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Contract N°. Specific contract 185/PP/ENT/IMA/12/1110333 implementing FC ENTR/29/PP/FC Lot 2

Report

Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:
Lot 8- Power Cables

DRAFT Task 6 report - Design options (improvement potential) (1st version)

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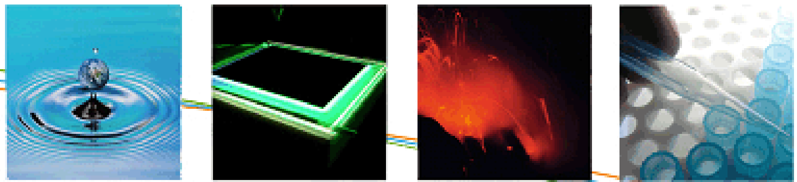

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EXECUTIVE SUMMARY

VITO is performing the preparatory study for the new upcoming eco-design directive for Energy-related Products (ErP) related to power cables, on behalf of the European Commission (more info http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/index_en.htm).

In order to improve the efficient use of resources and reduce the environmental impacts of energy-related products the European Parliament and the Council have adopted Directive 2009/125/EC (recast of Directive 2005/32/EC) establishing a framework for the setting Ecodesign requirements (e.g. energy efficiency) for energy-related products in the residential, tertiary, and industrial sectors. It prevents disparate national legislations on the environmental performance of these products from becoming obstacles to the intra-EU trade and contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, taking into account the whole life cycle cost. This should benefit both businesses and consumers, by enhancing product quality and environmental protection and by facilitating free movement of goods across the EU. It is also possible to introduce binding information requirements for components and sub-assemblies.

The MEErP methodology (Methodology for the Ecodesign of Energy-related Products) allows the evaluation of whether and to which extent various energy-related products fulfil the criteria established by the ErP Directive for which implementing measures might be considered. The MEErP model translates product specific information, covering all stages of the life of the product, into environmental impacts (more info http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm).

The tasks in the MEErP entail:
Task 1 - Scope (definitions, standards and legislation);
Task 2 – Markets (volumes and prices);
Task 3 – Users (product demand side);
Task 4 - Technologies (product supply side, includes both Best Available Technology (BAT) and Best Not Yet Available Technology (BNAT));
Task 5 – Environment & Economics (base case Life Cycle Assessment (LCA) & Life Cycle Costs (LCC));
Task 6 – Design options(improvement potential);
Task 7 – Scenarios (policy, scenario, impact and sensitivity analysis).
Tasks 1 to 4 can be performed in parallel, whereas 5, 6 and 7 are sequential.
Task 0 or a Quick-scan is optional to Task 1 for the case of large or inhomogeneous product groups, where it is recommended to carry out a first product screening. The objective is to re-group or narrow the product scope, as appropriate from an ecodesign point of view, for the subsequent analysis in tasks 2-7.

The preparatory phase of this study is to collect data for input in the MEErP model. An executive Summary of the complete study will be elaborated at completion of the draft final report.

Comment: This report is currently a working progress, as some parts of the study are missing comments and data from the stakeholders, therefore it shall not be viewed as a final report.

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List of Acronyms

α_c	corrected or circuit Load Factor
BAT	Best Available Technology
BAU	Business As Usual
BC	Base Case
BNAT	Best Not (Yet) Available Technology
BOM	Bill Of Materials
CSA	conductor Cross-Sectional Area
Cu	Copper
EC	European Commission
EOL	End Of Life
GER	Gross Energy Requirement
GWP	Global Warming Potential
HL	High length
HPL	High product lifetime
Kd	Distribution factor
Kf	Load Form Factor
LCA	(environmental) Life Cycle Assessment
LCC	Life Cycle Costs
LL	Low length
LLCC	Least Life Cycle Costs
LPL	Low product lifetime
LV	Low Voltage
MV	Medium Voltage
PAHs	Polycyclic Aromatic Hydrocarbons
Pf	Power Factor
PM	Particulate Matter
PVC	PolyVinyl Chloride
ρ	conductor resistivity
R	Resistance
TBC	To Be Confirmed
TBD	To Be Defined
VITO	Flemish institute for Technological Research
XLPE	Cross-Linked PolyEthylene

Use of text background colours

Blue: draft text
Yellow: text requires attention to be commented
Green: text changed in the last update

CHAPTER 6 TASK 6: DESIGN OPTIONS

The objective of this task is to identify design options, their monetary consequences in terms of Life Cycle Cost (LCC) for the user, their economic and possible social impacts, and pinpointing the solution with the Least Life Cycle Costs (LLCC) and the Best Available Technology (BAT).

The assessment of monetary LCC is relevant to indicate whether design solutions might impact the total user's expenditure over the total product life (purchase, operating, end-of-life costs, etc.). The distance between the LLCC and the BAT indicates —in a case an LLCC solution is set as a minimum target— the remaining space for product-differentiation (competition).

The BAT indicates a target in the shorter term that would probably be more subject to promotion measures than to restrictive action. The BNAT indicates possibilities in the longer term and helps to define the exact scope and definition of possible measures. Any intermediate options between the LLCC and the BAT have to be described, and their impacts assessed.

Remark: Further in this study the word "power cables" will be used as a general term for single core or multi-core LV power cables in buildings, unless otherwise stated.

Summary of Task 6:
Design options D1, D2 and D3 stand respectively for the S+1, S+2 and S+3 scenario for increased cable Cross-Sectional Areas (CSA) as described in Task 4 in section 4.2.4. Design option D4 stands for the '2S scenario', meaning two cables with section S are installed in parallel. These are the four design improvement options that are applied to the nine defined base cases in Task 5.
Section 6.2 concludes that those design options have a positive impact on almost any of the environment parameters generated with the MEErP EcoReport tool. In summary all the parameters including Global Warming Potential (GWP) improved, except impact from 'water (process)', 'heavy metals (emissions in water and air)' and 'Particulate Matter (PM)'. The defined base cases BC2, BC3, BC6 and BC7, representing the so-called lighting and socket-outlet circuits, performed relative less. In particular the parameters Polycyclic Aromatic Hydrocarbons (PAHs), PM and Eutrophication increased in several 'improvement' options. It was also found that the so-called base cases with a high load need only a few years to compensate the increase of greenhouse gas in the production and distribution. This period can be seen as a kind of 'environmental payback time'. For base cases representing circuits with a low load this 'environmental payback time' increased significantly up to almost the circuit life time. Therefore policy measures from Task 7 should be defined carefully not imposing an increased CSA for any circuit disregarding their loading. Looking at GWP alone, the BAT is in almost all base cases design option D3. Only for base case (BC) 3, it is design option D2.
Based on input from previous tasks, LCC has also been calculated in section 6.4 for all options and the LLCC improvement options were identified. For the so-called base cases BC2 (lighting circuits) and BC3 (socket circuits) in the services sector, the LLCC is 'Business As Usual' (BAU), hence no economic improvement is identified. All other defined base cases (1, 3-9) showed economic justified improvement potential that will be addressed in the proposed policy options in Task 7. The explanation for these differences is related to the variations in the loading behind the defined base cases.

Finally also a sensitivity analysis has been done in section 6.6 on the circuit loading parameters, circuit length and product lifetime. This can be useful information for the impact analysis in Task 7.

6.1 Identification of design options and assessment of their impacts

Available design options are identified by investigating and assessing the environmental impact and LCC of each suggested design option against each BC using the MEErP EcoReport tool 2011, and have to comply with the following rules:

- The design option should not have a significant variation in functionality, quality of the produced products, primary or secondary performance parameters compared to the BC, and in product-specific inputs.
- The design option should have a significant potential for improvement regarding at least one of the following ecodesign parameters without deteriorating others:
    - consumption of energy, water and other resources,
    - use of hazardous substances,
    - emissions to air, water or soil,
    - weight and volume of the product,
    - use of recycled material,
    - quantity and nature of consumables needed for proper use and maintenance,
    - ease for reuse and recycling,
    - extension of lifetime, or
    - amounts of waste generated.
- The design option should not entail excessive costs. Impacts on the manufacturer should be investigated regarding redesign, testing, investment and/or production costs, including economy of scale, sector-specific margins and market structure, and required time periods for market entrance of the design option and market decline of the current product. The assessment of the monetary impact for categories of users includes the estimation of the possible price increase due to implementation of the design option, either by looking at prices of the product on the market and/ or by applying a production cost model with sector-specific margins.

The identified design options are listed in Table 6-1. Design options D1, D2 and D3 stand respectively for the S+1, S+2 and S+3 scenario's as described in Task 4 in section 4.2.4. Design option D4 stands for the 2S scenario, meaning instead of installing a cable with section S, two cables with section S in parallel are installed. These design options are applied to the different base cases. BAU describes the Business As Usual option, not changing anything to the existing business.

These four design options have been selected for each of the base cases identified in Task 5. The formulas defined in Task 2 and Task 3 are used to calculate the effect on the input parameters for the EcoReport tool. For instance, a cable with a larger section will have an impact on the material use, product cost but also on the installation cost. For each BC – design option combination, these input parameters are fed into the EcoReport tool, resulting in an environmental impact assessment and LCC analysis. The next sections present these results, including the variation of the respective parameter due to the design option compared to the BAU option. This relative variation is defined as ((design option value – BAU value)/BAU value) expressed in percentile.

Table 6-1: Design options

			Unit	T	Base cases definiton								
		Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
		Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
		Application circuit			Distributio n circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distributio n circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Design option	Description	Parameter											
BAU	Business As Usual	CSA	mm²	I	120	1.5	2.5	10	300	1.5	2.5	35	70
D1	S+1	CSA	mm²	I	150	2.5	4	16	400	2.5	4	50	95
D2	S+2	CSA	mm²	I	185	4	6	25	500	4	6	70	120
D3	S+3	CSA	mm²	I	240	6	10	35	630	6	10	95	150
D4	2S	Cables in parallel multiplicator		I	2	2	2	2	2	2	2	2	2

6.2 Improvement of Ecoreport Impact indicators

Table 6-2 up to and including Table 6-15 show the LCA impact, calculated with the EcoReport tool, of the different design options on the respective parameters. In every table the impact is calculated in absolute values and in relative values versus the BAU design option. Table 6-20 summarizes for each of the parameters the design option with the lowest value. Table 6-16, Table 6-17 and Table 6-18 provide insight in the impact on Global Warming Potential (GWP) in more detail by giving the GWP value spread over its life cycle phases.

6.2.1 Impact per parameter

Table 6-2: Total Energy (Gross Energy Requirement, GER)

		Unit	Total Energy (GER)								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Total Energy (GER)	MJ	1844983	7289	5803	447921	7509255	14563	18316	1943151	1547287
D1	Total Energy (GER)	MJ	1502325	4900	4464	282332	5815923	9530	12574	1367955	1148097
D2	Total Energy (GER)	MJ	1250532	3760	3990	184289	4800293	7015	9753	988460	918571
D3	Total Energy (GER)	MJ	1011499	3351	4168	135517	4036890	5964	8255	742897	744630
D4	Total Energy (GER)	MJ	1011881	4706	4566	228186	4255457	8896	11408	989490	796183
D1	Versus BAU	%	-19%	-33%	-23%	-37%	-23%	-35%	-31%	-30%	-26%
D2		%	-32%	-48%	-31%	-59%	-36%	-52%	-47%	-49%	-41%
D3		%	-45%	-54%	-28%	-70%	-46%	-59%	-55%	-62%	-52%
D4		%	-45%	-35%	-21%	-49%	-43%	-39%	-38%	-49%	-49%

Table 6-3: Electricity

		Unit	of which, electricity (in primary MJ)								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**of which, electricity (in primary MJ)**	**MJ**	1791182	6668	4845	445443	7202865	13662	17050	1932280	1534557
D1	**of which, electricity (in primary MJ)**	**MJ**	1435369	4091	3161	278676	5412938	8336	10838	1352990	1131613
D2	**of which, electricity (in primary MJ)**	**MJ**	1167395	2667	2255	178767	4323256	5381	7426	967408	897418
D3	**of which, electricity (in primary MJ)**	**MJ**	904406	1899	1586	128076	3438519	3775	4774	714232	718966
D4	**of which, electricity (in primary MJ)**	**MJ**	904390	3575	2761	223341	3642788	7204	8987	967858	770833
D1	**Versus BAU**	%	-20%	-39%	-35%	-37%	-25%	-39%	-36%	-30%	-26%
D2		%	-35%	-60%	-53%	-60%	-40%	-61%	-56%	-50%	-42%
D3		%	-50%	-72%	-67%	-71%	-52%	-72%	-72%	-63%	-53%
D4		%	-50%	-46%	-43%	-50%	-49%	-47%	-47%	-50%	-50%

Table 6-4: Water (Process)

		Unit	Water (process)								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Water (process)	ltr	506	26	36	53	2537	41	49	122	236
D1	Water (process)	ltr	613	30	41	63	3150	46	56	150	281
D2	Water (process)	ltr	755	34	47	82	3356	53	64	193	357
D3	Water (process)	ltr	926	39	56	95	3996	60	76	244	402
D4	Water (process)	ltr	1012	53	72	107	5074	82	98	245	472
D1	Versus BAU	%	21%	13%	15%	18%	24%	13%	15%	22%	19%
D2		%	49%	29%	30%	54%	32%	29%	30%	58%	51%
D3		%	83%	46%	54%	78%	57%	46%	54%	100%	70%
D4		%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 6-5: Waste, non-hazardous / landfill

		Unit	Waste, non-haz./ landfill								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Waste, non-haz./ landfill**	g	956564	4345	3744	231841	3874360	8391	10449	1002600	819981
D1	**Waste, non-haz./ landfill**	g	780454	3156	3142	146588	2980585	5862	7610	704783	619814
D2	**Waste, non-haz./ landfill**	g	654581	2641	2982	96334	2360608	4678	6271	509882	510314
D3	**Waste, non-haz./ landfill**	g	532962	2499	3202	71213	1933799	4244	5675	384677	427290
D4	**Waste, non-haz./ landfill**	g	532972	3554	3811	119567	2202110	6306	7851	512326	455475
D1	**Versus BAU**	%	-18%	-27%	-16%	-37%	-23%	-30%	-27%	-30%	-24%
D2		%	-32%	-39%	-20%	-58%	-39%	-44%	-40%	-49%	-38%
D3		%	-44%	-42%	-14%	-69%	-50%	-49%	-46%	-62%	-48%
D4		%	-44%	-18%	2%	-48%	-43%	-25%	-25%	-49%	-44%

Table 6-6: Waste, hazardous / incinerated

		Unit	Waste, hazardous/ incinerated								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Waste, hazardous/ incinerated	g	28525	118	93	7053	115121	234	291	30534	24261
D1	Waste, hazardous/ incinerated	g	22975	79	69	4427	87368	152	196	21412	17917
D2	Waste, hazardous/ incinerated	g	18819	58	57	2862	70798	109	146	15344	14233
D3	Waste, hazardous/ incinerated	g	14762	48	51	2069	57412	87	110	11366	11430
D4	Waste, hazardous/ incinerated	g	14795	79	75	3571	60425	148	183	15362	12259
D1	Versus BAU	%	-19%	-33%	-26%	-37%	-24%	-35%	-33%	-30%	-26%
D2		%	-34%	-51%	-39%	-59%	-39%	-53%	-50%	-50%	-41%
D3		%	-48%	-59%	-45%	-71%	-50%	-63%	-62%	-63%	-53%
D4		%	-48%	-33%	-20%	-49%	-48%	-37%	-37%	-50%	-49%

Table 6-7: Greenhouse Gases in GWP100

		Unit	Greenhouse Gases in GWP100								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	79307	318	257	19145	323619	630	793	83067	66202
D1	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	64811	217	203	12088	252258	417	552	58554	49201
D2	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	54234	171	187	7921	209279	314	438	42424	39463
D3	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	44283	157	203	5859	177825	275	385	32031	32088
D4	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	44292	210	209	9785	187796	392	505	42475	34289
D1	**Versus BAU**	**%**	-18%	-32%	-21%	-37%	-22%	-34%	-30%	-30%	-26%
D2		**%**	-32%	-46%	-27%	-59%	-35%	-50%	-45%	-49%	-40%
D3		**%**	-44%	-50%	-21%	-69%	-45%	-56%	-51%	-61%	-52%
D4		**%**	-44%	-34%	-18%	-49%	-42%	-38%	-36%	-49%	-48%

Table 6-8: Acidification emissions

		Unit	Acidification, emissions								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Acidification, emissions	g SO2 eq.	451084	1884	2111	88463	2019521	3535	4843	387966	293986
D1	Acidification, emissions	g SO2 eq.	411973	1764	2460	59490	1899478	3097	4580	288233	219127
D2	Acidification, emissions	g SO2 eq.	394375	2046	3174	44424	1905327	3392	5142	228507	176406
D3	Acidification, emissions	g SO2 eq.	396238	2631	4812	39050	2020728	4220	7049	197081	144202
D4	Acidification, emissions	g SO2 eq.	396304	1900	2889	50809	2006017	3245	4918	228753	153827
D1	Versus BAU	%	-9%	-6%	17%	-33%	-6%	-12%	-5%	-26%	-25%
D2		%	-13%	9%	50%	-50%	-6%	-4%	6%	-41%	-40%
D3		%	-12%	40%	128%	-56%	0%	19%	46%	-49%	-51%
D4		%	-12%	1%	37%	-43%	-1%	-8%	2%	-41%	-48%

Table 6-9: Volatile Organic Compounds (VOC)

		Unit	Volatile Organic Compounds (VOC)								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Volatile Organic Compounds (VOC)**	g	39988	151	111	9951	160850	309	385	43158	34277
D1	**Volatile Organic Compounds (VOC)**	g	32039	94	74	6226	120967	190	246	30227	25285
D2	**Volatile Organic Compounds (VOC)**	g	26033	62	54	3994	97008	124	170	21613	20051
D3	**Volatile Organic Compounds (VOC)**	g	20145	45	38	2861	77331	88	110	15949	16072
D4	**Volatile Organic Compounds (VOC)**	g	20168	85	68	4993	81327	168	209	21623	17226
D1	**Versus BAU**	%	-20%	-38%	-34%	-37%	-25%	-38%	-36%	-30%	-26%
D2		%	-35%	-59%	-52%	-60%	-40%	-60%	-56%	-50%	-42%
D3		%	-50%	-70%	-66%	-71%	-52%	-71%	-71%	-63%	-53%
D4		%	-50%	-44%	-39%	-50%	-49%	-46%	-46%	-50%	-50%

