the purposes of this study.

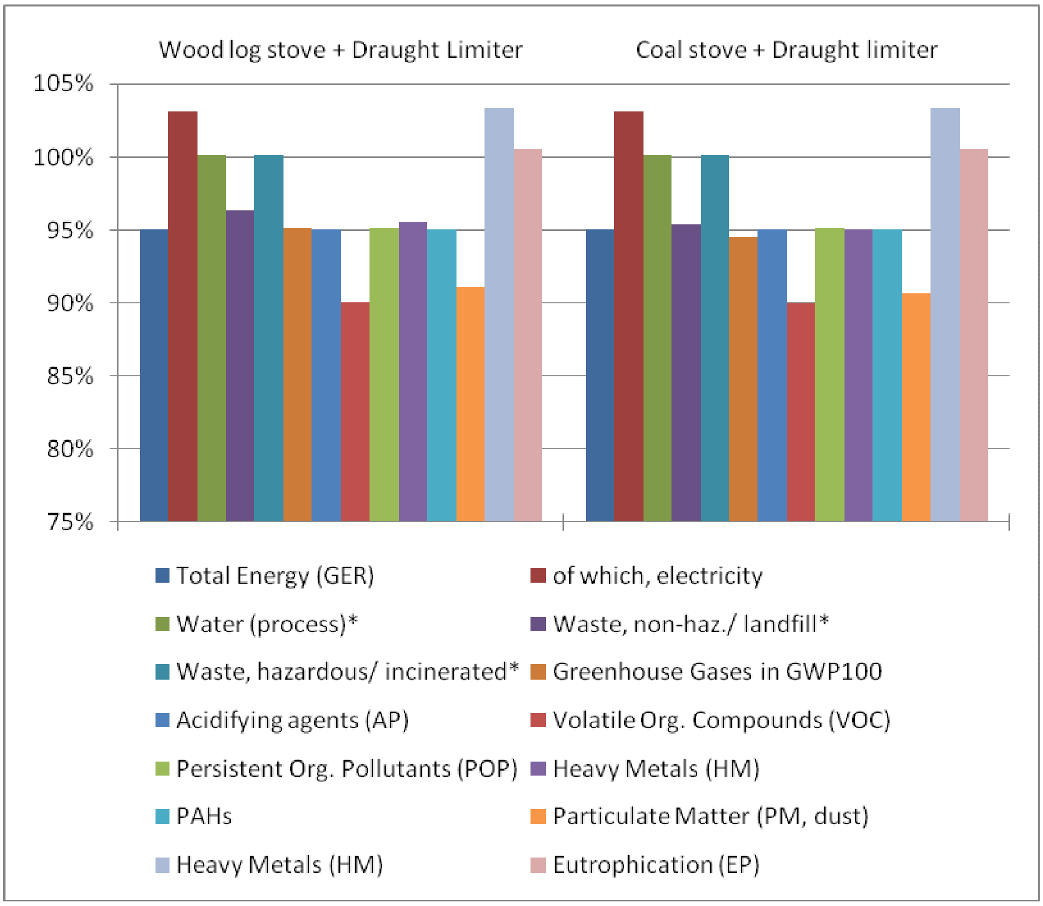

Figure 7-3: Comparison of the estimated effects of a draught limiter on two different fuel types for the same appliance

7.3. SUBTASK 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

Figure 7-1 presents the LCC for BC1 (open fireplaces) and component options 3 (draught limiter) and 6 (fan assisted direct heat exchange). Product case 1 (fireplace insert) is also presented.

Table 7-11: Life cycle costs comparison for open fireplace with wood logs, component options and fireplace insert (EUROS)

BC1	BC1 C3	BC1 C6	BAT P1
5997	5984	6828	3432

7.3.2. BASE CASE 2: CLOSED FIREPLACE

Table 7-12 presents the LCC for BC2 (closed fireplaces) and component options C1+C3 (advanced design and draught limiter), C1+C5 (advanced design and fan assisted draught) C1+C6 (advanced design and fan assisted heat transfer), C1+C7 (advanced design and catalyst), C1+C8 (advanced design and ESP). Product case BAT P1 (fireplace insert) is also presented alone and with after-treatment options C7 (catalyst) and C8 (ESP).

Table 7-12: Life cycle costs comparison for closed fireplace with wood logs, component options and fireplace insert (EUROS)

BC2	BC2 C1+C3	BC2 C1+C5	BC2 C1+C6	BC2 C1+C7	BC2 C1+C8	BAT P1	BAT P1 C7	BAT P1 C8
5288	4763	5333	5593	5710	6210	4492	4492	5992

7.3.3. BASE CASE 3: ADVANCED COOKER

Table 7-13 presents the LCC for BC3 (traditional cookers) and component options C1+C3 (advanced design and draught limiter), C1+C7 (advanced design and catalyst), C1+C8 (advanced design and ESP). Product case BAT C2 (advanced cooker) is also presented alone and with after-treatment options C7 (catalyst) and C8 (ESP).

Table 7-13: Life cycle costs comparison for traditional cooker with wood logs, component options and advanced cooker (EUROS)

BC3	BC3 C1+C3	BC3 C1+C7	BC3 C1+C8	BAT P2	BAT P2+C7	BAT P2+C8
3972	3742	4914	5567	4784	5804	6457

7.3.4. BASE CASE 4/5: TRADITIONAL/MODERN STOVE

Table 7-13 presents the LCC for BC4 and BC5 (traditional and modern stoves) and component options C1+C3 (advanced design and draught limiter), C1+C5 (advanced design and fan assisted draught) C1+C6 (advanced design and fan assisted heat transfer), C1+C7 (advanced design and catalyst), C1+C8 (advanced design and ESP). Product case BAT C3 (advanced stove) and product case BAT C4 (pellet stove) is also presented alone and with after-treatment options C7 (catalyst) and C8 (ESP).

Table 7-14: Life cycle costs comparison for traditional stove with wood logs, modern stove, component options and advanced stove (EUROS)

BC4	BC4 C1	BC5	BC4 C1+C3	BC4 C1+C5	BC4 C1+C6	BC4 C1+C7	BC4 C1+C8	BAT P3	BAT P4	BAT P3+ C7	BAT P3+ C8
6312	5176	5700	5192	5810	6070	6176	6795	4834	4504	5668	6287

7.3.5. BASE CASE 6: SMALL MANUAL BOILER

Table 7-15 presents the LCC for BC6 (small manual boilers) and component options C2+C5 (lambda probe and fan assisted draught), C5 (fan assisted draught), C7 (catalyst), C8 (ESP) and C5+C10 (fan assisted draught and fabric filter). Lambda probes are assumed to require a fan assisted draught. Fabric filters are assumed to require a fan assisted draught.

Product case BAT P5 (downdraught boiler) and product case BAT P6 (pellet boiler) is also presented alone and with after-treatment options 7 (catalyst), 8 (ESP) and 10 (fabric filter - product case 5 is assumed to already have a fan assisted draught).

Table 7-15: Life cycle costs comparison for small manual boiler with wood logs, component options and pellet boiler (EUROS)

BC6	BC6 C2+C5	BC6 C5	BC6 C7	BC6 C8	BC6 C5+C10	BAT P5	BAT P6	BAT P5 C7	BAT P5 C8	BAT P5 C10
11955	13505	12571	13158	13774	13571	10493	15449	12565	13181	12565

7.3.6. Base case 7: Small automatic boiler

Table 7-16 presents the LCC for BC7 (small automatic boilers) and component options C2+C5 (lambda probe and fan assisted draught), C5 (fan assisted draught), C7 (catalyst), C8 (ESP) and C5+C10 (fan assisted draught and fabric filter). Lambda probes are assumed to require a fan assisted draught. Fabric filters are assumed to require a fan assisted draught.