Table 6-10: Persistent Organic Pollutants (POP)

		Unit	Persistent Organic Pollutants (POP)								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Persistent Organic Pollutants (POP)	ng i-Teq	5590	23	25	1092	25090	43	59	4796	3813
D1	Persistent Organic Pollutants (POP)	ng i-Teq	5113	21	30	735	23683	37	56	3568	2956
D2	Persistent Organic Pollutants (POP)	ng i-Teq	4898	25	39	549	23918	41	63	2833	2492
D3	Persistent Organic Pollutants (POP)	ng i-Teq	4931	32	59	484	25450	51	86	2447	2176
D4	Persistent Organic Pollutants (POP)	ng i-Teq	4931	22	34	627	25065	38	58	2833	2262
D1	Versus BAU	%	-9%	-6%	17%	-33%	-6%	-13%	-5%	-26%	-22%
D2		%	-12%	9%	52%	-50%	-5%	-4%	6%	-41%	-35%
D3		%	-12%	41%	132%	-56%	1%	20%	47%	-49%	-43%
D4		%	-12%	-3%	34%	-43%	0%	-11%	-1%	-41%	-41%

Table 6-11: Heavy Metals to air

		Unit	Heavy Metals								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	**Heavy Metals**	**mg Ni eq.**	39033	178	264	5299	195517	307	464	23809	15736
D1	**Heavy Metals**	**mg Ni eq.**	40661	220	371	4082	218338	358	570	19779	11734
D2	**Heavy Metals**	**mg Ni eq.**	44042	307	525	3776	248225	486	758	18313	9440
D3	**Heavy Metals**	**mg Ni eq.**	50959	435	845	4046	292396	679	1178	18789	7721
D4	**Heavy Metals**	**mg Ni eq.**	50984	253	453	3842	282202	406	669	18324	8229
D1	**Versus BAU**	%	4%	23%	40%	-23%	12%	17%	23%	-17%	-25%
D2		%	13%	72%	99%	-29%	27%	58%	63%	-23%	-40%
D3		%	31%	144%	220%	-24%	50%	121%	154%	-21%	-51%
D4		%	31%	42%	71%	-27%	44%	32%	44%	-23%	-48%

Table 6-12: Polycyclic Aromatic Hydrocarbons (PAHs)

		Unit	PAHs								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	**PAHs**	**mg Ni eq.**	6335	30	37	1124	29318	53	74	4950	8148
D1	**PAHs**	**mg Ni eq.**	6039	31	46	783	29242	51	77	3778	8826
D2	**PAHs**	**mg Ni eq.**	6050	38	60	623	30295	61	92	3132	9915
D3	**PAHs**	**mg Ni eq.**	6421	50	92	584	33460	79	131	2857	11442
D4	**PAHs**	**mg Ni eq.**	6419	35	55	689	33519	56	86	3138	10930
D1	**Versus BAU**	%	-5%	3%	24%	-30%	0%	-3%	4%	-24%	8%
D2		%	-4%	27%	64%	-45%	3%	15%	25%	-37%	22%
D3		%	1%	67%	151%	-48%	14%	48%	78%	-42%	40%
D4		%	1%	15%	49%	-39%	14%	6%	17%	-37%	34%

Table 6-13: Particulate Matter (PM, dust)

		Unit	Particulate Matter (PM, dust)								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Particulate Matter (PM, dust)**	g	14526	271	357	2330	68339	432	529	9475	10006
D1	**Particulate Matter (PM, dust)**	g	14738	295	422	1803	74889	466	601	7718	9340
D2	**Particulate Matter (PM, dust)**	g	15561	348	476	1651	69363	544	667	7072	9803
D3	**Particulate Matter (PM, dust)**	g	17307	393	578	1648	76173	613	799	6869	10294
D4	**Particulate Matter (PM, dust)**	g	18339	501	687	1988	93625	784	957	7363	10818
D1	**Versus BAU**	%	1%	9%	18%	-23%	10%	8%	14%	-19%	-7%
D2		%	7%	29%	33%	-29%	1%	26%	26%	-25%	-2%
D3		%	19%	45%	62%	-29%	11%	42%	51%	-27%	3%
D4		%	26%	85%	92%	-15%	37%	81%	81%	-22%	8%

Table 6-14: Heavy Metals to water

		Unit	Heavy Metals								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Heavy Metals	mg Hg/20	43393	208	378	3263	240268	336	560	15592	8302
D1	Heavy Metals	mg Hg/20	50776	312	580	3346	302296	492	820	16211	7165
D2	Heavy Metals	mg Hg/20	60021	479	856	4119	367363	748	1186	18699	6758
D3	Heavy Metals	mg Hg/20	75228	707	1411	5235	454168	1098	1936	22792	6705
D4	Heavy Metals	mg Hg/20	75258	373	726	3652	434207	586	1013	18714	6710
D1	Versus BAU	%	17%	50%	54%	3%	26%	46%	46%	4%	-14%
D2		%	38%	131%	126%	26%	53%	122%	112%	20%	-19%
D3		%	73%	240%	273%	60%	89%	227%	246%	46%	-19%
D4		%	73%	80%	92%	12%	81%	74%	81%	20%	-19%

Table 6-15: Euthropication

		Unit	Eutrophication								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Eutrophication**	**g PO4**	415.8	2.5	2.8	88.3	1799.1	4.5	5.8	381.9	299.2
D1	**Eutrophication**	**g PO4**	367.2	2.3	3.0	58.5	1598.5	4.0	5.3	278.8	224.9
D2	**Eutrophication**	**g PO4**	338.8	2.5	3.5	42.2	1513.6	4.1	5.6	214.6	183.7
D3	**Eutrophication**	**g PO4**	322.6	2.9	4.6	35.3	1519.4	4.6	6.8	177.5	151.9
D4	**Eutrophication**	**g PO4**	325.8	3.1	4.3	50.4	1565.2	5.2	6.8	216.7	164.3
D1	**Versus BAU**	**%**	-12%	-7%	8%	-34%	-11%	-12%	-8%	-27%	-25%
D2		**%**	-19%	0%	25%	-52%	-16%	-9%	-3%	-44%	-39%
D3		**%**	-22%	16%	65%	-60%	-16%	3%	17%	-54%	-49%
D4		**%**	-22%	26%	53%	-43%	-13%	15%	18%	-43%	-45%

6.2.2 Impact on Greenhouse gas in more detail (per lifecycle phase)

Table 6-16: Greenhouse Gases (in detail, absolute values) in GWP100

		Unit	Greenhouse Gases in GWP100								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Production	kg CO2 eq.	4419	38	64	189	25116	58	87	896	1054
	Distribution	kg CO2 eq.	79	10	10	12	402	10	11	22	38
	Use	kg CO2 eq.	76248	278	198	18998	306518	573	715	82441	65412
	End of live	kg CO2 eq.	-1440	-8	-15	-55	-8417	-12	-20	-293	-303
	Total	kg CO2 eq.	79307	318	257	19145	323619	630	793	83067	66202
D1	Production	kg CO2 eq.	5498	53	92	287	32865	82	125	1228	1361
	Distribution	kg CO2 eq.	96	10	11	13	573	11	12	28	45
	Use	kg CO2 eq.	61016	167	124	11875	230020	344	448	57715	48204
	End of live	kg CO2 eq.	-1799	-12	-23	-87	-11200	-19	-32	-417	-408
	Total	kg CO2 eq.	64811	217	203	12088	252258	417	552	58554	49201
D2	Production	kg CO2 eq.	6847	76	127	439	38592	117	174	1738	1756
	Distribution	kg CO2 eq.	114	10	11	15	451	12	12	38	58
	Use	kg CO2 eq.	49494	105	83	7603	184147	216	299	41233	38167
	End of live	kg CO2 eq.	-2221	-19	-35	-136	-13912	-30	-47	-584	-517
	Total	kg CO2 eq.	54234	171	187	7921	209279	314	438	42424	39463
D3	Production	kg CO2 eq.	8837	105	198	598	48494	163	270	2388	2122
	Distribution	kg CO2 eq.	143	11	12	17	532	12	13	45	69
	Use	kg CO2 eq.	38183	70	51	5433	146322	144	181	30392	30540
	End of live	kg CO2 eq.	-2879	-29	-57	-189	-17523	-44	-78	-794	-643
	Total	kg CO2 eq.	44283	157	203	5859	177825	275	385	32031	32088
D4	Production	kg CO2 eq.	8839	75	128	379	50232	117	174	1793	2108
	Distribution	kg CO2 eq.	150	11	12	15	795	12	13	36	68
	Use	kg CO2 eq.	38183	139	100	9502	153602	287	359	41233	32719
	End of live	kg CO2 eq.	-2879	-15	-30	-110	-16833	-24	-41	-586	-605
	Total	kg CO2 eq.	44292	210	209	9785	187796	392	505	42475	34289

Table 6-17: Greenhouse Gases (in detail, each phase relative to total) in GWP100

			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC8
BAU	**Production**	%	6%	12%	25%	1%	8%	9%	11%	1%	1.6%
	Distribution	%	0%	3%	4%	0%	0%	2%	1%	0%	0%
	Use	%	96%	88%	77%	99%	95%	91%	90%	99%	98.8%
	End of live	%	-2%	-2%	-6%	0%	-3%	-2%	-3%	0%	-0.5%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D1	**Production**	%	8%	24%	45%	2%	13%	20%	23%	2%	3%
	Distribution	%	0%	5%	5%	0%	0%	3%	2%	0%	0%
	Use	%	94%	77%	61%	98%	91%	82%	81%	99%	98%
	End of live	%	-3%	-6%	-12%	-1%	-4%	-5%	-6%	-1%	-1%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D2	**Production**	%	13%	44%	68%	6%	18%	37%	40%	4%	4%
	Distribution	%	0%	6%	6%	0%	0%	4%	3%	0%	0%
	Use	%	91%	61%	44%	96%	88%	69%	68%	97%	97%
	End of live	%	-4%	-11%	-19%	-2%	-7%	-10%	-11%	-1%	-1%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D3	**Production**	%	20%	67%	97%	10%	27%	59%	70%	7%	7%
	Distribution	%	0%	7%	6%	0%	0%	4%	3%	0%	0%
	Use	%	86%	45%	25%	93%	82%	53%	47%	95%	95%
	End of live	%	-7%	-18%	-28%	-3%	-10%	-16%	-20%	-2%	-2%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D4	**Production**	%	20%	36%	61%	4%	27%	30%	35%	4%	6%
	Distribution	%	0%	5%	6%	0%	0%	3%	3%	0%	0%
	Use	%	86%	66%	48%	97%	82%	73%	71%	97%	95%
	End of live	%	-7%	-7%	-14%	-1%	-9%	-6%	-8%	-1%	-2%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 6-18: Greenhouse Gases (in detail, relative to BAU) in GWP100

			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC8
	Production	%	124%	140%	143%	152%	131%	140%	143%	137%	129%
	Distribution	%	121%	102%	107%	111%	143%	103%	109%	124%	118%
D1/BAU	**Use**	%	80%	60%	63%	63%	75%	60%	63%	70%	74%
	End of live	%	125%	161%	157%	159%	133%	161%	157%	142%	135%
	Total	%	82%	68%	79%	63%	78%	66%	70%	70%	74%
	Production	%	155%	201%	199%	232%	154%	201%	199%	194%	167%
	Distribution	%	144%	108%	110%	131%	112%	112%	113%	172%	152%
D2/BAU	**Use**	%	65%	38%	42%	40%	60%	38%	42%	50%	58%
	End of live	%	154%	253%	233%	247%	165%	253%	233%	199%	171%
	Total	%	68%	54%	73%	41%	65%	50%	55%	51%	60%
	Production	%	200%	279%	309%	316%	193%	279%	309%	266%	201%
	Distribution	%	180%	111%	117%	147%	133%	116%	122%	203%	182%
D3/BAU	**Use**	%	50%	25%	26%	29%	48%	25%	25%	37%	47%
	End of live	%	200%	375%	384%	345%	208%	375%	384%	271%	213%
	Total	%	56%	50%	79%	31%	55%	44%	49%	39%	48%
	Production	%	200%	200%	200%	200%	200%	200%	200%	200%	200%
	Distribution	%	189%	112%	116%	128%	198%	117%	121%	161%	178%
D4/BAU	**Use**	%	50%	50%	50%	50%	50%	50%	50%	50%	50%
	End of live	%	200%	200%	200%	200%	200%	200%	200%	200%	200%
	Total	%	56%	66%	82%	51%	58%	62%	64%	51%	52%

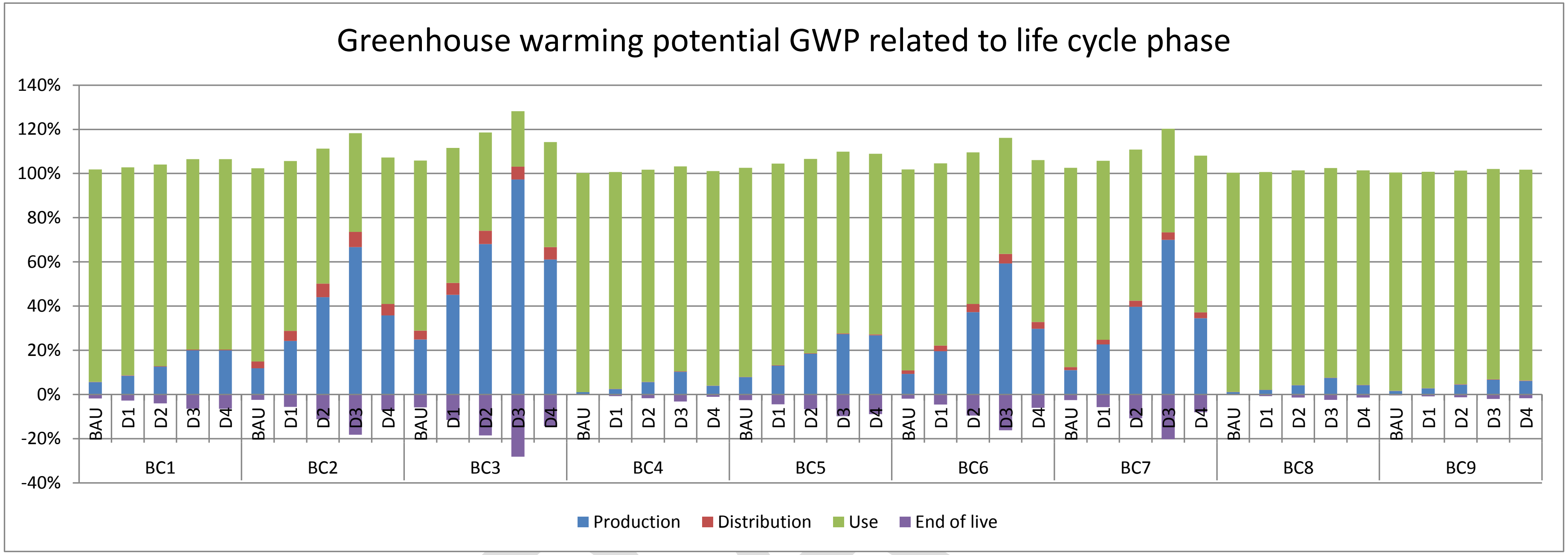

Figure 6-1 Greenhouse Gases (in detail, each phase relative to total) in GWP100

Figure 6-1 shows that for the design options compared to the BAU case, the emission of greenhouse gas shifts from the use phase towards the production (and distribution) phase. Figure 6-2 displays the absolute GWP values per life cycle phase. A shift of greenhouse gas emissions towards the production phase can be noticed in absolute terms, but one can also notice the significant reduction on greenhouse gas emissions during the use phase.

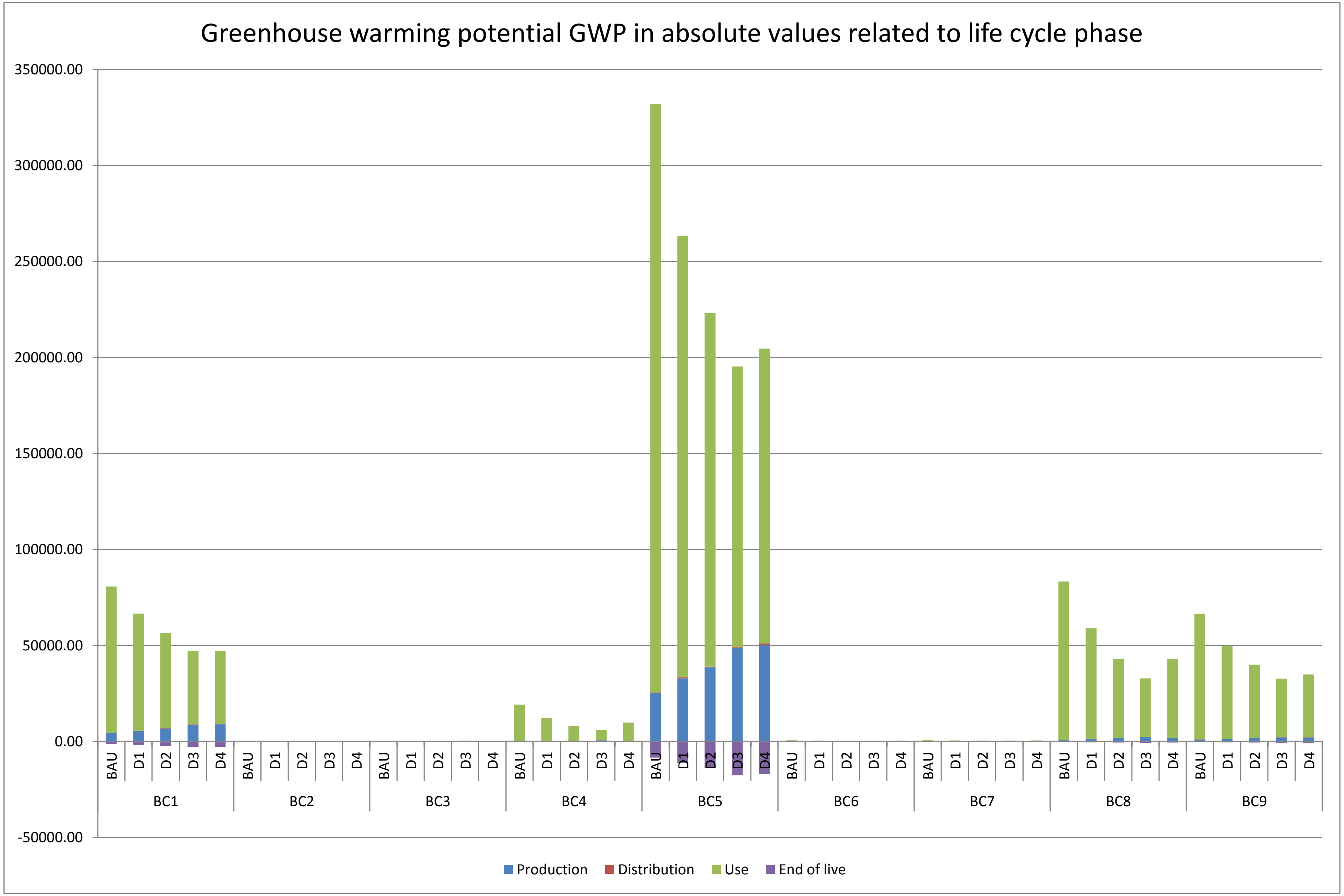

Figure 6-2 Greenhouse Gases in absolute values (in detail, each phase relative to total) in GWP100

Table 6-19 shows how many years it takes to match the increase of greenhouse gas in the production and distribution phase with the reduction of greenhouse gas in the use phase. The environmental payback period is calculated by means of formula 6.1.

$$EPP_{design\ option\ x\ -\ BAU} = dPD_{design\ option\ x\ -\ BAU} / (dU_{design\ option\ x\ -\ BAU} / \text{product lifetime}) \quad \text{(formula 6.1)}$$

Where

$EPP_{design\ option\ x\ -\ BAU}$ = Environmental Payback Period, in years

$dPD_{design\ option\ x\ -\ BAU}$ = Difference (increase) in production and distribution phase emission

$dU_{design\ option\ x\ -\ BAU}$ = Difference (decrease) in use phase emission

Table 6-19: Greenhouse Gases: environmental payback period in years

	Unit	Greenhouse Gases: payback period								
Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
Product lifetime	years	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
D1	years	1.80	3.45	9.61	0.35	2.59	2.59	3.61	0.34	0.46
D2	years	2.30	5.58	14.07	0.56	2.76	4.20	5.28	0.52	0.66
D3	years	2.94	8.24	23.07	0.76	3.67	6.19	8.64	0.73	0.79
D4	years	2.95	7.00	16.71	0.51	4.17	5.26	6.27	0.55	0.83

6.2.3 Conclusion on EcoReport tool impact parameters

Table 6-20 shows that for all the parameters, except for the parameters 'water (process)', 'heavy metals (emissions in water and air)' and 'Particulate Matter (PM)', the design options for almost all base cases have a lower value than the BAU scenario. Looking vertically at Table 6-20 in function of base case, the design options for the base cases 2, 3, 6 and 7 representing the lighting and socket-outlet circuits perform less compared to the other base cases, in particular for the parameters PAHs, PM and Eutrophication.

Table 6-20: best performing design option per parameter and base case

	Best performing design option per parameter and base case								
Base case id	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector	Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Other resources and waiste									
Total Energy (GER)	D3	D3	D2	D3	D3	D3	D3	D3	D3
of which, electricity (in primary MJ)	D4	D3	D3	D3	D3	D3	D3	D3	D3
Water (process)	BAU	BAU	BAU	BAU	BAU	BAU	BAU	BAU	BAU
Waste, non-haz./ landfill	D3	D3	D2	D3	D3	D3	D3	D3	D3
Emissions (air)									
Waste, hazardous/ incinerated	D3	D3	D3	D3	D3	D3	D3	D3	D3
Greenhouse Gases in GWP100	D3	D3	D2	D3	D3	D3	D3	D3	D3
Acidification, emissions	D2	D1	BAU	D3	D1	D1	D1	D3	D3
Volatile Organic Compounds (VOC)	D3	D3	D3	D3	D3	D3	D3	D3	D3
Persistent Organic Pollutants (POP)	D2	D1	BAU	D3	D1	D1	D1	D3	D3
Heavy Metals	BAU	BAU	BAU	D2	BAU	BAU	BAU	D2	D3
PAHs	D1	BAU	BAU	D3	D1	D1	BAU	D3	BAU
Particulate Matter (PM, dust)	BAU	BAU	BAU	D3	BAU	BAU	BAU	D3	D1
Emissions (water)									
Heavy Metals	BAU	BAU	BAU	BAU	BAU	BAU	BAU	BAU	D3
Eutrophication	D3	D1	BAU	D3	D2	D1	D1	D3	D3

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6.3 Impact on Life Cycle Cost

Per base case and design option the product price, installation cost, and the electricity cost during the products' lifetime are calculated according the formulas in Task 2, Task 3 and Task 4. Besides the variation of the total cost per design option compared to the BAU case ((Design option value – BAU value)/BAU value expressed in percentile) also the payback period is calculated. This is the time period it takes for an investor to recuperate the extra investment in purchase price dPP through reduction in annual operating expense dOE. The simple payback period approach can be used due to the fact that the product life of the circuit regardless of the applied design option or BAU option does not change.

When assuming that the discount and escalation rate are equal the Simple Payback Period SPP can be used. The formula, as defined by the MEErP 2011 methodology[1], for comparing the alternatives is:

$$SPP_{design\ option\ x\ -\ BAU} = dPP_{design\ option\ x\ -\ BAU} / dOE_{design\ option\ x\ -\ BAU} \quad \text{(formula 6.2)}$$

Where

$SPP_{design\ option\ x\ -\ BAU}$ = simple payback period, in years

$dPP_{design\ option\ x\ -\ BAU}$ = difference (increase) in purchase price

$dOE_{design\ option\ x\ -\ BAU}$ = difference (decrease) in operating expenses

[1] VHK, MEErP 2011 METHODOLOGY PART 1.

Table 6-21 shows that when applying a design option for the base cases representing lighting circuits and socket-outlet circuits (BC2, BC3, BC6 and BC7) the simple payback period is almost for all cases greater than the product lifetime. This can be explained by the increase in product and installation cost for these small cable sections but especially by the low load on these circuits in these base cases. A low load means low energy cost and thus a longer payback period. BC1 and BC5 perform better, but still have long periods. BC4, BC8 and BC9 have really small payback periods.

Table 6-21: LCC of design options referred to a unit of product over its lifetime and compared to base cases

		Unit	Life Cycle Costs per base case per year								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Product price	€	6727.15	66.41	87.11	254.01	38235.44	88.70	102.97	1339.24	1586.41
	Installation cost	€	693.23	78.65	98.45	137.78	3572.78	107.30	113.40	334.55	391.53
	Electricity cost	€	22968.99	83.72	59.43	5725.54	92313.73	172.57	215.40	24845.00	19712.35
	Total	€	30389.36	228.78	244.99	6117.33	134121.95	368.57	431.77	26518.79	21690.29
D1	Product price	€	8319.14	86.96	124.45	401.55	50980.59	120.54	153.92	1894.67	2210.69
	Installation cost	€	794.69	101.12	123.98	161.27	4281.80	137.96	141.25	362.39	422.59
	Electricity cost	€	18375.19	50.23	37.15	3578.46	69235.30	103.54	134.62	17391.50	14524.89
	Total	€	27489.02	238.31	285.57	4141.29	124497.69	362.04	429.79	19648.56	17158.17
	Purchase price compared to BAU		**+23%**	**+30%**	**+34%**	**+44%**	**+32%**	**+32%**	**+36%**	**+35%**	**+33%**
	Total cost compared to BAU		**-10%**	**+4%**	**+17%**	**-32%**	**-7%**	**-2%**	**-0%**	**-26%**	**-21%**
	SPP	years	**9.22**	**32.11**	**70.52**	**1.99**	**14.57**	**22.63**	**24.39**	**1.96**	**3.16**
D2	Product price	€	10255.66	117.77	194.15	613.30	63725.73	168.30	236.31	2703.30	2802.23
	Installation cost	€	872.46	128.81	153.16	200.52	6225.20	174.61	181.07	412.30	463.83
	Electricity cost	€	14898.80	31.40	24.76	2290.22	55388.24	64.71	89.75	12422.50	11498.87
	Total	€	26026.91	277.98	372.07	3104.03	125339.17	407.62	507.12	15538.10	14764.93
	Purchase price compared to BAU		**+50%**	**+70%**	**+87%**	**+108%**	**+67%**	**+75%**	**+93%**	**+86%**	**+65%**
	Total cost compared to BAU		**-14%**	**+22%**	**+52%**	**-49%**	**-7%**	**+11%**	**+17%**	**-41%**	**-32%**
	SPP	years	**11.49**	**48.50**	**116.64**	**3.07**	**19.05**	**34.05**	**39.99**	**2.90**	**3.92**
D3	Product price	€	13174.30	187.36	293.73	880.09	80294.42	264.75	372.16	3726.47	3434.42
	Installation cost	€	1067.49	152.89	178.68	227.93	7773.60	211.94	208.92	444.83	532.44
	Electricity cost	€	11484.49	20.93	14.86	1635.87	43958.92	43.14	53.85	9153.42	9199.10
	Total	€	25726.28	361.19	487.27	2743.89	132026.94	519.84	634.92	13324.72	13165.95
	Purchase price compared to BAU		**+92%**	**+135%**	**+155%**	**+183%**	**+111%**	**+143%**	**+169%**	**+149%**	**+101%**
	Total cost compared to BAU		**-15%**	**+58%**	**+99%**	**-55%**	**-2%**	**+41%**	**+47%**	**-50%**	**-39%**
	SPP	years	**14.85**	**77.72**	**160.89**	**4.38**	**23.92**	**54.22**	**56.44**	**3.98**	**4.73**
D4	Product price	€	13454.30	132.82	174.21	508.02	76470.88	177.39	205.95	2678.48	3172.83
	Installation cost	€	1386.45	157.30	196.91	275.56	7145.55	214.60	226.81	669.10	783.05
	Electricity cost	€	11484.49	41.86	29.72	2862.77	46156.87	86.28	107.70	12422.50	9856.17
	Total	€	26325.24	331.98	400.84	3646.34	129773.30	478.28	540.45	15770.08	13812.06
	Purchase price compared to BAU		**+100%**	**+100%**	**+100%**	**+100%**	**+100%**	**+100%**	**+100%**	**+100%**	**+100%**
	Total cost compared to BAU		**-13%**	**+45%**	**+64%**	**-40%**	**-3%**	**+30%**	**+25%**	**-41%**	**-36%**
	SPP	years	**16.15**	**86.63**	**156.11**	**3.42**	**22.64**	**56.79**	**50.23**	**3.37**	**5.02**

6.4 Analysis of BAT and LLCC

The total energy (Gross Energy Requirement, GER) and LCC are calculated by means of the EcoReport tool for each BC and design option, including BAU. Table 6-22 summarizes the results of this calculation. Per BC the Least (minimum) Life Cycle Costs (LLCC) and Best Available Technology (BAT) are identified. The figures Figure 6-3 up to and including Figure 6-11 display these results graphically. In Figure 6-12, the results of BC8 and BC9 (similar circuits but with Copper and Aluminium cable conductors respectively) are shown for comparison.

Looking at the total energy usage, the BAT is in almost all base cases design option D3. Only for BC3 it is design option D2.

Looking at the LCC, the results are more dispersed. For the base cases BC2 and BC3 the LLCC is the BAU option. This can be explained by the low load on these circuits (less gain in use phase) while having a large increase in material when opting for one of the design options D1, D2, D3 or D4. The same can be said for the base cases BC6 and BC7, except that the D1 design option is the LLCC, owing to a higher load on these circuits in the industry. This reinforces the decision to leave out residential circuits, because the residential circuits are similar to BC2 and BC3, except that the loading is even lower.

For the base cases with a high load and a large CSA (BC1, BC4 and BC8) the design option D3 is the LLCC, owing to the lesser energy expenses during the use phase. Although BC5 is a base case with a high load and a very large CSA, design option D1, and not D3, is the best solution. The BAT and LLCC design options for BC9 (with Aluminium based cables) are equal to BC8.

Table 6-22: LLCC and BAT per base case

		Unit	Base cases								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Total Energy (GER)	MJ	1844983	7289	5803	447921	7509255	14563	18316	1943151	1547287
D1	Total Energy (GER)	MJ	1502325	4900	4464	282332	5815923	9530	12574	1367955	1148097
D2	Total Energy (GER)	MJ	1250532	3760	3990	184289	4800293	7015	9753	988460	918571
D3	Total Energy (GER)	MJ	1011499	3351	4168	135517	4036890	5964	8255	742897	744630
D4	Total Energy (GER)	MJ	1011881	4706	4566	228186	4255457	8896	11408	989490	796183
BAU	LCC	€	30389.36	228.78	244.99	6117.33	134121.95	368.57	431.77	26518.79	21690.29
D1	LCC	€	27489.02	238.31	285.57	4141.29	124497.69	362.04	429.79	19648.56	17158.17
D2	LCC	€	26026.91	277.98	372.07	3104.03	125339.17	407.62	507.12	15538.10	14764.93
D3	LCC	€	25726.28	361.19	487.27	2743.89	132026.94	519.84	634.92	13324.72	13165.95
D4	LCC	€	26325.24	331.98	400.84	3646.34	129773.30	478.28	540.45	15770.08	13812.06
BAT			D3	D3	D2	D3	D3	D3	D3	D3	D3
LLCC			D3	BAU	BAU	D3	D1	D1	D1	D3	D3