Product case BAT P6 (pellet boiler) is also presented alone and with after-treatment options C7 (catalyst), C8 (ESP) and C10 (fabric filter - product case BAT P6 is assumed to already have a fan assisted draught).

Table 7-16: Life cycle costs comparison for small automatic boiler with pellets, component options and chips boiler (EUROS)

BC7	BC7 C2+C5	BC7 C5	BC7 C5+C10	BC7 C7	BC7 C8	BAT P6	BAT P6 C7	BAT P6 C8	BAT P6 C10
18276	19322	18439	19439	19276	19907	16318	20338	20968	20338

7.3.7. Base case 8: Medium automatic boiler

Table 7-17 presents the LCC for BC8 (medium automatic boilers) and component options C2+C5 (lambda probe and fan assisted draught), C5 (fan assisted draught), C7 (catalyst), C8 (ESP), C5+C9 (fan assisted draught and cyclone) and C5+C10 (fan assisted draught and fabric filter). Lambda probes are assumed to require a fan assisted draught. Fabric filters and cyclones are assumed to require a fan assisted draught.

Product case BAT P8 (downdraught boiler) is also presented alone and with after-treatment options C7 (catalyst), C8 (ESP) and C10 (fabric filter - product case 8 is assumed to already have a fan assisted draught).

Table 7-17: Life cycle costs comparison for medium automatic boiler with lignite, component options, chips boiler and downdraught gasifying boiler (EUROS)

BC8	BC8 C2+C5	BC8 C5	BC8 C7	BC8 C8	BC8 C5+C9	BC8 C5+C10	BAT P8	BAT P8 C7	BAT P8 C8	BAT P8 C9	BAT P8 C10
68602	66664	66282	69602	70279	67371	67282	65204	67204	67881	66992	67204

7.4. SUBTASK 7.4 – ANALYSIS LLCC AND BAT

The Least Life Cycle Costs (LLCC) analysis and BAT analysis assess the improvements on 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 components on the Base Cases is presented in Figure 7-11. Not every combination of components which has been calculated is shown below for the sake of presentation, rather the simpler combinations containing either one or two components only is shown.

Table 7-18: Summary of the effects on gross energy requirement (GER) change for the components on base cases

	Advanced design	Draught limiter	Forced draught	Fan assisted direct heat exchange	Catalyst after-treatment	ESP after-treatment	Advanced design and draught limiter	Advanced design and forced draught	Advanced design and fan assisted heat exchange	Advanced design and catalyst after-treatment	Advanced design and ESP after-treatment	Lambda probe CO control with forced draught	Forced draught and cyclone	Forced draught and fabric filter
	C1	C3	C5	C6	C7	C8	C1+C3	C1+C5	C1+C6	C1+C7	C1+C8	C2+C5	C5+C9	C5+C10
BC1 - open fireplace (wood)		5%		5%										
BC2 - closed fireplace (wood)							30%	30%	30%	27%	25%			
BC3 - traditional cooker (wood)							33%			27%	25%			
BC4/BC5 – stoves (wood)	33%						36%	36%	36%	33%	32%			
BC6 - small manual boiler (wood)			0%		-5%	-6%						1%		0%
BC7 - small automatic boiler (pellets)			5%		0%	-1%						6%		5%
BC8 - medium automatic boiler (lignite)			5%		0%	0%						6%	5%	5%

Table 7-18 shows that the energy savings potential of many components is negligible or in fact increases the energy consumption. This is because many of the components are intended not to increase appliance efficiency, but to reduce the production of specific air emissions, specifically, PM, VOC and CO.

7.4.2. LEAST LIFE CYCLE COST SUMMARY

A summary of the life cycle cost change for the components on the Base Cases is presented in Figure 7-11. Not every combination of components which has been calculated is shown below for the sake of presentation, rather the simpler combinations containing either one or two components only is shown.

7-19: Summary of the effects for life cycle cost (LCC) change for the components on base cases

	Advanced design	Draught limiter	Forced draught	Fan assisted direct heat exchange	Catalyst after-treatment	ESP after-treatment	Advanced design and draught limiter	Advanced design and forced draught	Advanced design and fan assisted heat exchange	Advanced design and catalyst after-treatment	Advanced design and ESP after-treatment	Lambda probe CO control with forced draught	Forced draught and cyclone	Forced draught and fabric filter
	C1	C3	C5	C6	C7	C8	C1+C3	C1+C5	C1+C6	C1+C7	C1+C8	C2+C5	C5+C9	C5+C10
BC1 - open fireplace (wood)		0%		-14%										
BC2 - closed fireplace (wood)							10%	-1%	-6%	-8%	-17%			
BC3 - traditional cooker (wood)							6%			-24%	-40%			
BC4/BC5 – stoves (wood)	18%						18%	8%	4%	2%	-8%			
BC6 - small manual boiler (wood)			-5%		-10%	-15%						-13%		-14%
BC7 - small automatic boiler (pellets)			-1%		-5%	-9%						-6%		-6%
BC8 - medium automatic boiler (lignite)			3%		-1%	-2%						3%	2%	2%

7.4.3. BASE CASE 1: OPEN FIREPLACE

The LLCC and BAT for BC1 is BAT P1, a fireplace insert (Figure 7-4).

Life cycles costs for BAT P1 at the LLCC are € 2565 lower than for BC1 (89%) and Total energy consumption (GER) is 516 GJ lower (43%). PM emissions are also 88% lower than for BC1, at 8429 kg (Figure 7-4). These results can be explained by the fact that BAT P1 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.

A combination of BC1 with some improvement options always makes the product more expensive. Moreover, the best environmental performance which can be achieved with options, by combining C3 and C6 (a draught limiter and fan assisted direct heat exchange), is only 10% lower than that of BC1 for GER. Similar patterns are observed between PM and GER (Figure 7-5) for all option combinations. This is expected, since neither C3 nor C6 enable a reduction in PM emissions.

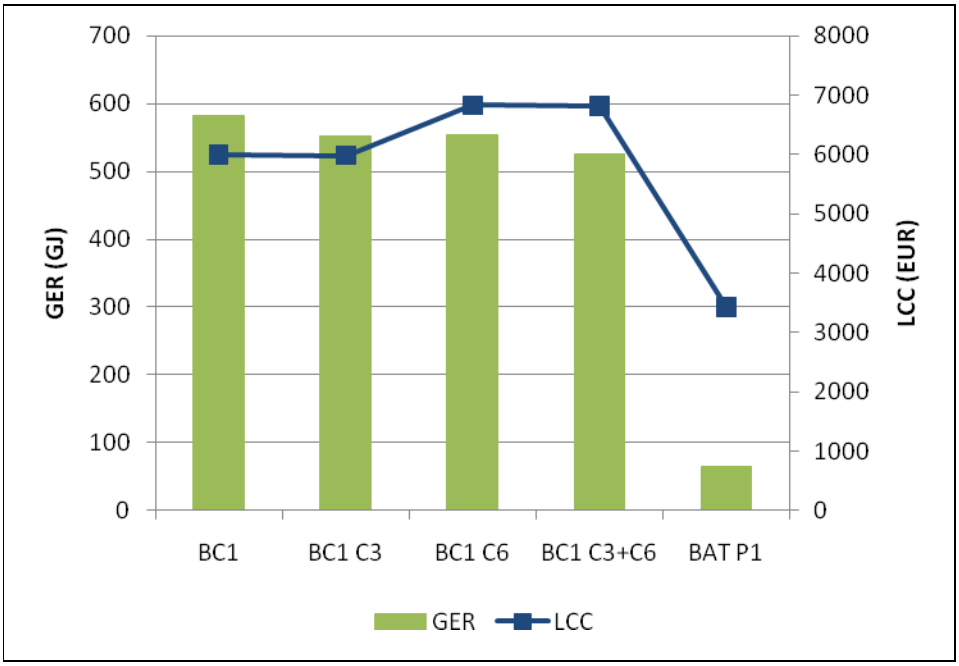

Figure 7-4: BC1: open fireplace with wood logs– Total life cycle cost (LCC) and BAT (in terms of GER) per option

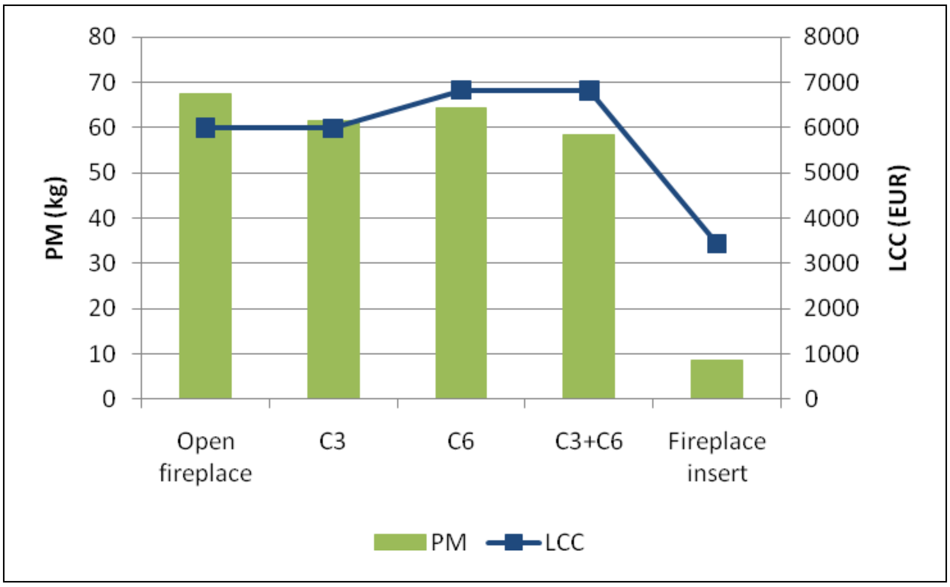

Figure 7-5: BC1: open fireplace with wood logs – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.4. BASE CASE 2: CLOSED FIREPLACE

The LLCC and BAT for BC2 is BAT P1, an advanced closed fireplace, with or without C7, a catalyst (Figure 7-6). As can be seen from Figure 7-6, BAT P1 is more or less equivalent to BC2 with C1 and C3, a closed fireplace with improved air distribution/combustion chamber and draught control.

Life cycle costs for BAT P1 at the LLCC point (with or without C7) are € 796 lower than for BC2 (15%).

Total energy consumption (GER) of BAT P1 is 257 GJ or 34% lower than for BC2. However, most other combinations offer similar energy improvements (range 25% to 33%). In addition, BAT P1 is not the best performing appliance in terms of PM emissions (Figure 7-7). BAT P1 emits 23 kg of PM over its lifetime (58.6% less than BC2), whereas addition of C8, an ESP, to any combinations of BC2 and C1 (a closed fireplace with improved air distribution/ combustion chamber) leads to 84-91% reductions in PM emissions compared to BC2. Although, addition of C1 does not yield an increase in cost compared to BC2, addition of C8 yields to an increase in LCC of 17-54%, depending on how many other options its is combined with.

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

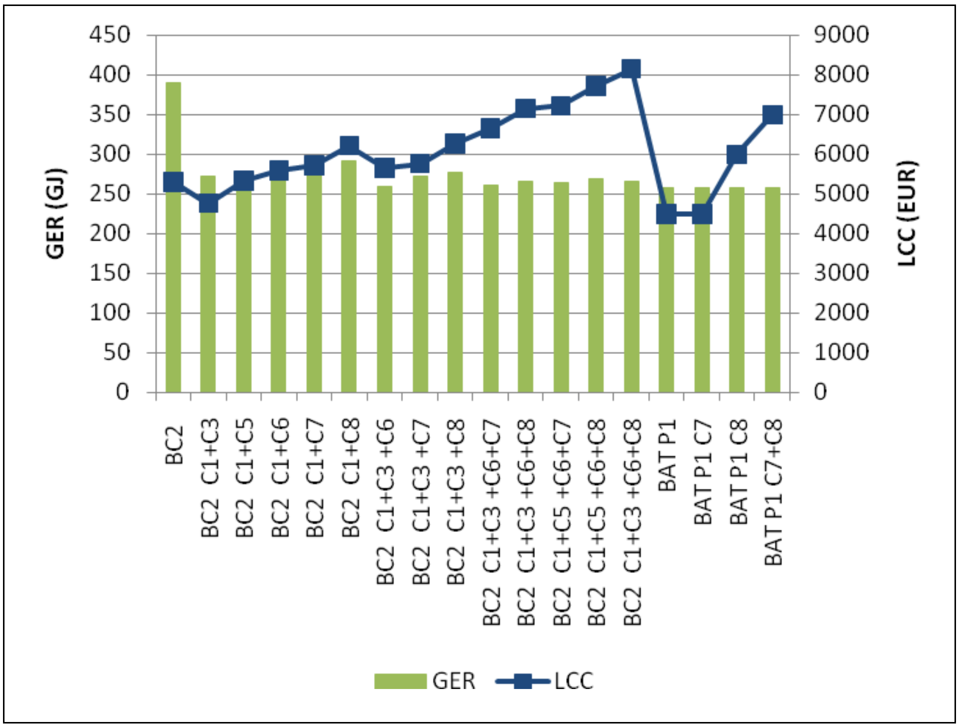

Figure 7-6: BC2: closed fireplace with wood logs – Total life cycle cost (LCC) and BAT (in terms of GER) per option