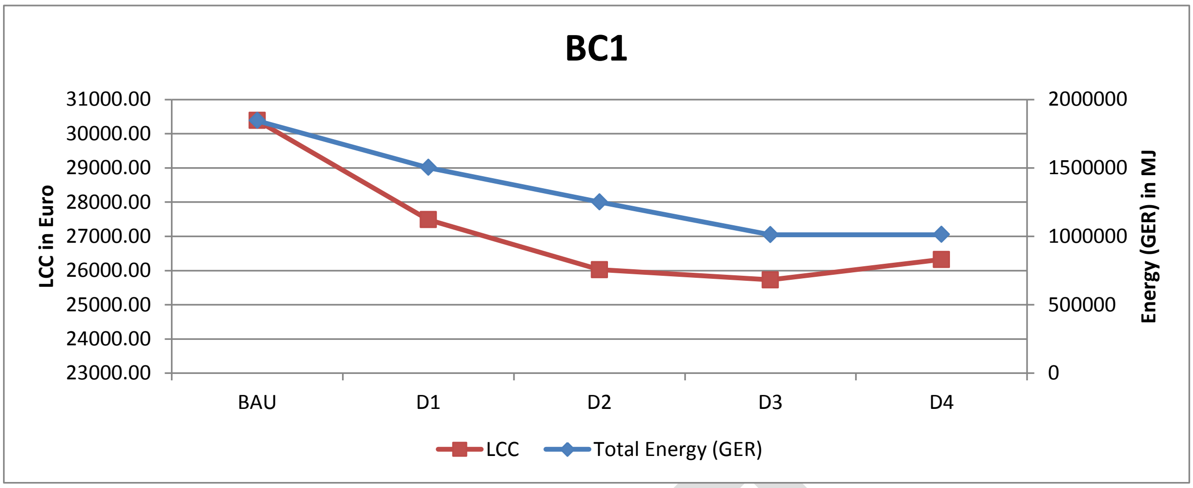


Figure 6-3 BAT and LLCC for BC1

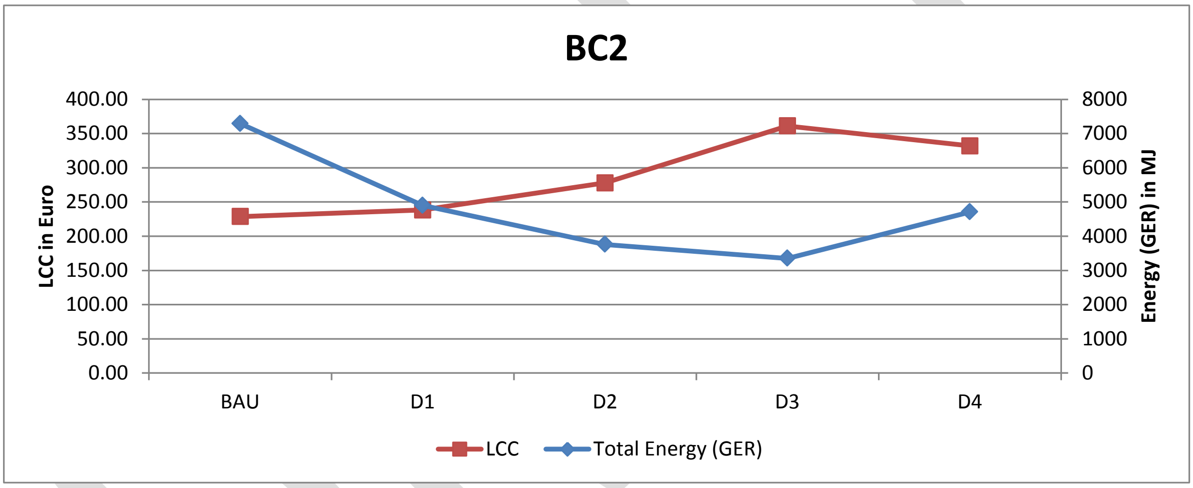


Figure 6-4 BAT and LLCC for BC2

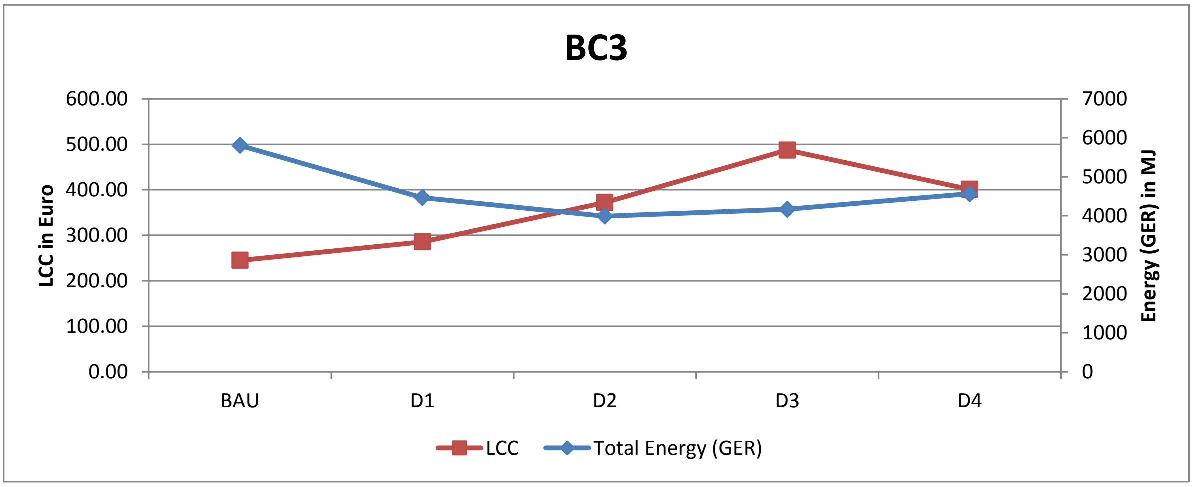


Figure 6-5 BAT and LLCC for BC3

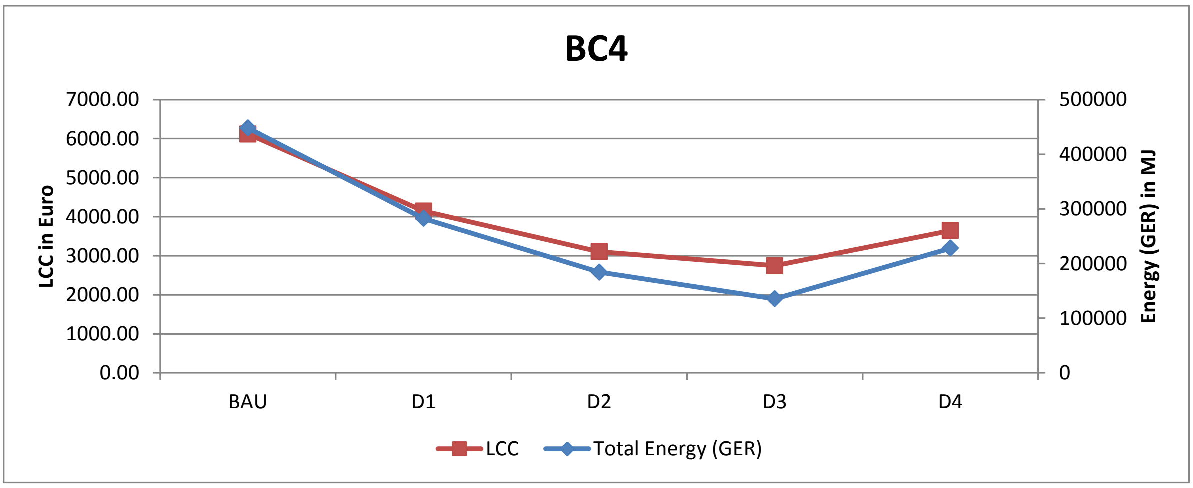


Figure 6-6 BAT and LLCC for BC4

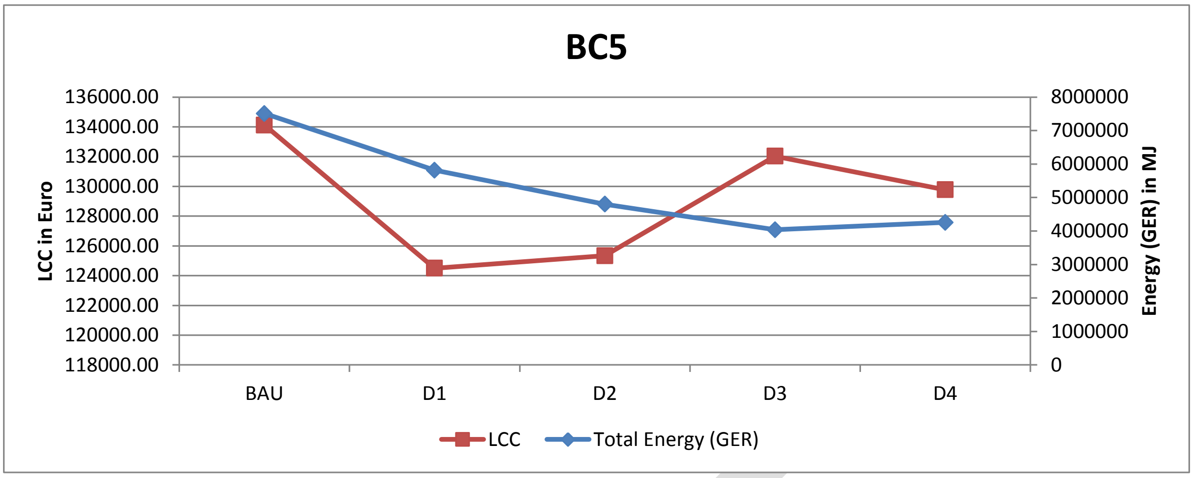


Figure 6-7 BAT and LLCC for BC5

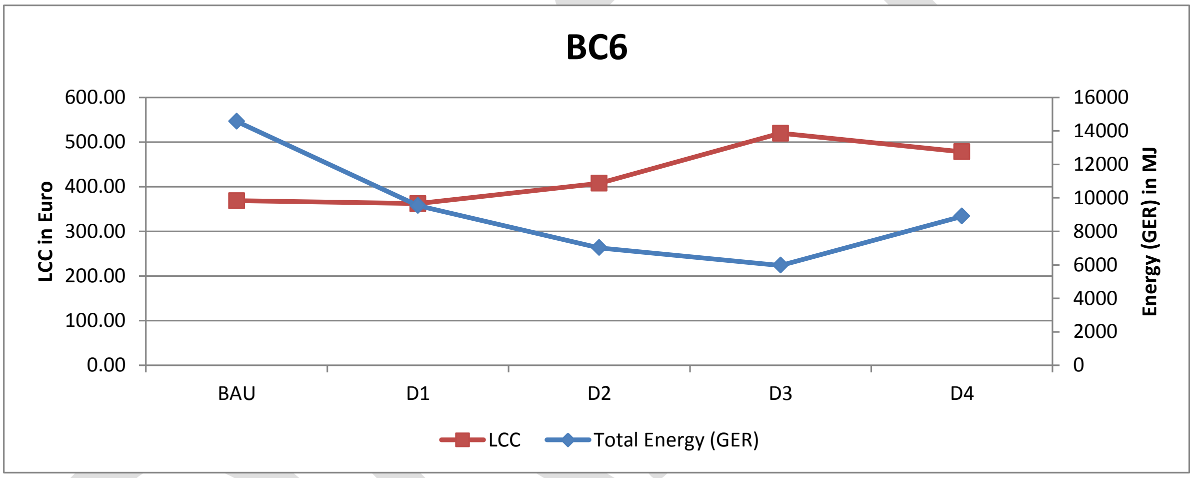


Figure 6-8 BAT and LLCC for BC6

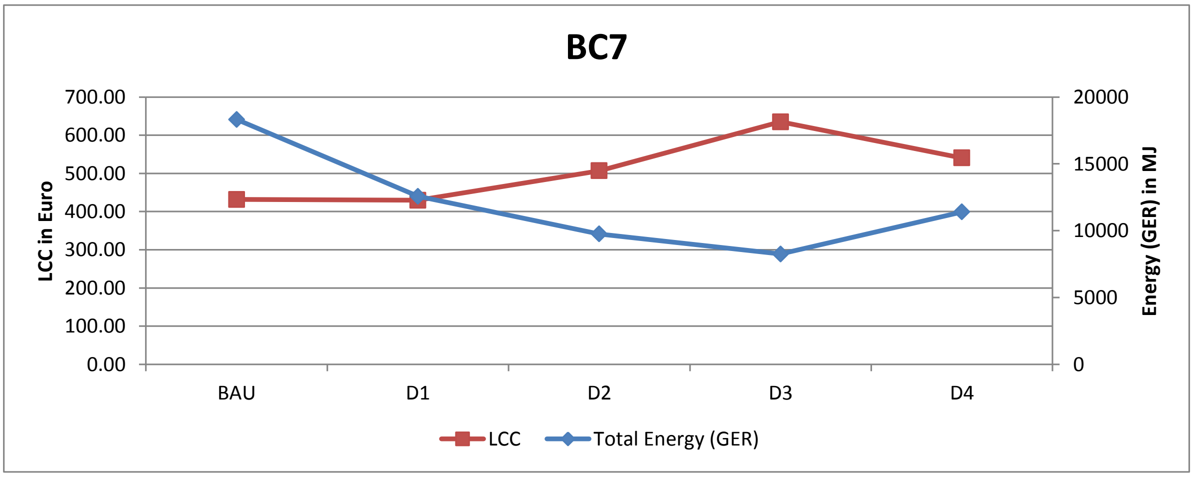


Figure 6-9 BAT and LLCC for BC7

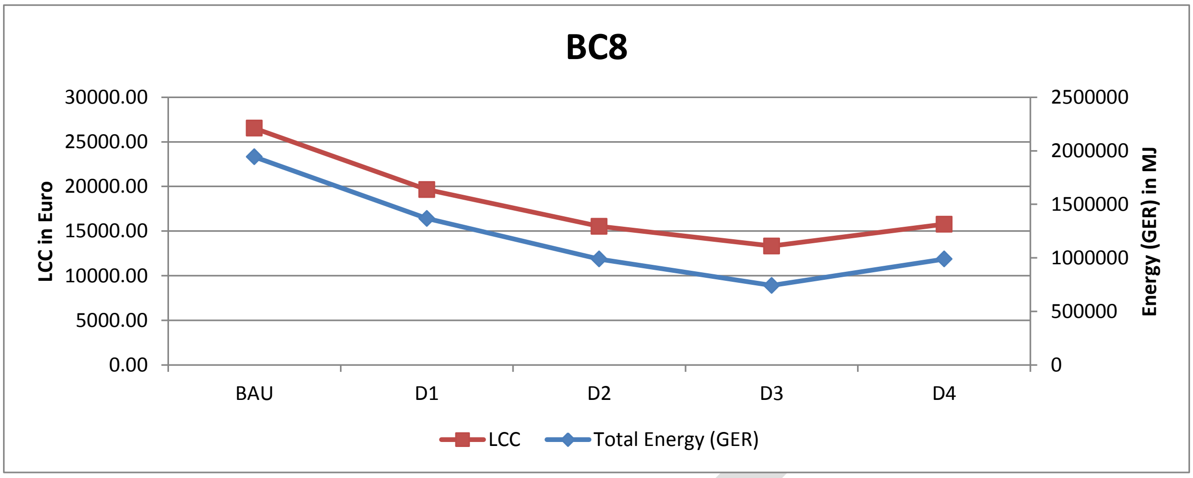


Figure 6-10 BAT and LLCC for BC8

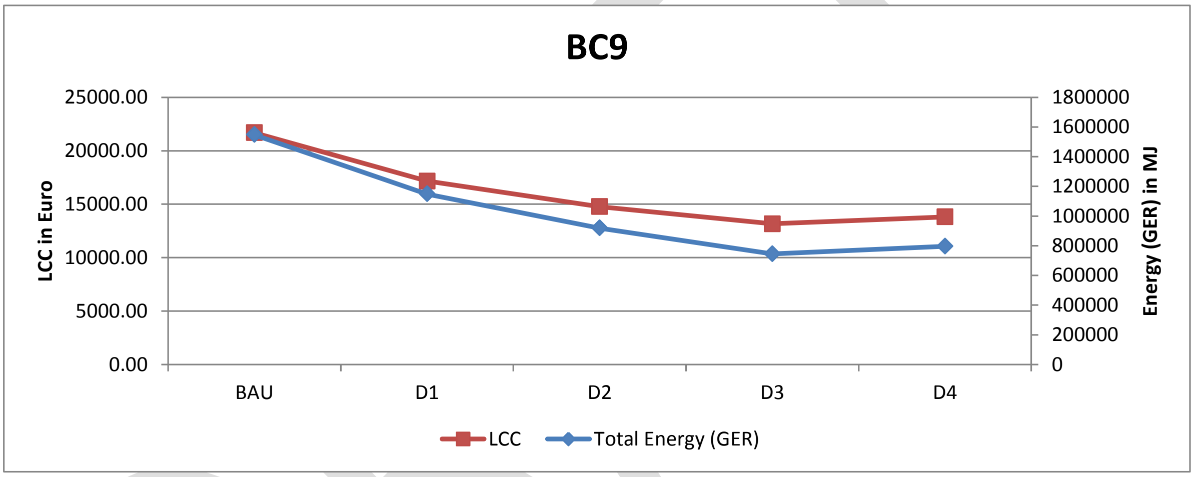


Figure 6-11 BAT and LLCC for BC9

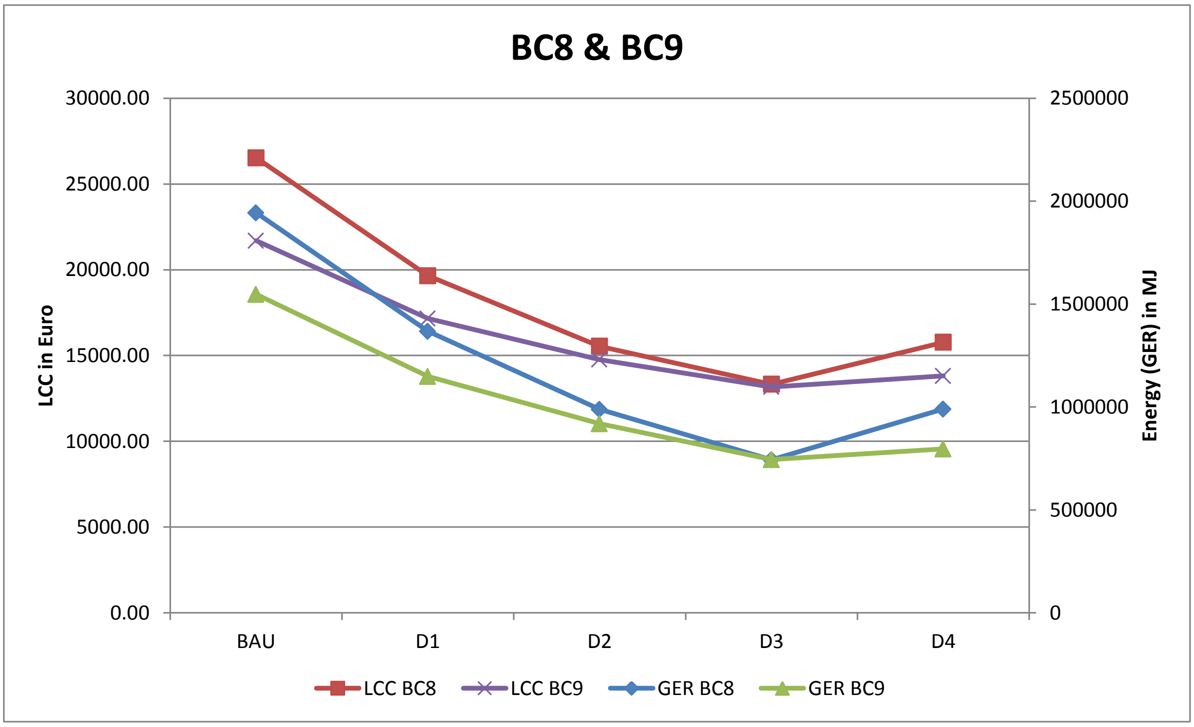


Figure 6-12 BAT and LLCC BC8 & BC9

Figure 6-12 shows that in case of circuit and loading characteristics of BC8/BC9, the solution based upon aluminium conductors has a lower LCC and BAT value in almost every option (except for D3) than the solution based upon copper.

6.5 Long term potential (BNAT) & systems analysis

Regarding BNAT options for power cables, nothing was identified in Task 4, as a consequence that there is also no further analysis.

At circuit system level section 4.1.4 referred to 380 VDC systems replacing 230 VAC. The rationale was that cable insulation is related to the peak voltage(Vpeak). In AC systems peak voltage is Vrms.$\sqrt{2}$ = 325 Vpeak. In DC systems the peak voltage is equivalent to the VDC. As a consequence an identical cable with identical insulation would need less current in DC (e.g.: 325VDC, 1A, 325 VA) compared to AC (e.g.: 230 Vrms, 1.41A, 325 W). Cable loss will therefore reduce by half $(1/.\sqrt{2})^2$ in DC compared to AC. As mentioned in section 4.1.4 such a switch from AC to DC would require another power distribution system which is so far not a viable improvement option today (10/2014).

6.6 Sensitivity analysis

The basic calculation in the previous section is based upon the reference values of the parameters defined in Task 2 and Task 3. In this section the LCC and GER are recalculated per BC with the parameters (e.i. circuit loading, length of the circuits, and product lifetime) set to their low value and to their high value. The low, reference and high values are listed in the tables in Task 2 and Task 3.

6.6.1 Sensitivity to circuit loading

In this section, the following parameters are taken into account:

- the load factor;
- load form factor;
- Kd factor;
- number of nodes per circuit.

The load, load form and Kd factors have an impact on the energy losses in the use phase. The number of nodes influences the Kd factor and thus the energy used in the use phase.

The load, load form and Kd factor have not impact on the production cost, but on the use phase cost. The number of nodes per circuit will have an impact on the production cost, meaning needing more or less connectors, and the use phase cost, by means of the Kd factor.