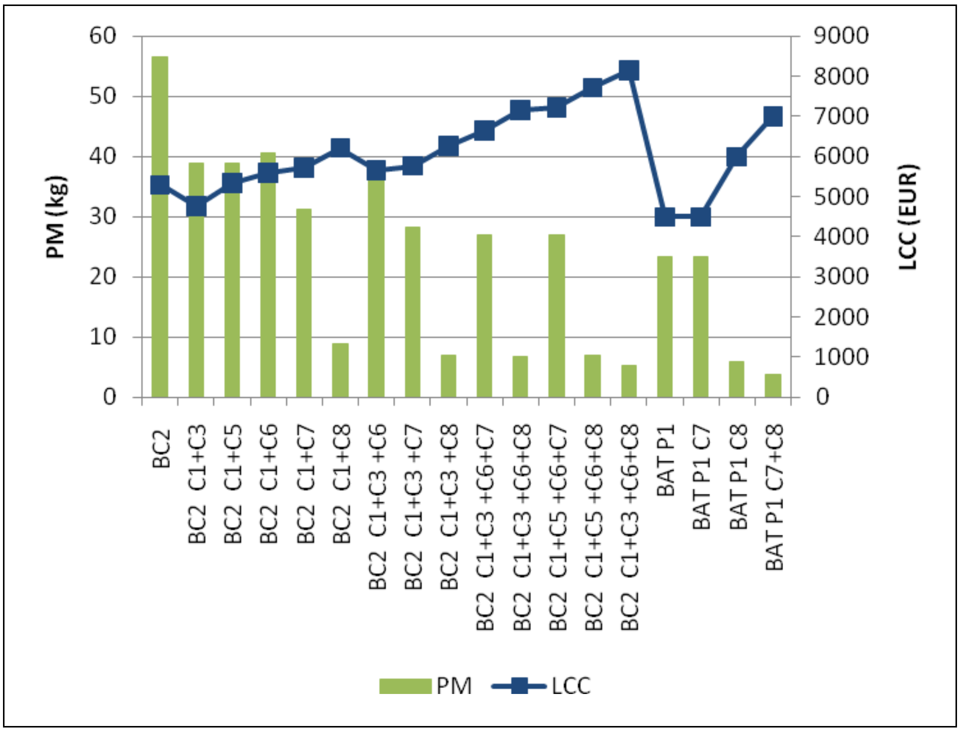

Figure 7-7: BC2: closed fireplace with wood logs – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.5. BASE CASE 3: TRADITIONAL COOKER

The LLCC for BC3 is BC3 with C1 and C3, a cooker with improved air distribution/combustion chamber and draught control (Figure 7-8).

Life cycle costs for BC3+C1+C3 at the LLCC point are € 230 lower than for BC3 (6%, Figure 7-8).

However, the BAT is BAT P2, with GER 122 GJ (41% lower than for BC3), although BC3+C1+C3 has very similar energy consumption (138 GJ). However, neither BAT P2 nor BC3+C1+C3 is the best performing appliance in terms of PM emissions (Figure 7-9). BAT P2 emits 26 kg of PM over its lifetime (11% less than BC3) and BC3+C1+C3 emits 20.5 kg of PM (30% less than BC3). The lowest PM emissions are obtained by adding C8, to either of those two BATs, but leads to an increase in LCC of 40% compared to BC3.

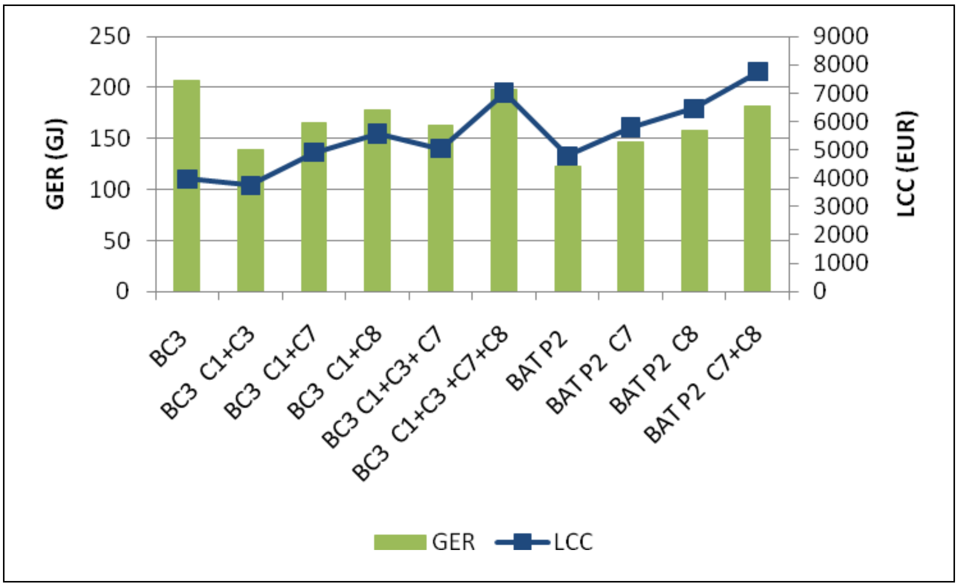

Figure 7-8: BC3: traditional cooker with wood logs – Total life cycle cost (LCC) and BAT (in terms of GER) per option

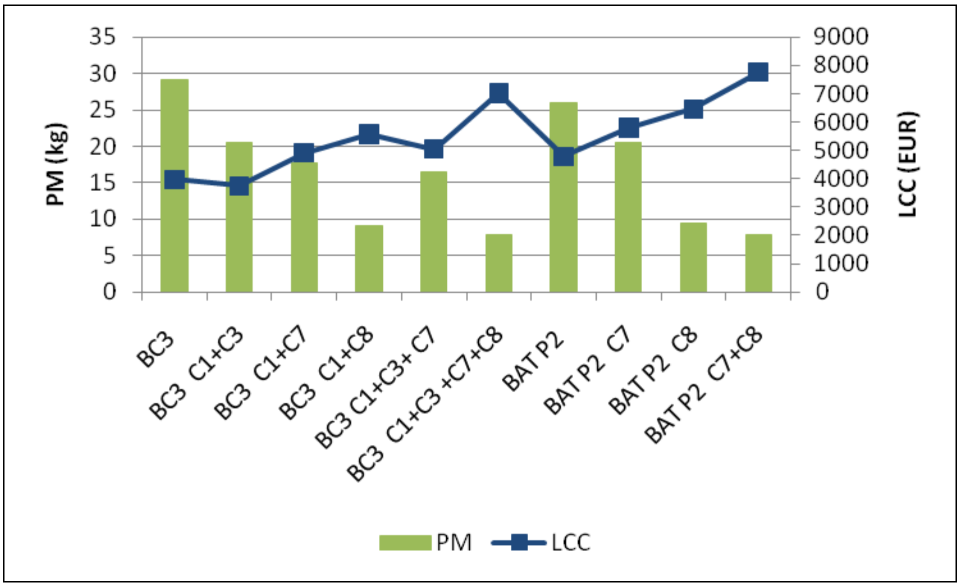

Figure 7-9: BC3: traditional cooker with wood logs – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.6. BASE CASE 4/5: TRADITIONAL STOVE/MODERN STOVE

BC5 and BC4+C1 are essentially similar appliances, stoves with improved air distribution/combustion chamber and an efficiency of 60%. Yet, BC5 consumes XX% more energy over its lifetime than BC4+C1. This may be explained by the fact that the lifetime of BC5 is assumed to be half that of BC4+C1 (12.5 years instead of 27.5 years), as well as by the fact that BC5 is approximately 10% heavier overall than BC4.

The LLCC and BAT for BC4 and BC5 is BAT P4, a pellet stove (Figure 7-10), although that appliance is in fact fuelled with pellets rather than wood logs like BC4. Thus some of the differences observed may simply be due to the different fuels, rather than to the performance of the appliance itself. Life cycle costs for BAT P4 at the LLCC point are €

4504, 29% less than for BC4 and 21% than for BC5. The total energy consumption (GER) of BAT P4 is 168 GJ or 74% lower than that of BC4.

However, within stoves fired with wood logs, the BAT and LLCC is BAT P3, an advanced stove. BAT P3 has a GER of 264 GJ (60% lower than that of BC4) and a very similar LLCC as BAT P4 at € 4834. All other combinations of options offer worse energy performance (range 32% to 39% improvement compared to BC4), and worse LLCC (range -18% to +40% change compared to BC4). A combination of BC4 with more than two improvement options always makes the LLCC increase significantly.

BAT P4 is also the best performing appliance in terms of PM emissions, with 6 kg emitted over its lifetime (92% less than BC4). In contrast, BAT P3 emits 45 kg of PM (43% less than BC4). Addition of C8, an ESP, to any combinations of BC4 and C1 (a stove with improved air distribution/ combustion chamber) leads to 85-91% reductions in PM emissions compared to BC4. But although the addition of C1 does not yield an increase in cost compared to BC4, addition of C8 yields to a substantial increase in LCC.

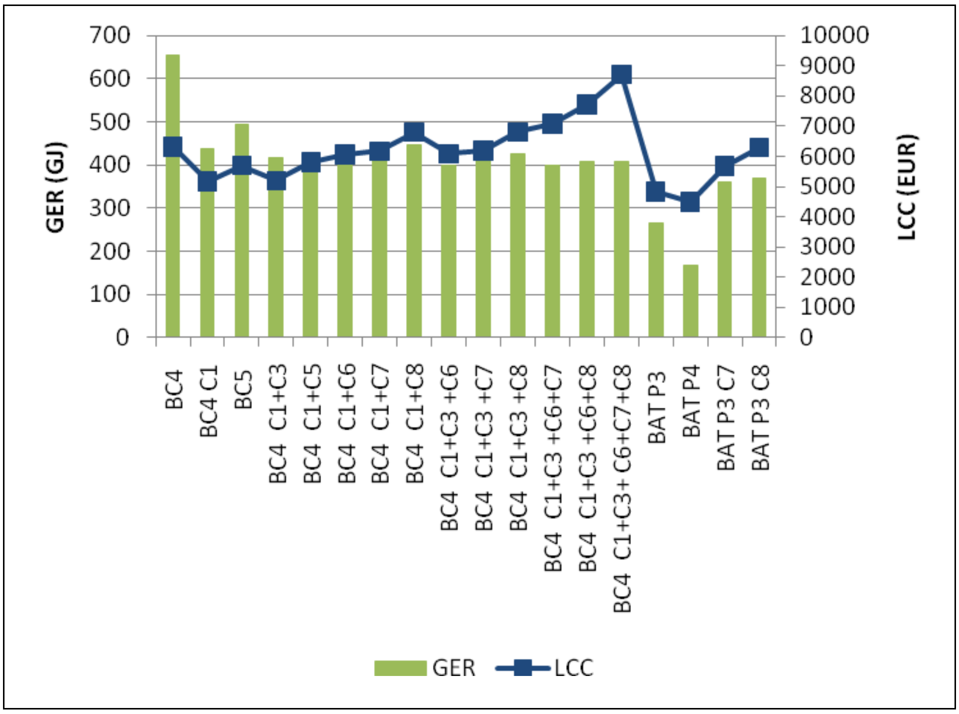

Figure 7-10: BC4: traditional stove and BC5: modern stove with wood logs – Total life cycle cost (LCC) and BAT (in terms of GER) per option

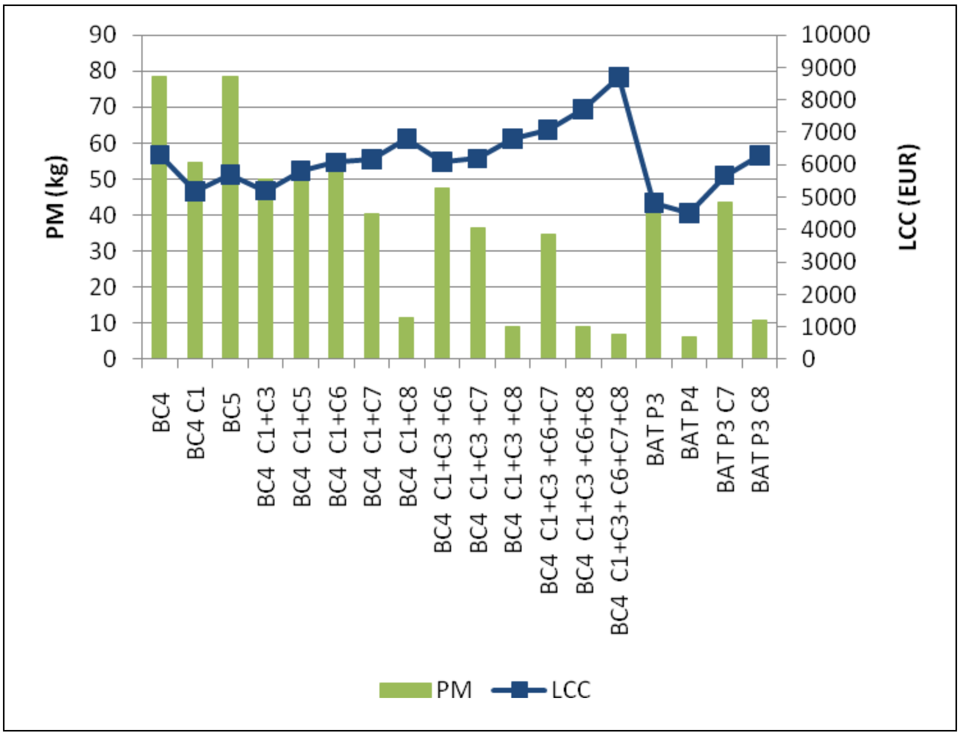

Figure 7-11: BC4: traditional stove and BC5: modern stove with wood logs – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.7. BASE CASE 6: SMALL MANUAL BOILER

The LLCC and BAT for BC6 is BAT P5, a downdraught boiler (Figure 7-12). Life cycle costs for BAT P5 at the LLCC point are € 10493, 12% lower than for BC6, while it uses 920 GJ of energy over its lifetime (20% lower than for BC6). BAT P5 is also the second best performing appliance in terms of PM emissions, with 44 kg over its lifetime (84% less than BC6; Figure 7-13).

BAT P6, a pellet boiler, is the next best performing appliance in terms of GER and LLCC, and the best performing appliance in terms of PM (95% PM reduction compared to BC6 - Figure 7-13) – although it is difficult to make a direct comparison of BAT P6 with the others, since it is fuelled with pellets rather than wood logs.

All other combinations offer little improvements in terms of energy (range -1 to +1% change compared to BC6), but most options offer significant PM reductions (range 0-87% reductions compared to BC6).