Table 6-23: Sensitivity data BC1

	Base Case Id		BC1		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	338347	1844983	2768423
D1	Total Energy (GER)	0	297016	1502325	2241077
D2	Total Energy (GER)	0	273255	1250532	1849520
D3	Total Energy (GER)	0	258181	1011499	1473219
D4	Total Energy (GER)	MJ	258563	1011881	1473601
BAU	LCC	€	11006	30389	42270
D1	LCC	€	11982	27489	36993
D2	LCC	€	13454	26027	33733
D3	LCC	€	16034	25726	31667
D4	LCC	0	16633	26325	32265

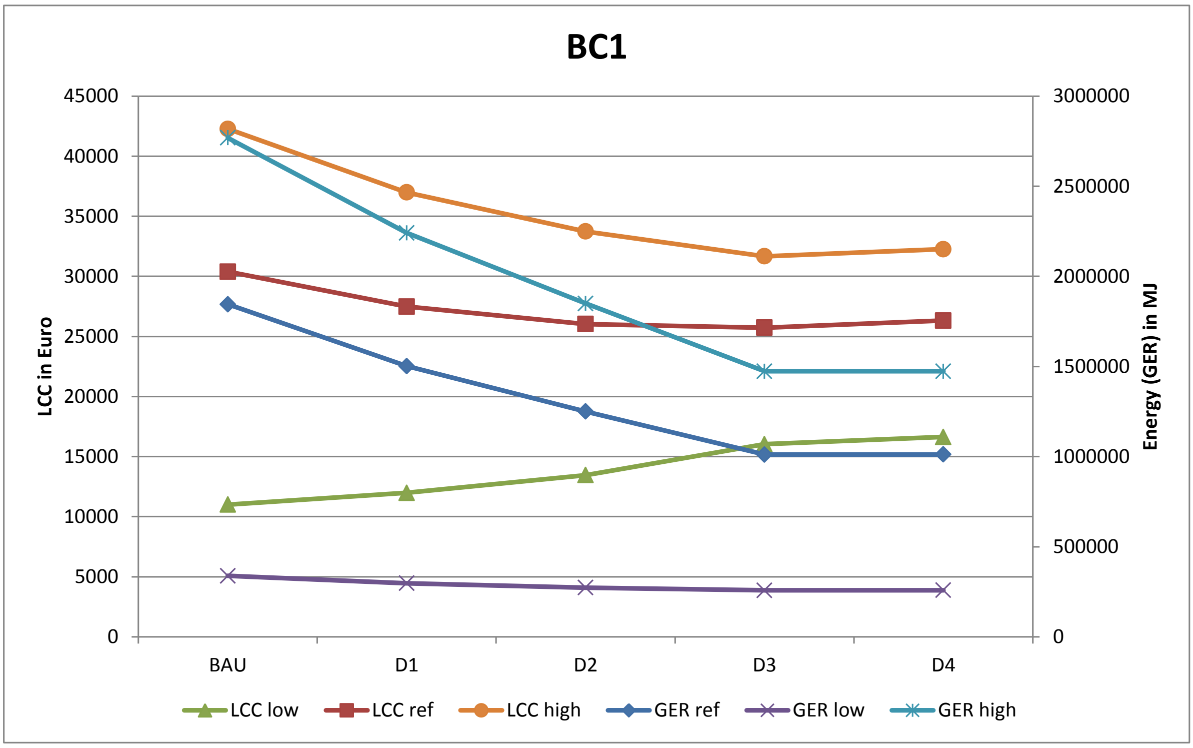


Figure 6-13 BC1 sensitivity to low, reference and high values

Table 6-24: Sensitivity data BC2

	Base Case Id		BC2		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1925	7289	15471
D1	Total Energy (GER)	0	1682	4900	9810
D2	Total Energy (GER)	0	1749	3760	6829
D3	Total Energy (GER)	0	2010	3351	5396
D4	Total Energy (GER)	MJ	2024	4706	8797
BAU	LCC	€	110	229	404
D1	LCC	€	139	238	381
D2	LCC	€	184	278	413
D3	LCC	€	256	361	510
D4	LCC	0	197	332	524

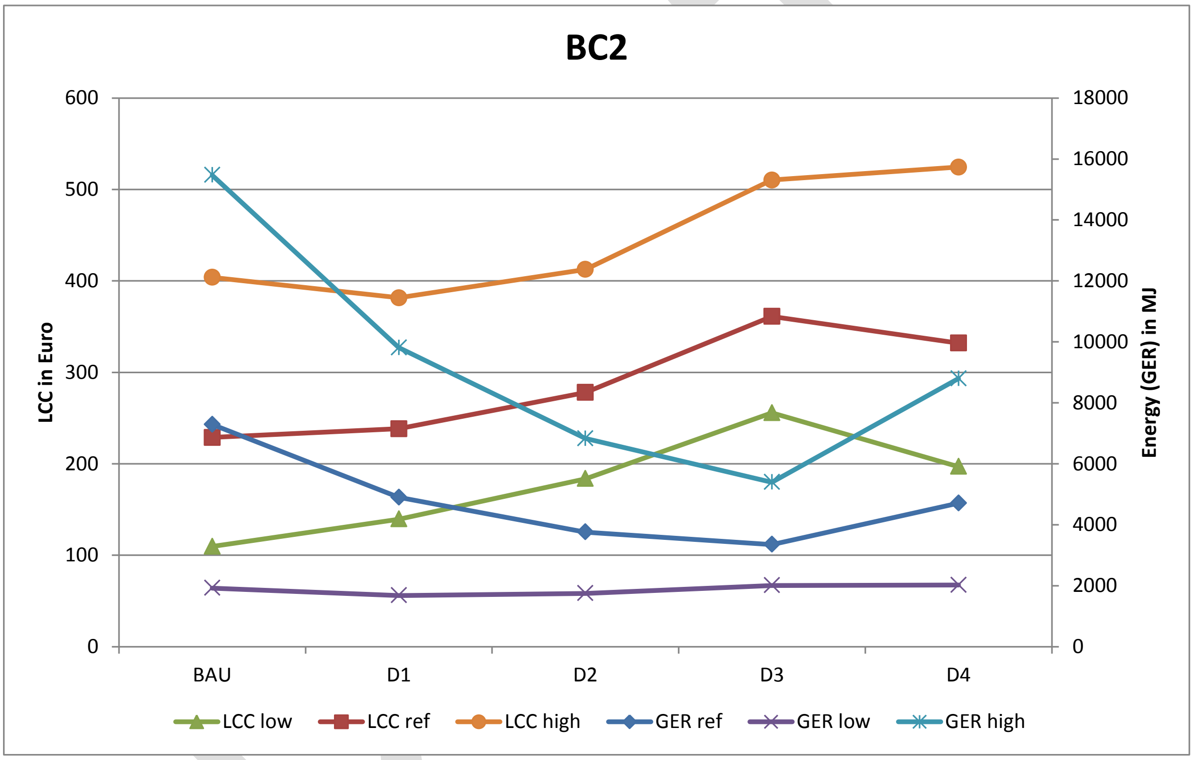


Figure 6-14 BC2 sensitivity to low, reference and high values

Table 6-25: Sensitivity data BC3

	Base Case Id		BC3		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1664	5803	10461
D1	Total Energy (GER)	0	1877	4464	7375
D2	Total Energy (GER)	0	2266	3990	5931
D3	Total Energy (GER)	0	3133	4168	5332
D4	Total Energy (GER)	MJ	2496	4566	6894
BAU	LCC	€	165	245	347
D1	LCC	€	221	286	373
D2	LCC	€	309	372	462
D3	LCC	€	428	487	575
D4	LCC	0	321	401	516

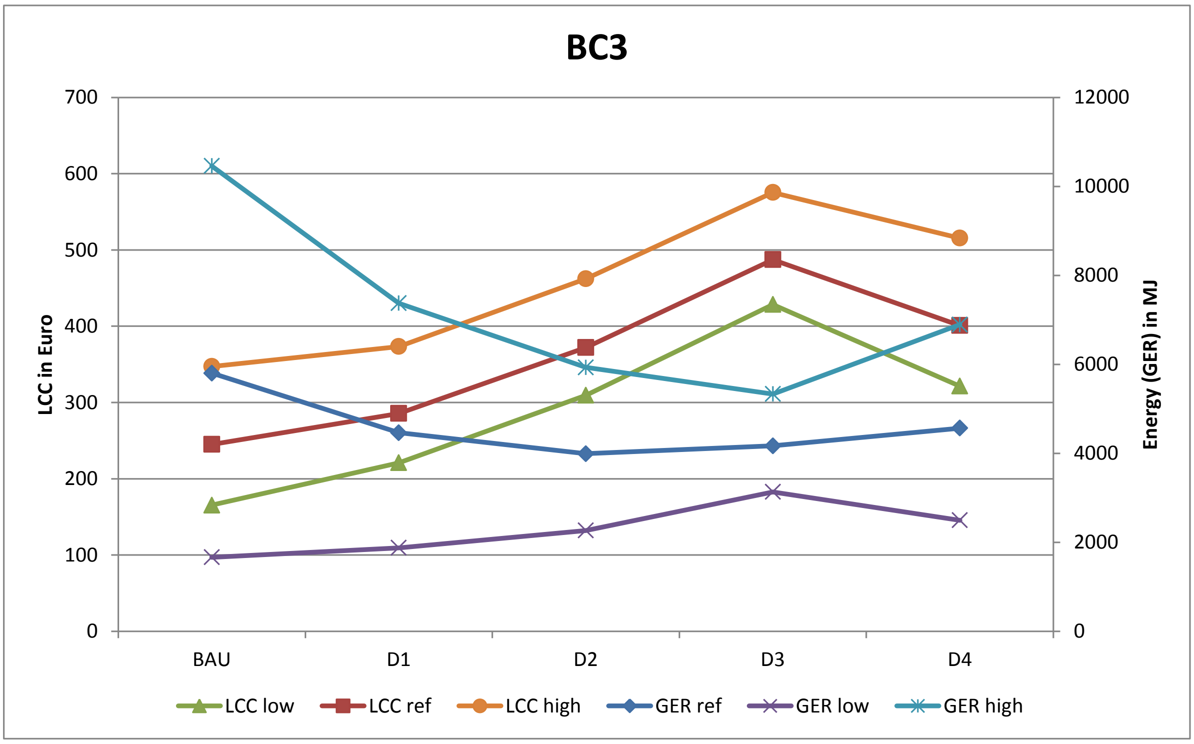


Figure 6-15 BC3 sensitivity to low, reference and high values

Table 6-26: Sensitivity data BC4

	Base Case Id		BC4		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	72358	447921	678109
D1	Total Energy (GER)	0	47605	282332	426200
D2	Total Energy (GER)	0	34063	184289	276364
D3	Total Energy (GER)	0	28213	135517	201285
D4	Total Energy (GER)	MJ	40404	228186	343280
BAU	LCC	€	1273	6117	9120
D1	LCC	€	1106	4141	6041
D2	LCC	€	1155	3104	4340
D3	LCC	€	1334	2744	3682
D4	LCC	0	1205	3646	5209

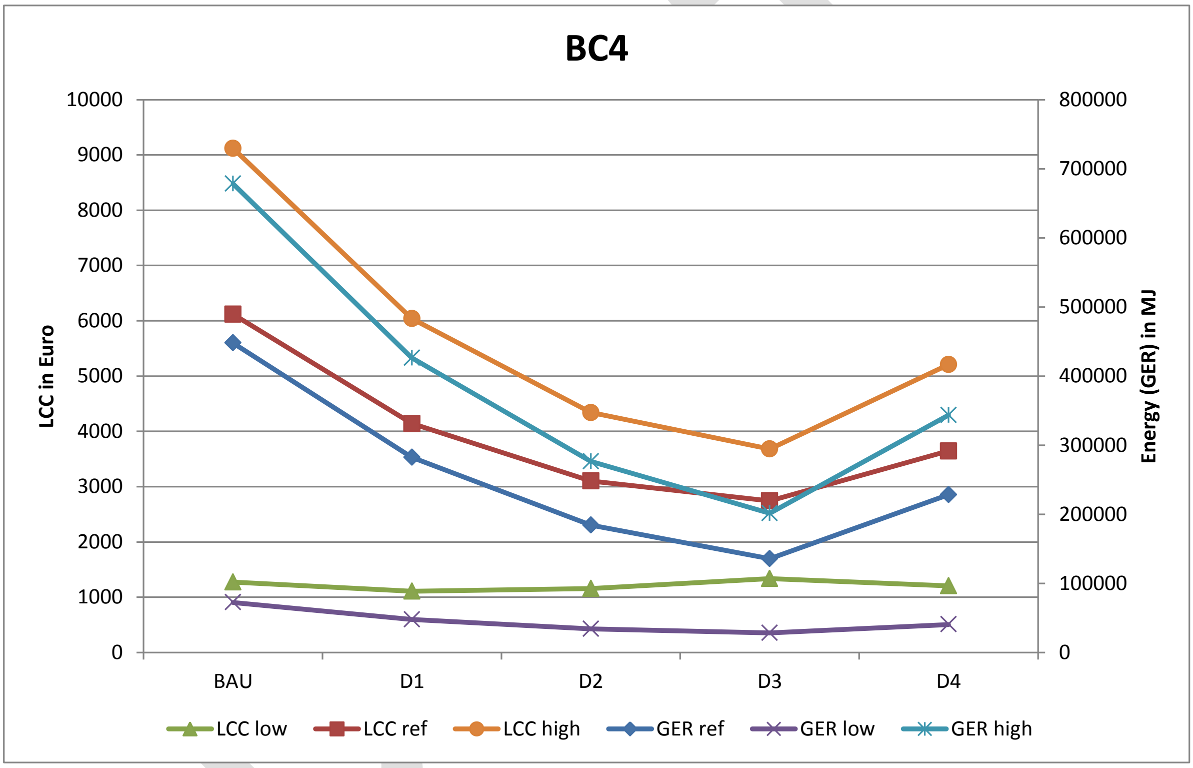


Figure 6-16 BC4 sensitivity to low, reference and high values

Table 6-27: Sensitivity data BC5

	Base Case Id		BC5		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1419277	7509255	11327342
D1	Total Energy (GER)	0	1248439	5815923	8679489
D2	Total Energy (GER)	0	1146306	4800293	7091146
D3	Total Energy (GER)	0	1136901	4036890	5855027
D4	Total Energy (GER)	MJ	1210468	4255457	6164501
BAU	LCC	€	55771	134122	183244
D1	LCC	€	65735	124498	161339
D2	LCC	€	78329	125339	154812
D3	LCC	€	94717	132027	155418
D4	LCC	0	90598	129773	154334

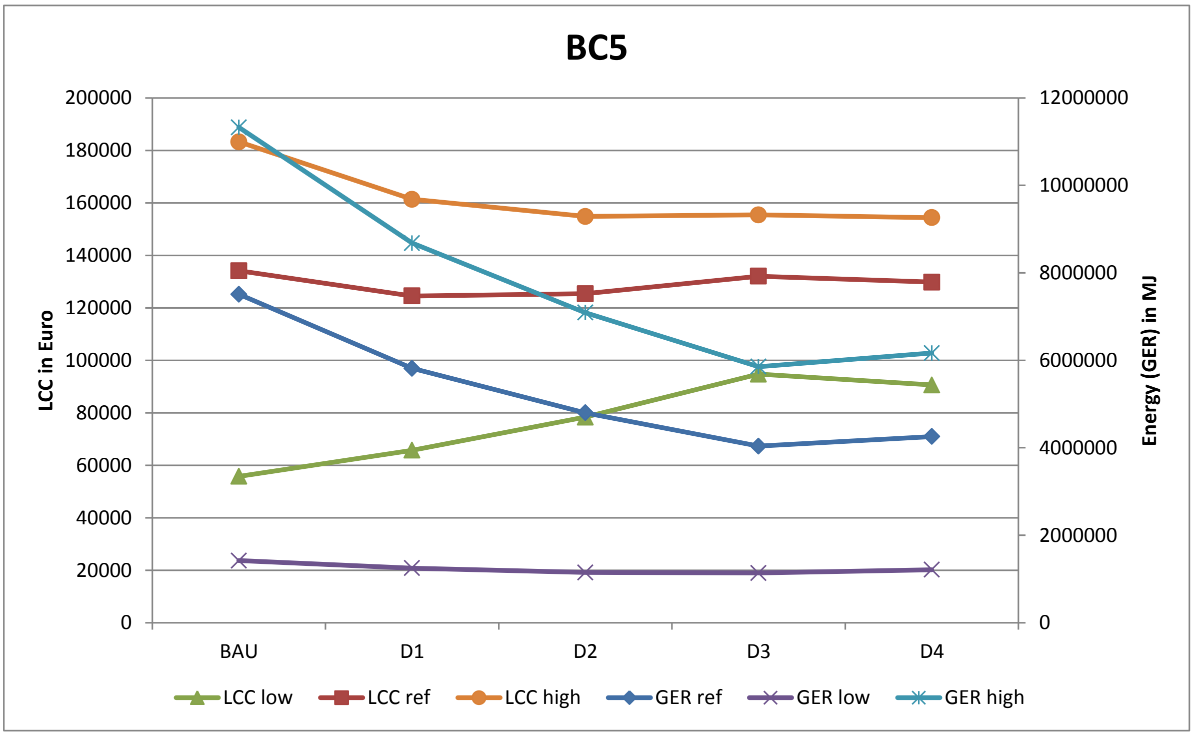


Figure 6-17 BC5 sensitivity to low, reference and high values

Table 6-28: Sensitivity data BC6

	Base Case Id		BC6		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1419277	14563	31369
D1	Total Energy (GER)	0	1248439	9530	19614
D2	Total Energy (GER)	0	1146306	7015	13317
D3	Total Energy (GER)	0	1136901	5964	10165
D4	Total Energy (GER)	MJ	1210468	8896	17299
BAU	LCC	€	55771	369	660
D1	LCC	€	65735	362	578
D2	LCC	€	78329	408	591
D3	LCC	€	94717	520	706
D4	LCC	0	90598	478	737

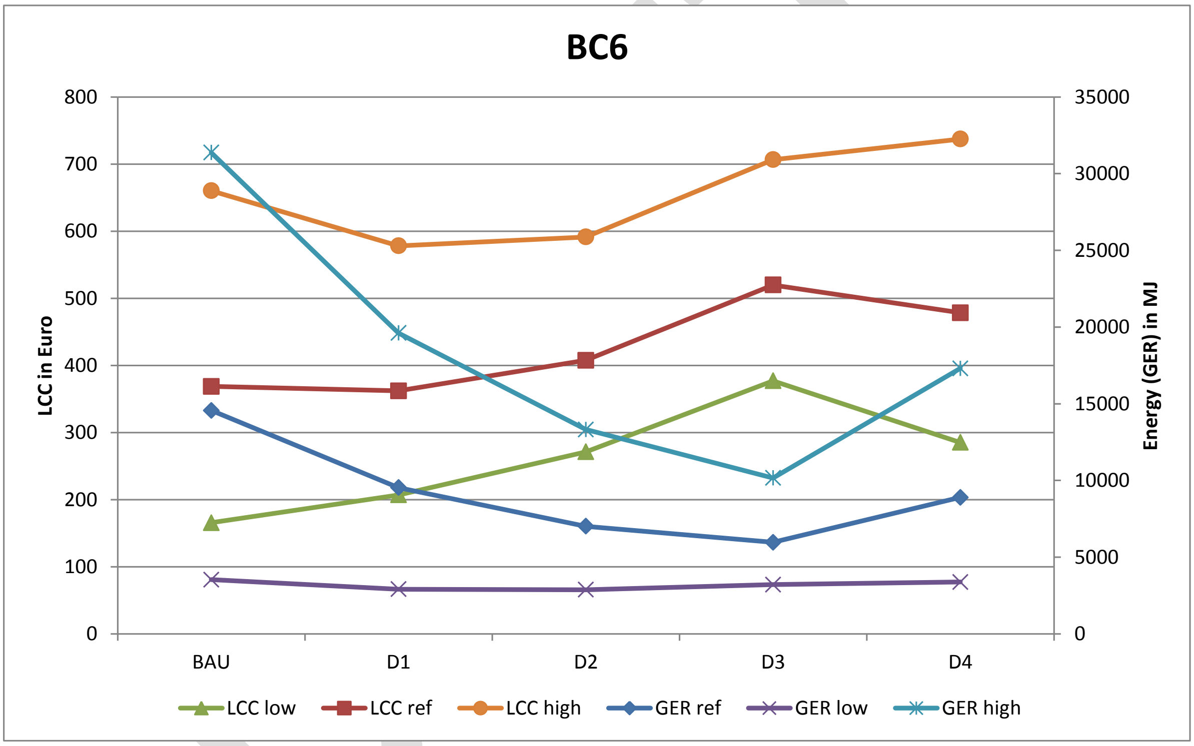


Figure 6-18 BC6 sensitivity to low, reference and high values

Table 6-29: Sensitivity data BC7

	Base Case Id		BC7		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	2753	18316	41438
D1	Total Energy (GER)	0	2847	12574	27025
D2	Total Energy (GER)	0	3269	9753	19387
D3	Total Energy (GER)	0	4364	8255	14036
D4	Total Energy (GER)	MJ	3627	11408	22969
BAU	LCC	€	208	432	756
D1	LCC	€	277	430	648
D2	LCC	€	388	507	672
D3	LCC	€	545	635	756
D4	LCC	0	394	540	743

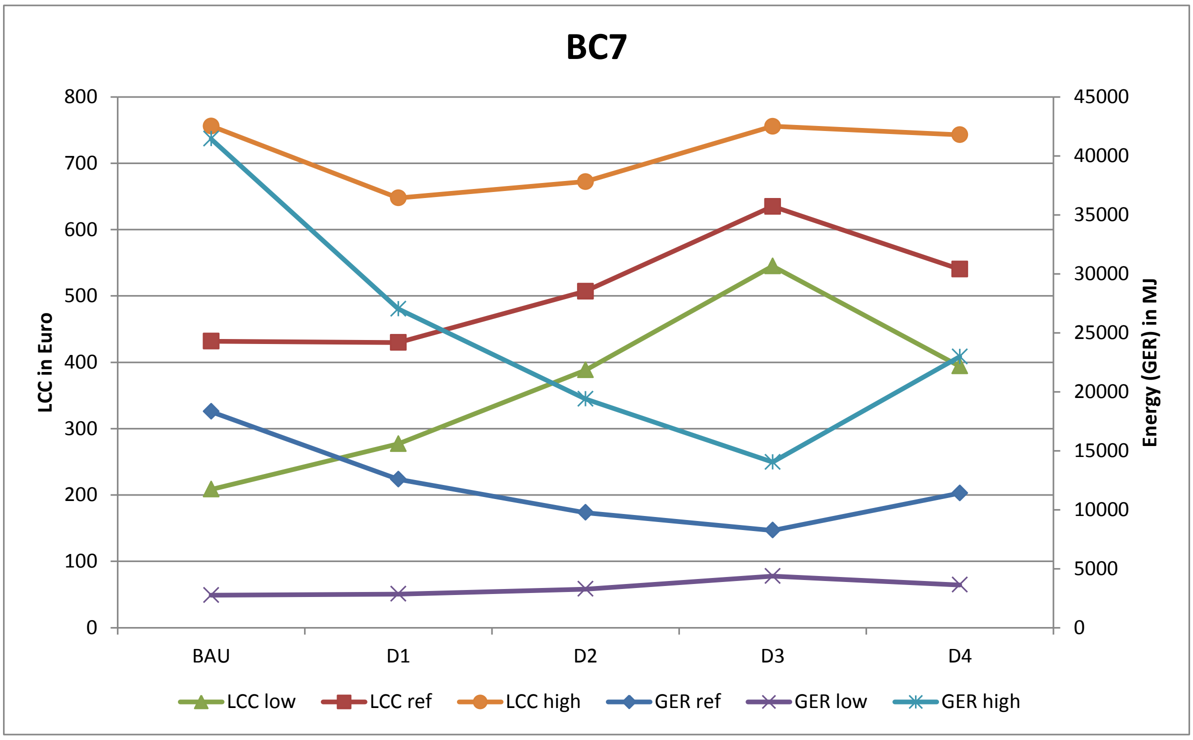


Figure 6-19 BC7 sensitivity to low, reference and high values

Table 6-30: Sensitivity data BC8

	Base Case Id		BC8		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	300377	1943151	2995535
D1	Total Energy (GER)	0	218013	1367955	2104624
D2	Total Energy (GER)	0	167073	988460	1514652
D3	Total Energy (GER)	0	137664	742897	1130617
D4	Total Energy (GER)	MJ	168103	989490	1515682
BAU	LCC	€	5358	26519	40130
D1	LCC	€	4827	19649	29204
D2	LCC	€	4917	15538	22458
D3	LCC	€	5448	13325	18568
D4	LCC	0	5152	15770	22683

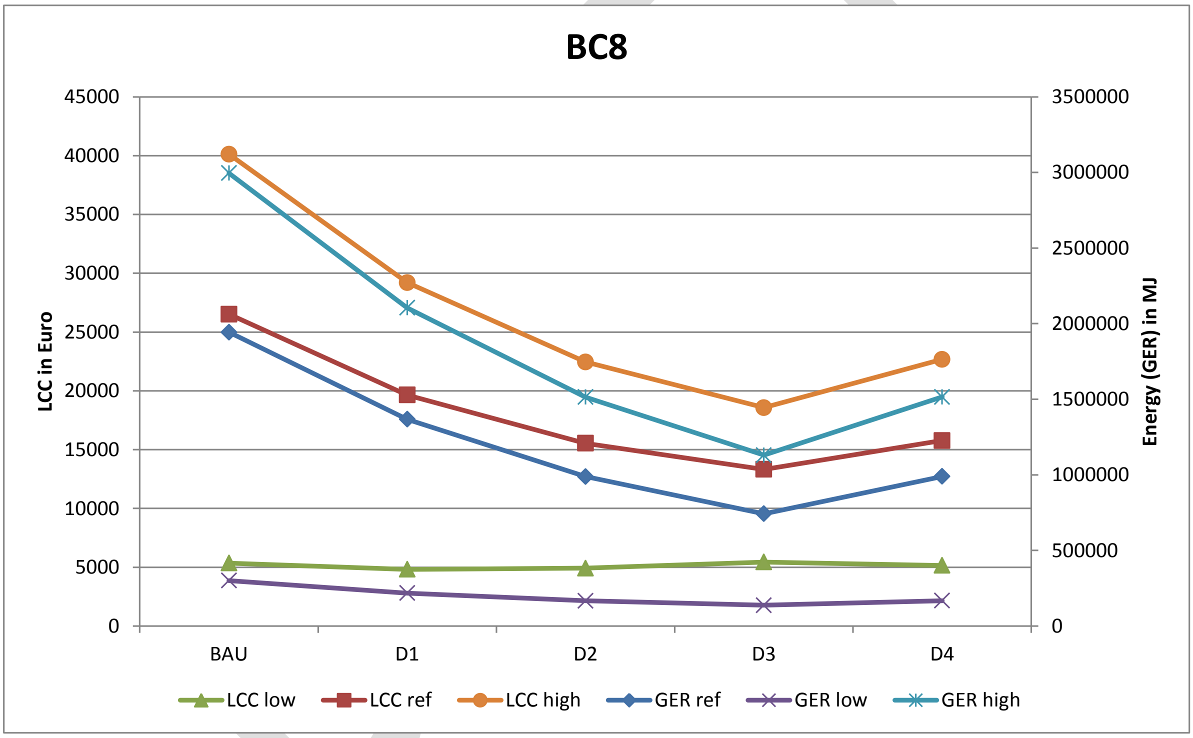


Figure 6-20 BC8 sensitivity to low, reference and high values

Table 6-31: Sensitivity data BC9

	Base Case Id		BC9		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	243889	1547287	2382262
D1	Total Energy (GER)	0	187698	1148097	1763342
D2	Total Energy (GER)	0	158255	918571	1405640
D3	Total Energy (GER)	0	136377	744630	1134285
D4	Total Energy (GER)	MJ	144484	796183	1213671
BAU	LCC	€	4869	21690	32581
D1	LCC	€	4713	17158	25326
D2	LCC	€	4872	14765	21347
D3	LCC	€	5223	13166	18511
D4	LCC	0	5323	13812	19479

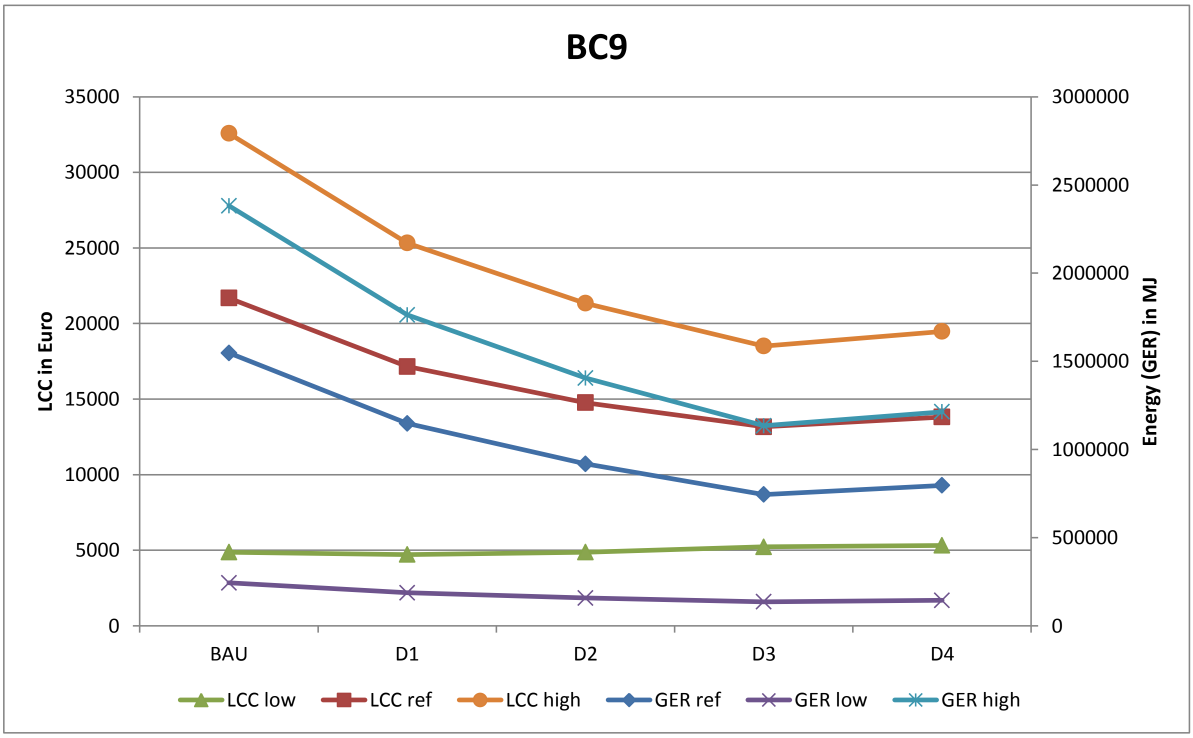


Figure 6-21 BC9 sensitivity to low, reference and high values

Conclusion:

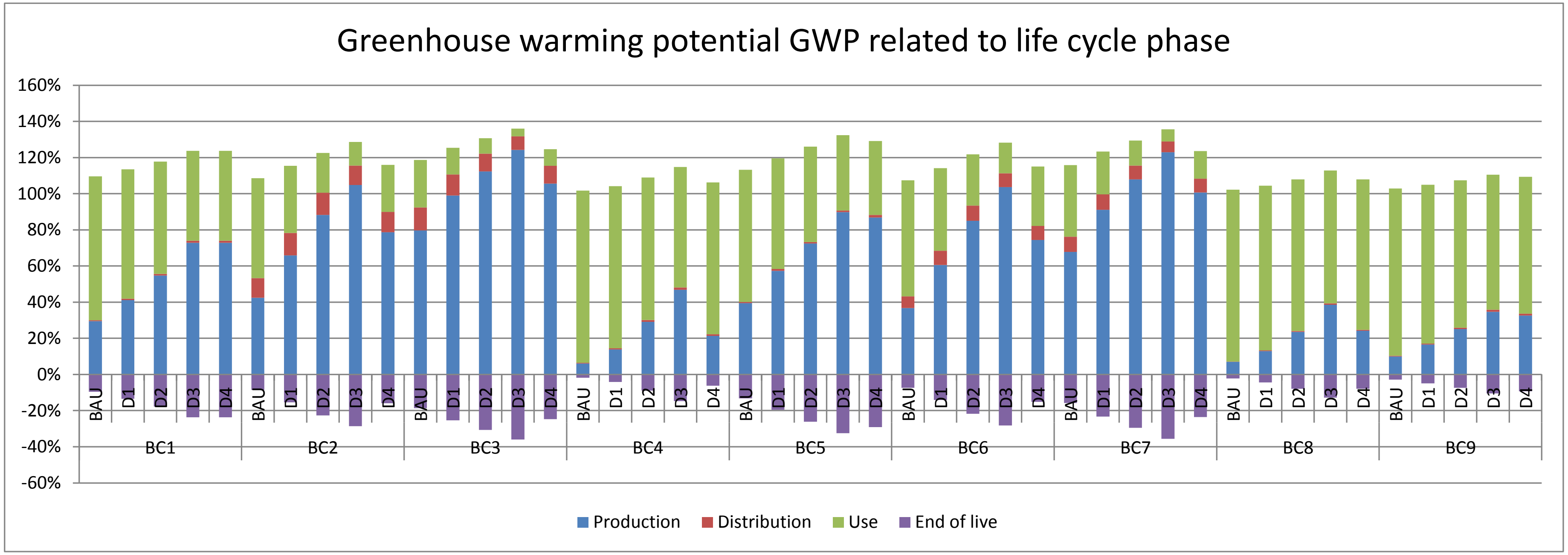
Table 6-32 summarizes the BAT and LLCC sensitivity to the loading of the circuit in terms of design options shifts. In case of BAT there is no shift in design option for BC1, BC4, BC5, BC8 and BC9. However for BC2, BC3, BC6 and BC7 being the lighting and socket-outlet circuits and having a lower overall load, it is more difficult to compensate the extra energy needed at production by the energy gains during the use phase.

A lower load means it is more difficult to compensate the investment costs by the gains made during the use phase due to the lesser electricity consumption. A higher load is favourable for the LCC of more costly design options, as to be expected.
One can notice also that for circuits having a low load in general, the BAU solution is the best option.
Even for circuits having a high load, like BC1, a lower load can cause the LLCC to shift from D3 to BAU.