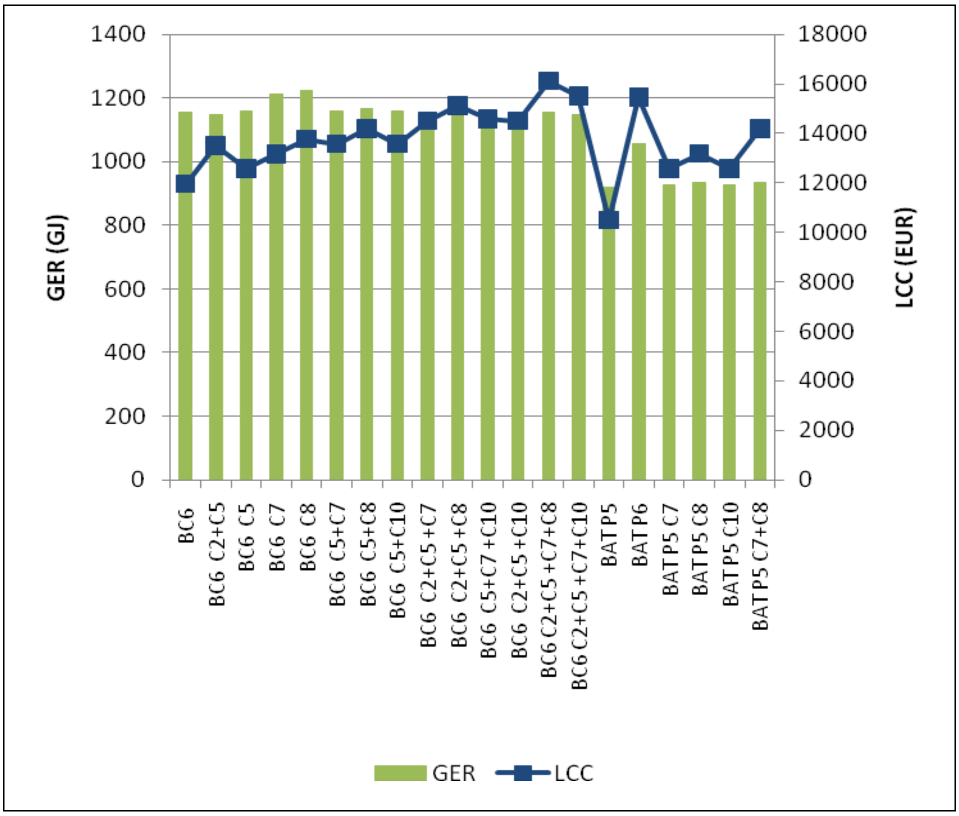

Figure 7-12: BC6: small manual boiler with wood logs – Total life cycle cost (LCC) and BAT (in terms of GER) per option

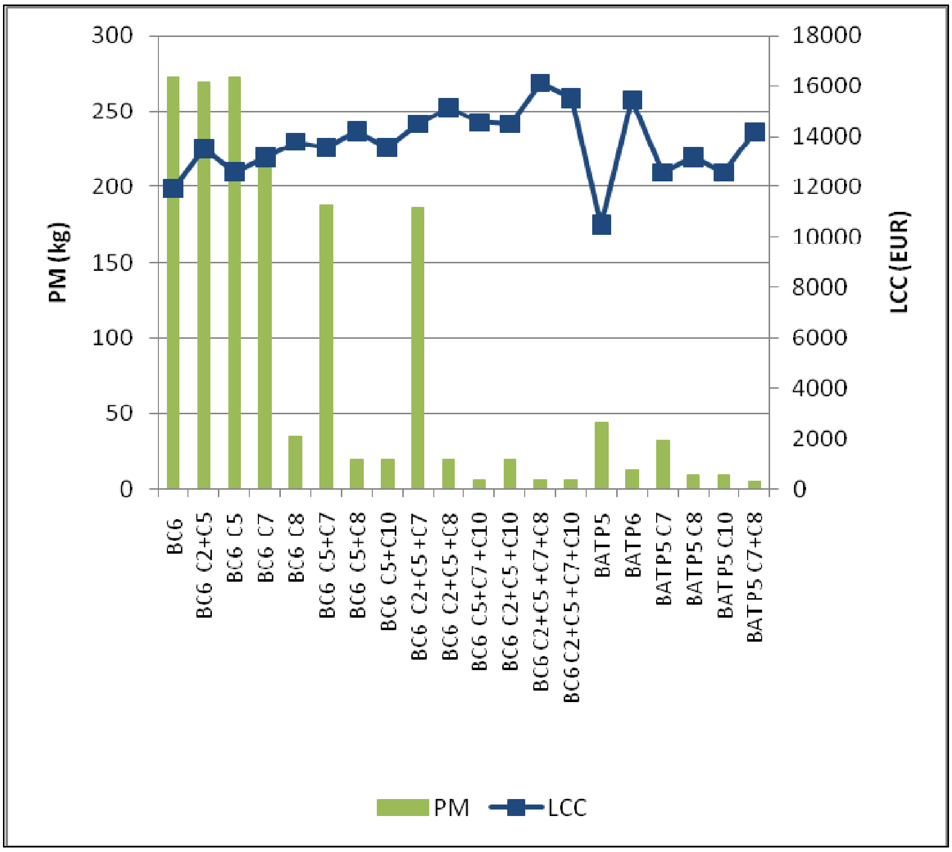

Figure 7-13: BC6: small manual boiler with wood logs – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.8. BASE CASE 7: SMALL AUTOMATIC BOILER

The LLCC and BAT for BC7 is BAT P6, a pellet boiler (Figure 7-14). Life cycle costs for BAT P6 at the LLCC point are € 16318, 11% lower than for BC7, while it uses 1204 GJ of energy over its lifetime (15% lower than for BC7). However, since BAT P6 is fuelled with wood pellets instead of wood logs, some of the differences observed may simply be due to the different fuel, rather than to the performance of the appliance itself (pellets tend to use slightly more energy than wood logs over their lifetime, but emit approximately three times less PM, Task5 Section 5.2.1). BAT P6 also has low PM emissions (13.8 kg) although the lowest PM emissions (6.2 kg) are obtained with an after-treatment, whether an ESP (C8) or a fabric filter (C10).

Within wood log appliances, the BAT is BC7 with C2 and C5, fan assisted draught and lambda probe, with a GER of 1333 GJ (5.5% less than BC7). BC7 + C5 (fan assisted draught) is the second LLCC at € 18439. PM emissions are equivalently reduced with C8 (ESP) or C10 (fabric filter) and BC7 + C5 (fan assisted draught) emit 8.7 kg of dust with both options. However, the BAT in terms of PM emissions within wood log appliances is BC7 + C5 (fan assisted draught) + C7 (catalyst) + C10 (fabric filter), with 6.6 kg of dust emitted. The increase in life cycle cost for the PM emissions BATs ranges from 5.5% to 11.8% compared to BC7.

All other combinations offer little improvements in terms of energy (range -5.5-0% change compared to BC7), but any option with a PM abatement treatment offer significant PM reductions (range 8-87% reductions compared to BC7).

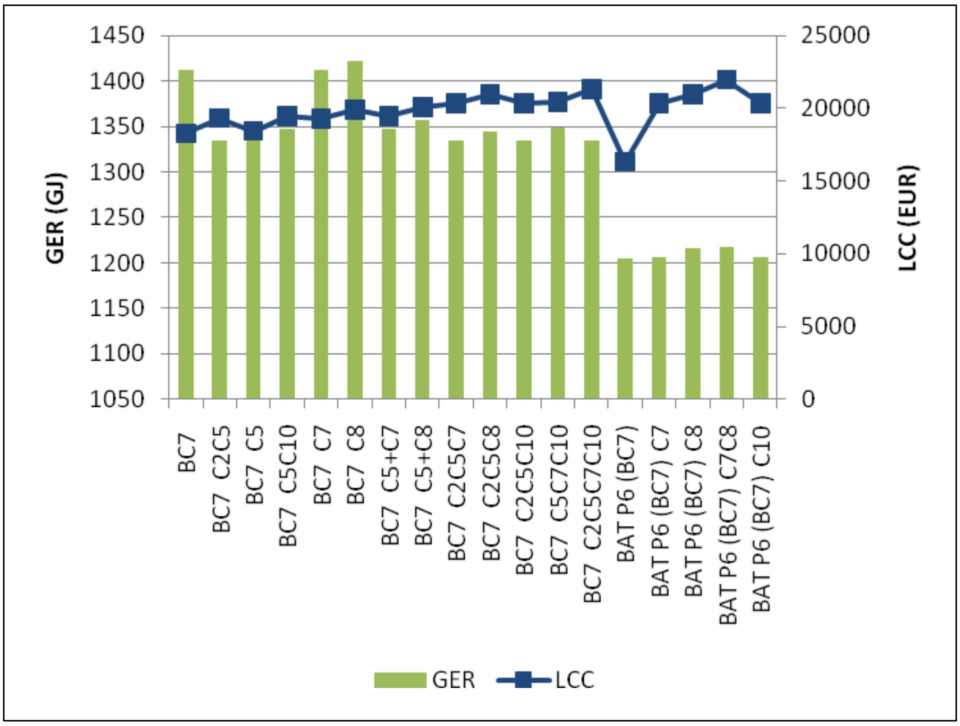

Figure 7-14: BC7: small automatic boiler with pellets – Total life cycle cost (LCC) and BAT (in terms of GER) per option

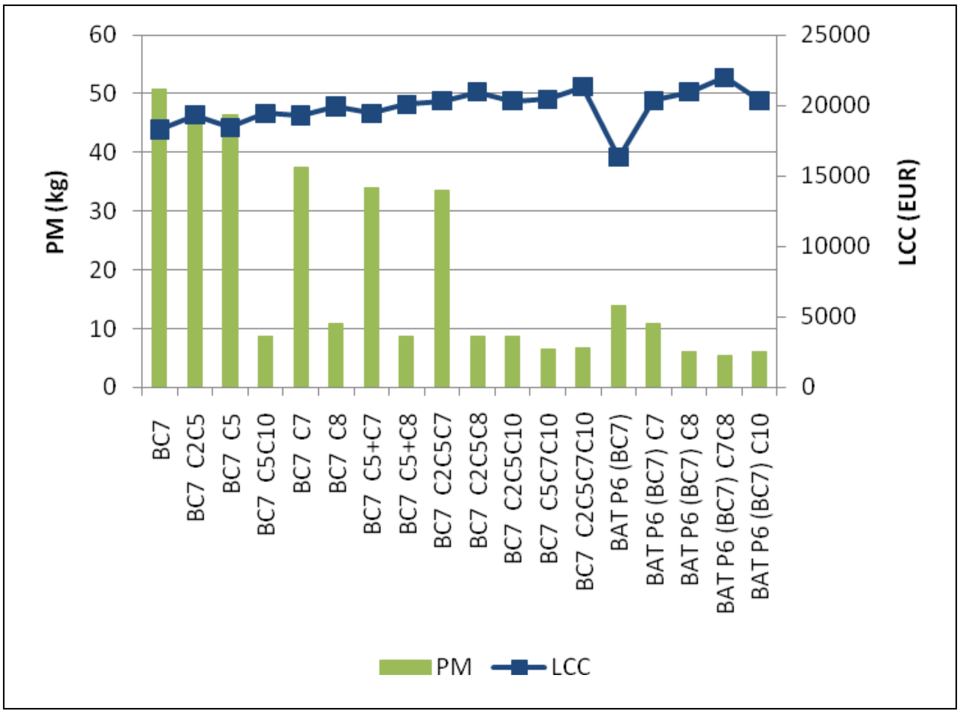

Figure 7-15: BC7: small automatic boiler with pellets – Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.9. BASE CASE 8: MEDIUM AUTOMATIC BOILER

The LLCC and BAT for BC8 is BAT P8, a downdraught gasifying boiler (Figure 7-16). Life cycle costs for BAT P8 at the LLCC point are € 65204, 4.5% lower than for BC8, while it uses 8433 GJ of energy over its lifetime (8% lower than for BC6). However, BAT P8 is not the BAT in terms of PM emissions, with 567 kg of dust emitted over its lifetime (69% less than BC6; Figure 7-17). The best performing appliance in terms of emissions is BC8 combined with C2+C5+C7+C10 (an automatic boiler with fan assisted draught, lambda probe, catalyst and fabric filter), which emits 24 kg of dust over its lifetime (99% less than BC8).

However, except for BC8 combined simply with C7 (catalyst) or C8 (ESP), all other combinations offer similar improvements as BAT P8 in terms of energy (range 5-6% improvement compared to BC6), and similar LLCC (range 0-3%).

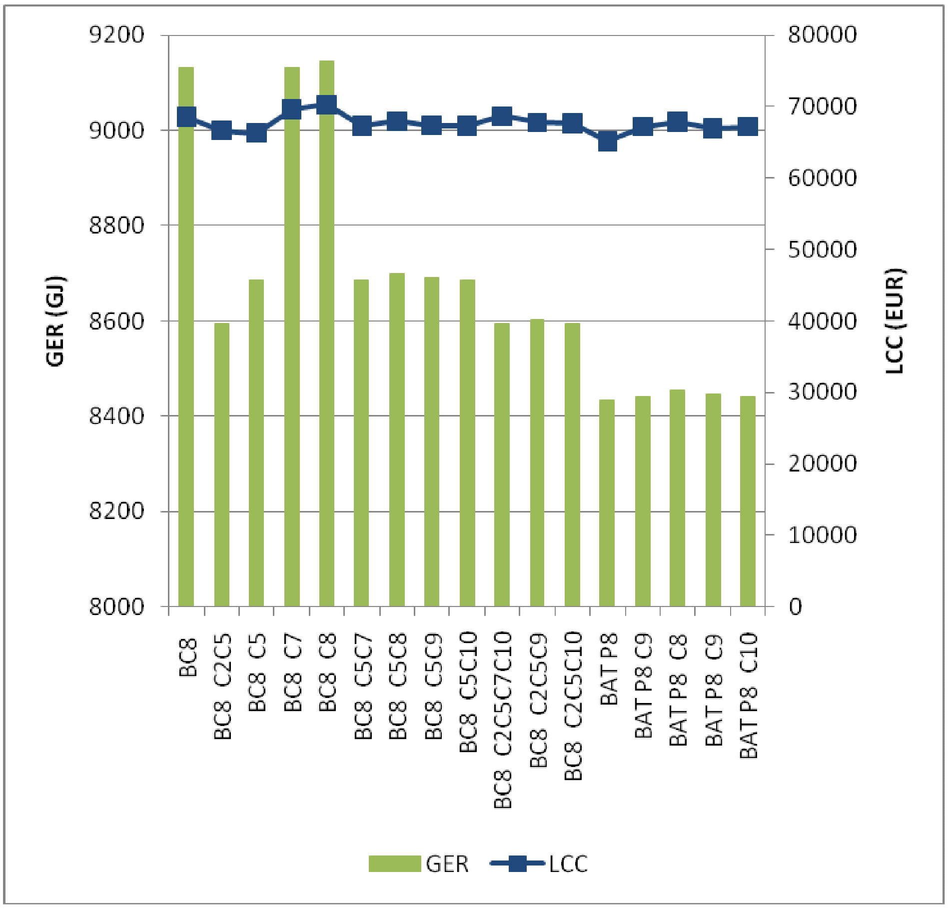

Figure 7-16: BC8: medium automatic boiler with lignite – Total life cycle cost (LCC) and BAT (in terms of GER) per option