Table 6-32: design option sensitivity to circuit use (load)

	BAT - load sensitivity			LLCC - load sensitivity		
	low	ref	high	low	ref	high
BC1	D3	D3	D3	BAU	D3	D3
BC2	D1	D3	D3	BAU	BAU	D1
BC3	BAU	D2	D3	BAU	BAU	BAU
BC4	D3	D3	D3	D1	D3	D3
BC5	D3	D3	D3	BAU	D1	D4
BC6	D2	D3	D3	BAU	D1	D1
BC7	BAU	D3	D3	BAU	D1	D1
BC8	D3	D3	D3	D1	D3	D3
BC9	D3	D3	D3	D1	D3	D3

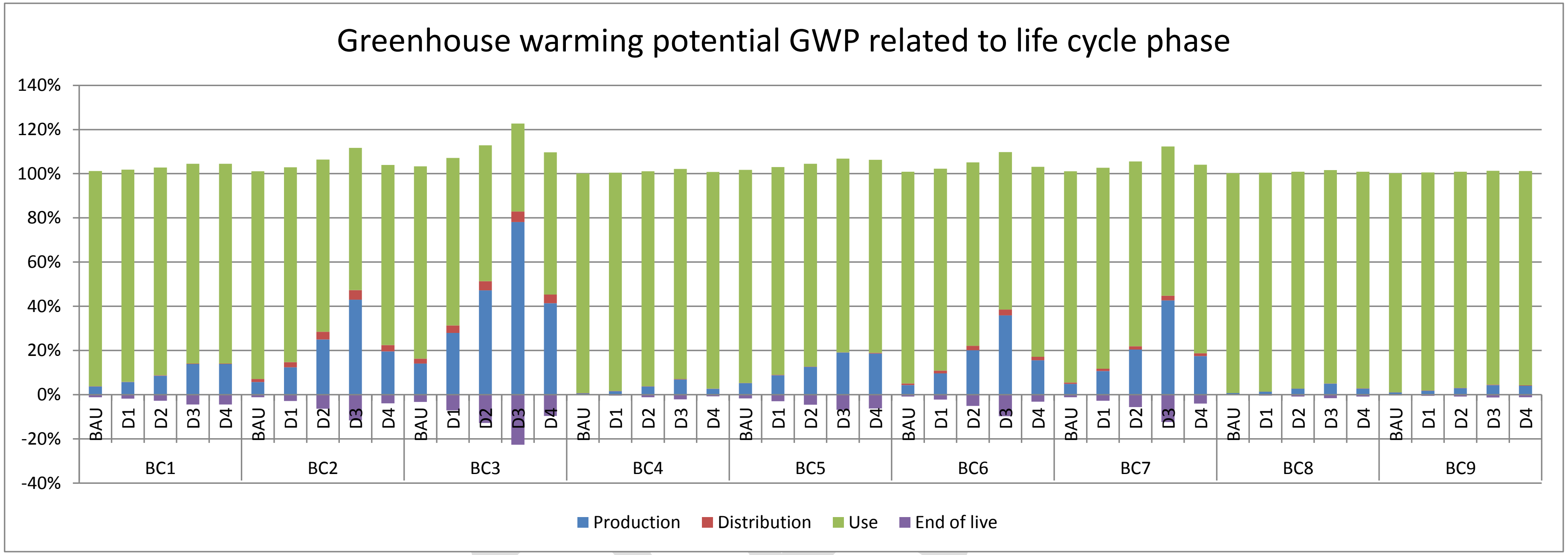
1



2

3 *Figure 6-22 Greenhouse Gases (in detail, relative of each phase to total) in GWP100 for the 'low values'*

4

1 

2 *Figure 6-23 Greenhouse Gases (in detail, relative of each phase to total) in GWP100 for the 'high values'*

3

6.6.2 Sensitivity to length of the circuits

This section analyses the impact from the circuit length parameter. Longer circuits mean more energy needed for production and transport.

The circuit length will have an impact on the LCC during all phase of the product life.

Table 6-33: Sensitivity data BC1

	Base Case Id		BC1				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	656065	1844983	6559658	-64%	+256%
D1	Total Energy (GER)	0.00	534231	1502325	5341318	-64%	+256%
D2	Total Energy (GER)	0.00	444705	1250532	4446055	-64%	+256%
D3	Total Energy (GER)	0.00	359715	1011499	3596159	-64%	+256%
D4	Total Energy (GER)	MJ	359851	1011881	3597517	-64%	+256%
BAU	LCC	€	11082	30389	106951	-64%	+252%
D1	LCC	€	10066	27489	96579	-63%	+251%
D2	LCC	€	9598	26027	91178	-63%	+250%
D3	LCC	€	9516	25726	90008	-63%	+250%
D4	LCC	€	9915	26325	91402	-62%	+247%
GER	D1 compared to BAU		-19%	-19%	-19%		
	D2 compared to BAU		-32%	-32%	-32%		
	D3 compared to BAU		-45%	-45%	-45%		
	D4 compared to BAU		-45%	-45%	-45%		
LCC	D1 compared to BAU		-9%	-10%	-10%		
	D2 compared to BAU		-13%	-14%	-15%		
	D3 compared to BAU		-14%	-15%	-16%		
	D4 compared to BAU		-11%	-13%	-15%		

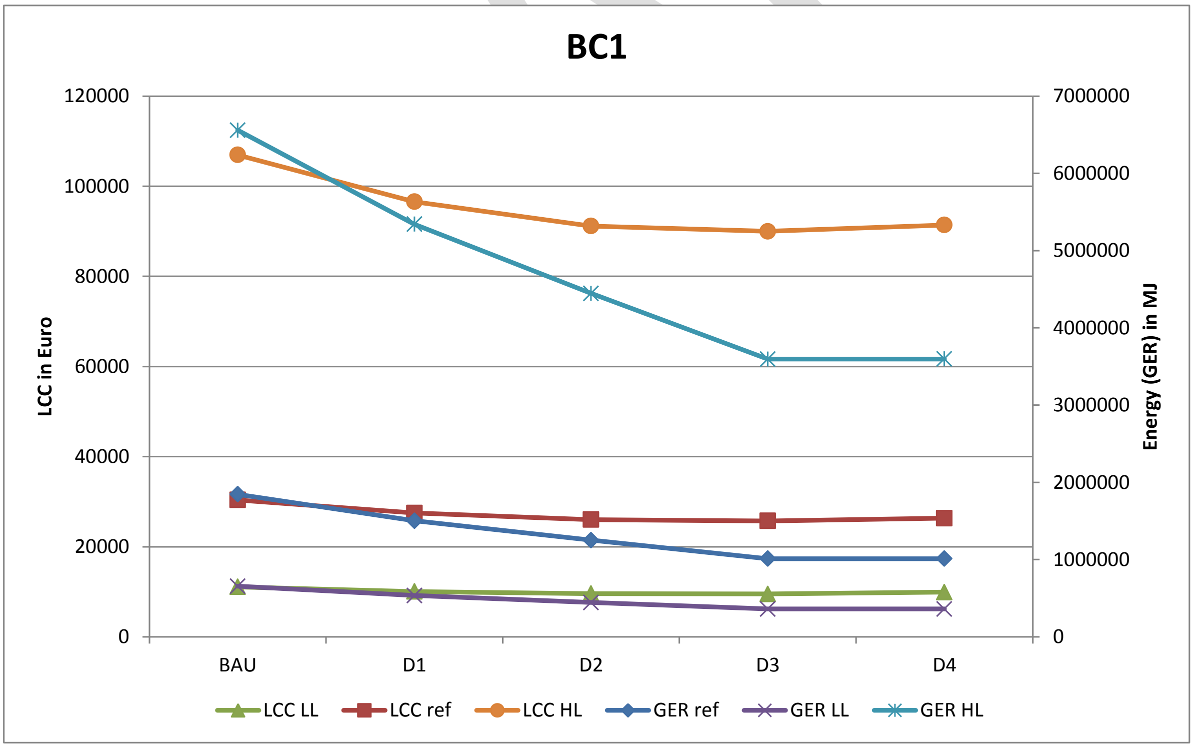


Figure 6-24 BC1 sensitivity to length of circuit

Table 6-34: Sensitivity data BC2

	Base Case Id		BC2				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	2088	7289	39664	-71%	+444%
D1	Total Energy (GER)	0	1430	4900	26503	-71%	+441%
D2	Total Energy (GER)	0	1116	3760	20223	-70%	+438%
D3	Total Energy (GER)	0	1003	3351	17964	-70%	+436%
D4	Total Energy (GER)	MJ	1377	4706	25432	-71%	+440%
BAU	LCC	€	115	229	935	-50%	+309%
D1	LCC	€	125	238	941	-47%	+295%
D2	LCC	€	148	278	1089	-47%	+292%
D3	LCC	€	191	361	1419	-47%	+293%
D4	LCC	€	196	332	1179	-41%	+255%
GER	D1 compared to BAU		-32%	-33%	-33%		
	D2 compared to BAU		-47%	-48%	-49%		
	D3 compared to BAU		-52%	-54%	-55%		
	D4 compared to BAU		-34%	-35%	-36%		
LCC	D1 compared to BAU		+9%	+4%	+1%		
	D2 compared to BAU		+28%	+22%	+16%		
	D3 compared to BAU		+66%	+58%	+52%		
	D4 compared to BAU		+70%	+45%	+26%		

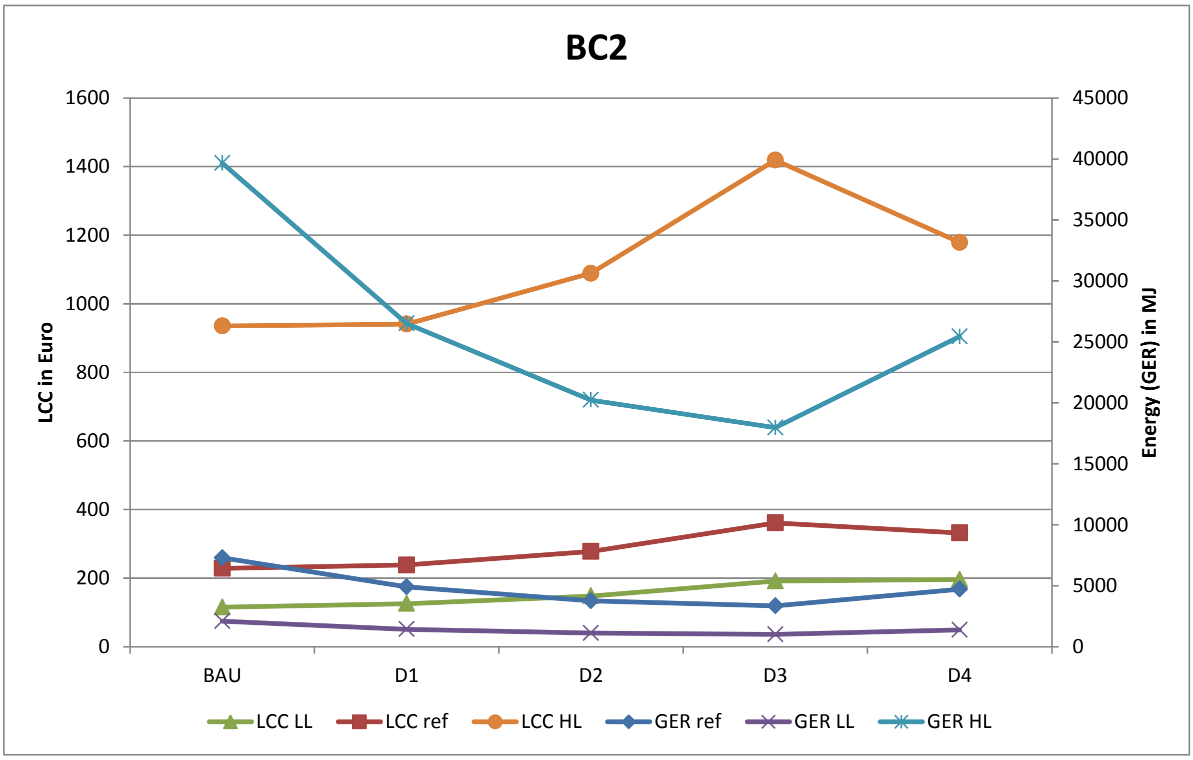


Figure 6-25 BC2 sensitivity to length of circuit

Table 6-35: Sensitivity data BC3

	Base Case Id		BC3				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	1189	5803	32466	-80%	+460%
D1	Total Energy (GER)	0	935	4464	24854	-79%	+457%
D2	Total Energy (GER)	0	846	3990	22163	-79%	+455%
D3	Total Energy (GER)	0	879	4168	23172	-79%	+456%
D4	Total Energy (GER)	MJ	955	4566	25434	-79%	+457%
BAU	LCC	€	93	245	1123	-62%	+358%
D1	LCC	€	110	286	1302	-62%	+356%
D2	LCC	€	142	372	1700	-62%	+357%
D3	LCC	€	173	487	2304	-65%	+373%
D4	LCC	€	169	401	1738	-58%	+334%
GER	D1 compared to BAU		-21%	-23%	-23%		
	D2 compared to BAU		-29%	-31%	-32%		
	D3 compared to BAU		-26%	-28%	-29%		
	D4 compared to BAU		-20%	-21%	-22%		
LCC	D1 compared to BAU		+18%	+17%	+16%		
	D2 compared to BAU		+53%	+52%	+51%		
	D3 compared to BAU		+86%	+99%	+105%		
	D4 compared to BAU		+82%	+64%	+55%		

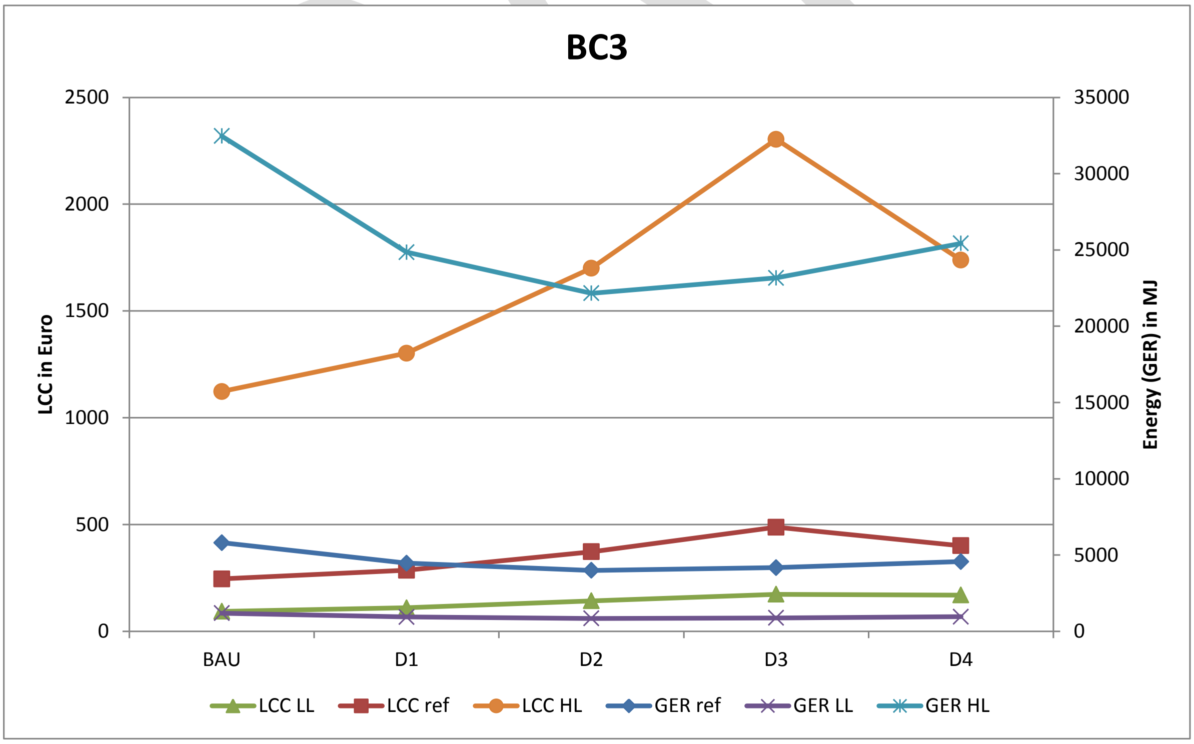


Figure 6-26 BC3 sensitivity to length of circuit

Table 6-36: Sensitivity data BC4

	Base Case Id		BC4				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	88688	447921	2657448	-80%	+493%
D1	Total Energy (GER)	0	55935	282332	1674832	-80%	+493%
D2	Total Energy (GER)	0	36541	184289	1093036	-80%	+493%
D3	Total Energy (GER)	0	26894	135517	803619	-80%	+493%
D4	Total Energy (GER)	MJ	45224	228186	1353524	-80%	+493%
BAU	LCC	€	1238	6117	36130	-80%	+491%
D1	LCC	€	852	4141	24370	-79%	+488%
D2	LCC	€	648	3104	18208	-79%	+487%
D3	LCC	€	605	2744	15899	-78%	+479%
D4	LCC	€	777	3646	21297	-79%	+484%
GER	D1 compared to BAU		-37%	-37%	-37%		
	D2 compared to BAU		-59%	-59%	-59%		
	D3 compared to BAU		-70%	-70%	-70%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-31%	-32%	-33%		
	D2 compared to BAU		-48%	-49%	-50%		
	D3 compared to BAU		-51%	-55%	-56%		
	D4 compared to BAU		-37%	-40%	-41%		

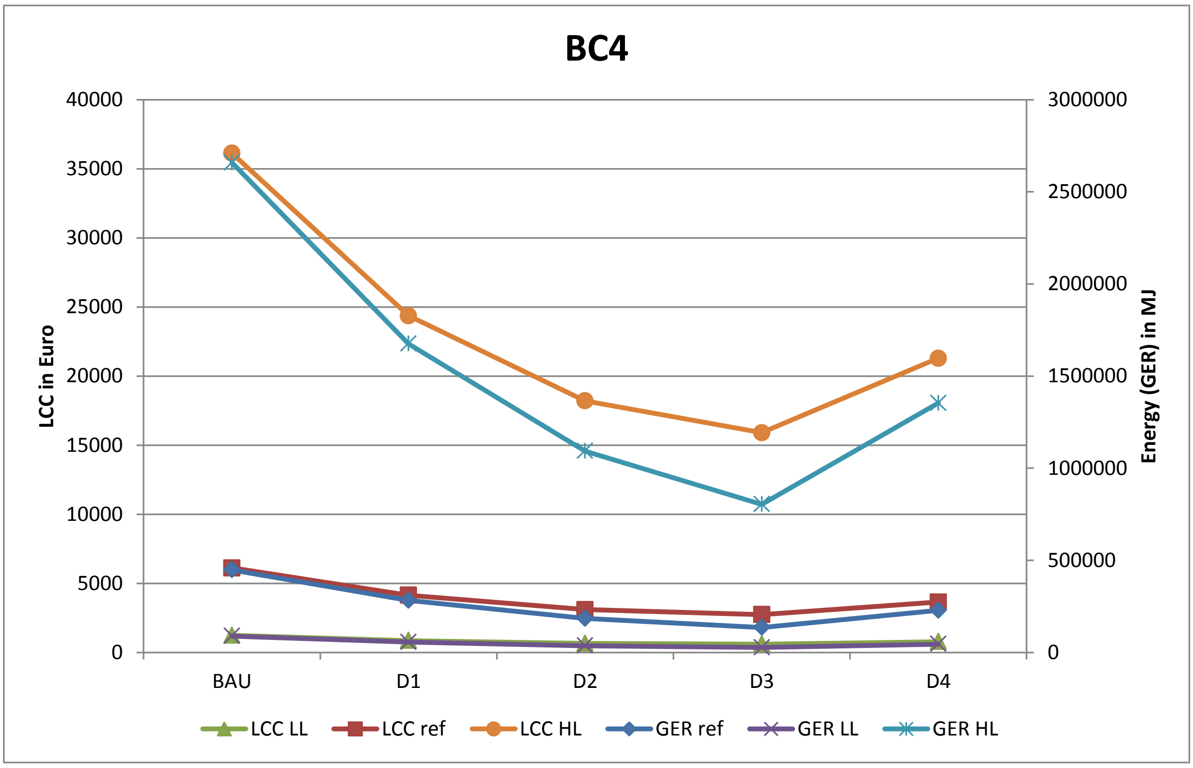


Figure 6-27 BC4 sensitivity to length of circuit

Table 6-37: Sensitivity data BC5

	Base Case Id		BC5				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	2730708	7509255	21844894	-64%	+191%
D1	Total Energy (GER)	0	2114951	5815923	16918838	-64%	+191%
D2	Total Energy (GER)	0	1745632	4800293	13964279	-64%	+191%
D3	Total Energy (GER)	0	1468030	4036890	11743470	-64%	+191%
D4	Total Energy (GER)	MJ	1547509	4255457	12379301	-64%	+191%
BAU	LCC	€	49571	134122	387775	-63%	+189%
D1	LCC	€	46418	124498	358737	-63%	+188%
D2	LCC	€	47151	125339	359903	-62%	+187%
D3	LCC	€	50147	132027	377668	-62%	+186%
D4	LCC	€	48789	129773	372727	-62%	+187%
GER	D1 compared to BAU		-23%	-23%	-23%		
	D2 compared to BAU		-36%	-36%	-36%		
	D3 compared to BAU		-46%	-46%	-46%		
	D4 compared to BAU		-43%	-43%	-43%		
LCC	D1 compared to BAU		-6%	-7%	-7%		
	D2 compared to BAU		-5%	-7%	-7%		
	D3 compared to BAU		+1%	-2%	-3%		
	D4 compared to BAU		-2%	-3%	-4%		