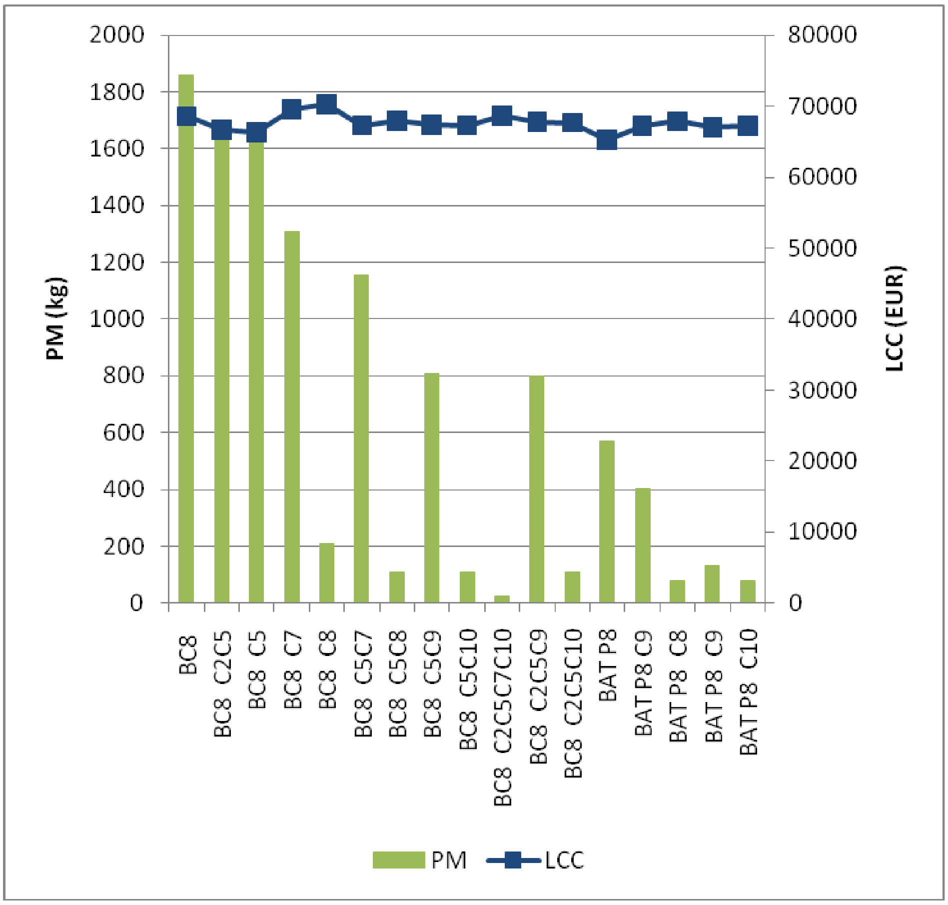

Figure 7-17: BC8: medium automatic boiler with options - Total life cycle cost (LCC) and BAT (in terms of PM) per option

7.4.10. SUMMARY

Table 7-20 and Table 7-21 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 7-20: Overview of the BAT options for each base case

Base case	**Best environmental impact reduction improvement option**	**Life cycle energy reduction potential**	**Life cycle costs reduction potential**
BC1: Open fireplace (wood)	BAT P1: Fireplace insert (wood)	**89%**	43%
BC2: Closed fireplace (wood)	BAT P1: Fireplace insert (wood)	**34%**	15%
BC3: Traditional cooker (wood)	BAT P2: Advanced cooker (wood)	**41%**	-20%
BC4: Traditional stove (wood)	BAT P4: Pellet stove (pellet)	**74%**	29%
BC5: Modern stove (wood)	BAT P4: Pellet stove (pellet)	**74%**	29%
BC6: Small manual boiler (wood)	BAT P5: Downdraught boiler (wood)	**20%**	12%
BC7: Small automatic boiler (wood)	BAT P6 : Pellet boiler (pellet)	**15%**	11%
BC8: Medium automatic boiler (wood)	BAT P8: Downdraught gasifying boiler (lignite)	**8%**	5%

Table 7-21: Overview of the LLCC options for each base case

Base case	Least life cycle cost improvement option	Life cycle costs reduction potential	Life cycle energy reduction potential
BC1: Open fireplace (wood)	BAT P1: Fireplace insert (wood)	**43%**	89%
BC2: Closed fireplace (wood)	BAT P1: Fireplace insert (wood)	**10%**	30%
BC3: Traditional cooker (wood)	BAT P2: Advanced cooker (wood)	**6%**	33%
BC4: Traditional stove (wood)	BAT P4: Pellet stove (pellet)	**29%**	74%
BC5: Modern stove (wood)	BAT P4: Pellet stove (pellet)	**29%**	74%
BC6: Small manual boiler (wood)	BAT P5: Downdraught boiler (wood)	**12%**	20%
BC7: Small automatic boiler (wood)	BAT P6 : Pellet boiler (pellet)	**11%**	15%
BC8: Medium automatic boiler (wood)	BAT P8: Downdraught gasifying boiler (lignite)	**5%**	8%

➔ 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:

- Product case 1: fireplace insert/closed fireplace – this appliance is applicable to upgrade open fireplaces and replace closed fireplaces. Calculations show that this product provides the greatest reduction in energy consumption relative to its compatible base case.
- Product case 4: small pellet stove – this appliance is applicable for replacing traditional stoves which have the largest use (stock and yearly use) in Europe based on Task 5 assumptions. They can provide the largest reduction in energy consumption to their relevant base case and provide more emissions reductions as well.

  Since this product requires a change of fuel type, it may not always be applicable as a replacement option for base case 4 and 5 (stoves), and therefore the next largest potential energy savings impact in Europe with the same fuel type as the appliance it is replacing is product case 3: advanced stove with wood fuel.

The energy savings potential for indirect heating appliances is less dramatic because the base case appliances had fairly good efficiencies already, nevertheless, the largest potential energy savings impact in Europe for indirect heating appliances is:

- Product case 6: Downdraught gasifying boiler – this appliance is applicable for replacing small manual boiler <50kW.

None of the component options were found to have comprehensive high emission reductions or high reduction in energy consumption. In every case, the product cases available on the market were calculated to be superior for environmental benefits than traditional (base case) appliances with upgraded components. The main reason for this is that the efficiency of new, advanced designed products far outweighs the incremental benefits one can achieve by upgrading traditional designs.

➔ 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 bag filter performed well in terms of filtering particulate matter, minimizing other environmental indicator increases (through materials usage, disposal, etc) and in terms of life cycle costs. The bag filter is estimated to provide as much filtration efficiency for particulate matter **provided it is maintained regularly (clean)** as ESPs and consume less electricity while producing less other environmental impacts.

However, cleaning bag filters is a major concern because as a bag filter material fills with particulate matter, its pressure drop increases, disrupting the airflow through the appliance and potentially significantly disrupting the combustion efficiency. This problem does not occur with ESPs and hence the performance from ESP would be more reliable throughout the lifetime of the appliance. The spectrum or range of particle sizes on which a bag filter is expected to be effective is different and potentially less beneficial than the particle size ranges on which ESPs are effective.

➔ LEAST LIFE CYCLE COSTS SAVINGS POTENTIAL

Based on Table 7-20 and Table 7-21, the appliances which had the best life cycle costs savings potential were:

- Product case 1: Fireplace inserts/closed fireplace – this appliance is applicable to upgrade open fireplaces and replace closed fireplaces. Calculations show that this product provides the greatest life cycle cost savings relative to its compatible base case.
- Product case 4: Small pellet stove – this appliance is applicable for replacing traditional stoves which have the largest use (stock and yearly use) in Europe based on Task 5 assumptions. They can provide the second largest life cycle cost savings to their relevant base case.

  Since this product requires a change of fuel type, it may not always be applicable as a replacement option for base case 4 and 5 (stoves), and therefore the next largest cost savings impact in Europe with the same fuel type as the appliance it is replacing is product case 3: advanced stove with wood fuel.

The life cycle costs savings potential for indirect heating appliances is less dramatic because the base case appliances had fairly good efficiencies already, nevertheless, the largest life cycle costs savings potential in Europe for indirect heating appliances is:

- Product case 6: Downdraught gasifying boiler – this appliance is applicable for replacing small manual boiler <50kW.

7.5. CONCLUSIONS

As presented in this task, the improvement potential of each of the 8 base cases is significant. The EcoReport analysis show 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 in the scope of this study.