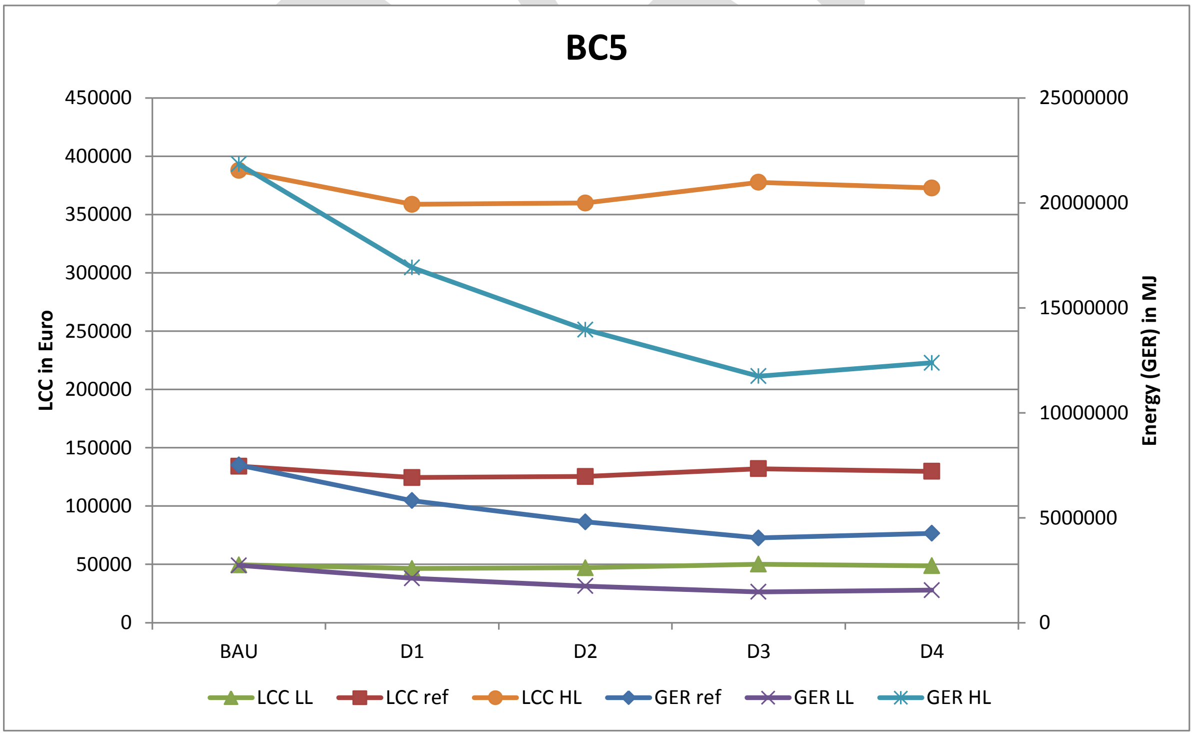


Figure 6-28 BC5 sensitivity to length of circuit

Table 6-38: Sensitivity data BC6

	Base Case Id		BC6				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	2730708	14563	72910	18651%	+401%
D1	Total Energy (GER)	0	2114951	9530	47558	22092%	+399%
D2	Total Energy (GER)	0	1745632	7015	34890	24784%	+397%
D3	Total Energy (GER)	0	1468030	5964	29595	24515%	+396%
D4	Total Energy (GER)	MJ	1547509	8896	44365	17295%	+399%
BAU	LCC	€	49571	369	1522	13350%	+313%
D1	LCC	€	46418	362	1440	12721%	+298%
D2	LCC	€	47151	408	1597	11467%	+292%
D3	LCC	€	50147	520	2030	9547%	+291%
D4	LCC	€	48789	478	1740	10101%	+264%
GER	D1 compared to BAU		-23%	-35%	-35%		
	D2 compared to BAU		-36%	-52%	-52%		
	D3 compared to BAU		-46%	-59%	-59%		
	D4 compared to BAU		-43%	-39%	-39%		
LCC	D1 compared to BAU		-6%	-2%	-5%		
	D2 compared to BAU		-5%	+11%	+5%		
	D3 compared to BAU		+1%	+41%	+33%		
	D4 compared to BAU		-2%	+30%	+14%		

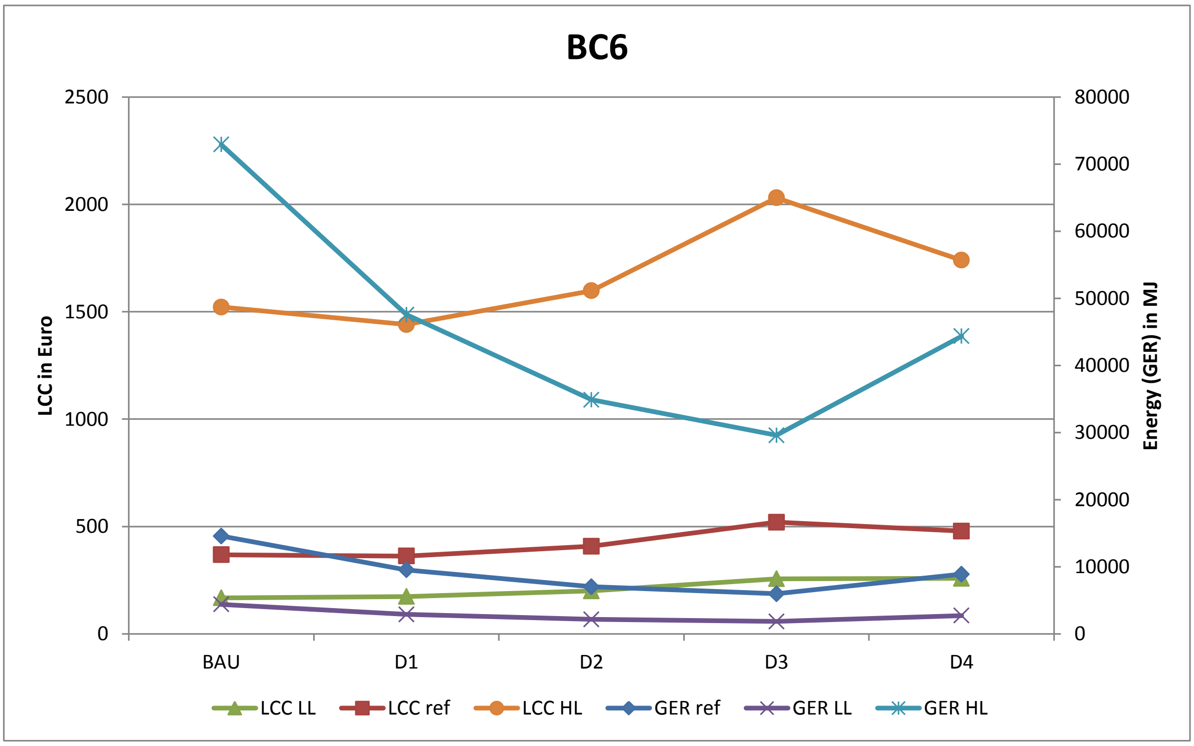


Figure 6-29 BC6 sensitivity to length of circuit

Table 6-39: Sensitivity data BC7

	Base Case Id		BC7				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	3903	18316	126538	-79%	+591%
D1	Total Energy (GER)	0	2707	12574	86664	-78%	+589%
D2	Total Energy (GER)	0	2119	9753	67074	-78%	+588%
D3	Total Energy (GER)	0	1807	8255	56671	-78%	+586%
D4	Total Energy (GER)	MJ	2464	11408	78567	-78%	+589%
BAU	LCC	€	123	432	2749	-71%	+537%
D1	LCC	€	129	430	2688	-70%	+526%
D2	LCC	€	157	507	3140	-69%	+519%
D3	LCC	€	189	635	3980	-70%	+527%
D4	LCC	€	179	540	3255	-67%	+502%
GER	D1 compared to BAU		-31%	-31%	-32%		
	D2 compared to BAU		-46%	-47%	-47%		
	D3 compared to BAU		-54%	-55%	-55%		
	D4 compared to BAU		-37%	-38%	-38%		
LCC	D1 compared to BAU		+5%	-0%	-2%		
	D2 compared to BAU		+27%	+17%	+14%		
	D3 compared to BAU		+54%	+47%	+45%		
	D4 compared to BAU		+45%	+25%	+18%		

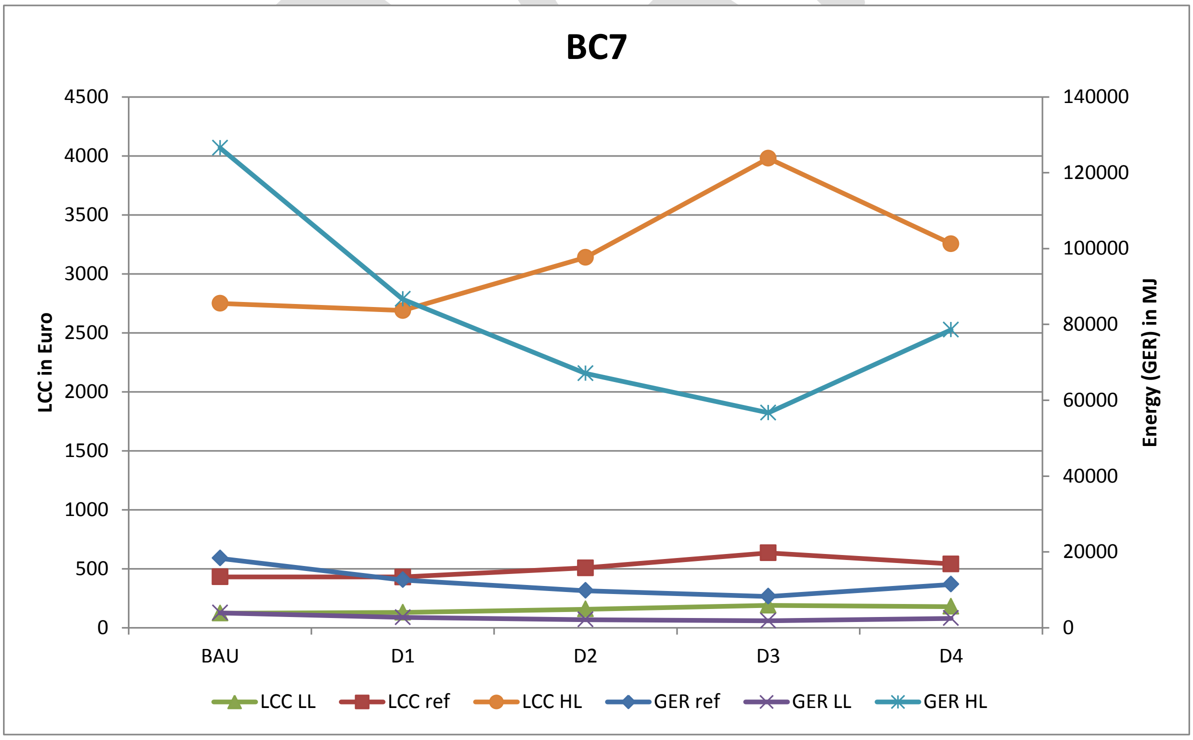


Figure 6-30 BC7 sensitivity to length of circuit

Table 6-40: Sensitivity data BC8

	Base Case Id		BC8				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	371392	1943151	9900954	-81%	+410%
D1	Total Energy (GER)	0	261482	1367955	6970019	-81%	+410%
D2	Total Energy (GER)	0	188967	988460	5036288	-81%	+410%
D3	Total Energy (GER)	0	142044	742897	3785009	-81%	+409%
D4	Total Energy (GER)	MJ	189164	989490	5041537	-81%	+410%
BAU	LCC	€	5127	26519	134825	-81%	+408%
D1	LCC	€	3819	19649	99792	-81%	+408%
D2	LCC	€	3094	15538	78542	-80%	+405%
D3	LCC	€	2759	13325	66820	-79%	+401%
D4	LCC	€	3133	15770	79752	-80%	+406%
GER	D1 compared to BAU		-30%	-30%	-30%		
	D2 compared to BAU		-49%	-49%	-49%		
	D3 compared to BAU		-62%	-62%	-62%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-26%	-26%	-26%		
	D2 compared to BAU		-40%	-41%	-42%		
	D3 compared to BAU		-46%	-50%	-50%		
	D4 compared to BAU		-39%	-41%	-41%		

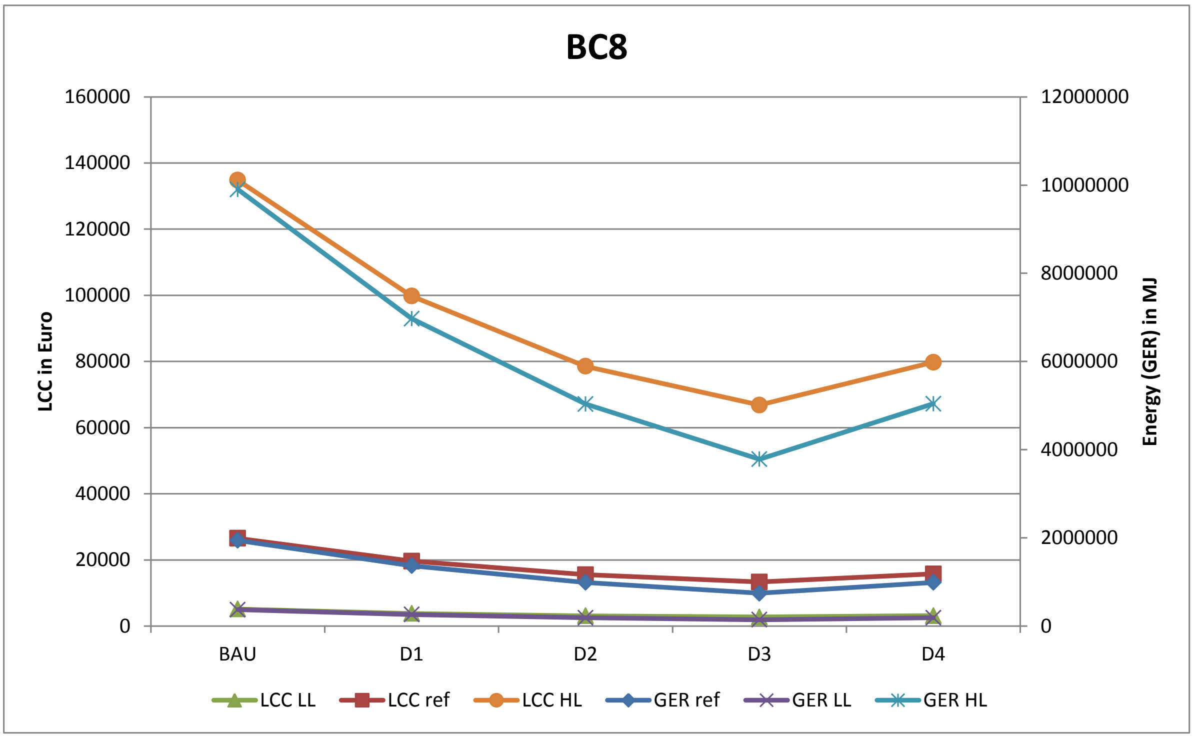


Figure 6-31 BC8 sensitivity to length of circuit

Table 6-41: Sensitivity data BC9

	Base Case Id		BC9				
		Unit	LL	Ref	HL	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	295749	1547287	7883814	-81%	+410%
D1	Total Energy (GER)	0	219471	1148097	5849724	-81%	+410%
D2	Total Energy (GER)	0	175613	918571	4680166	-81%	+410%
D3	Total Energy (GER)	0	142375	744630	3793839	-81%	+409%
D4	Total Energy (GER)	MJ	152226	796183	4056532	-81%	+409%
BAU	LCC	€	4268	21690	109899	-80%	+407%
D1	LCC	€	3489	17158	86365	-80%	+403%
D2	LCC	€	3084	14765	73905	-79%	+401%
D3	LCC	€	2792	13166	65687	-79%	+399%
D4	LCC	€	2886	13812	69131	-79%	+401%
GER	D1 compared to BAU		-26%	-26%	-26%		
	D2 compared to BAU		-41%	-41%	-41%		
	D3 compared to BAU		-52%	-52%	-52%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-18%	-21%	-21%		
	D2 compared to BAU		-28%	-32%	-33%		
	D3 compared to BAU		-35%	-39%	-40%		
	D4 compared to BAU		-32%	-36%	-37%		

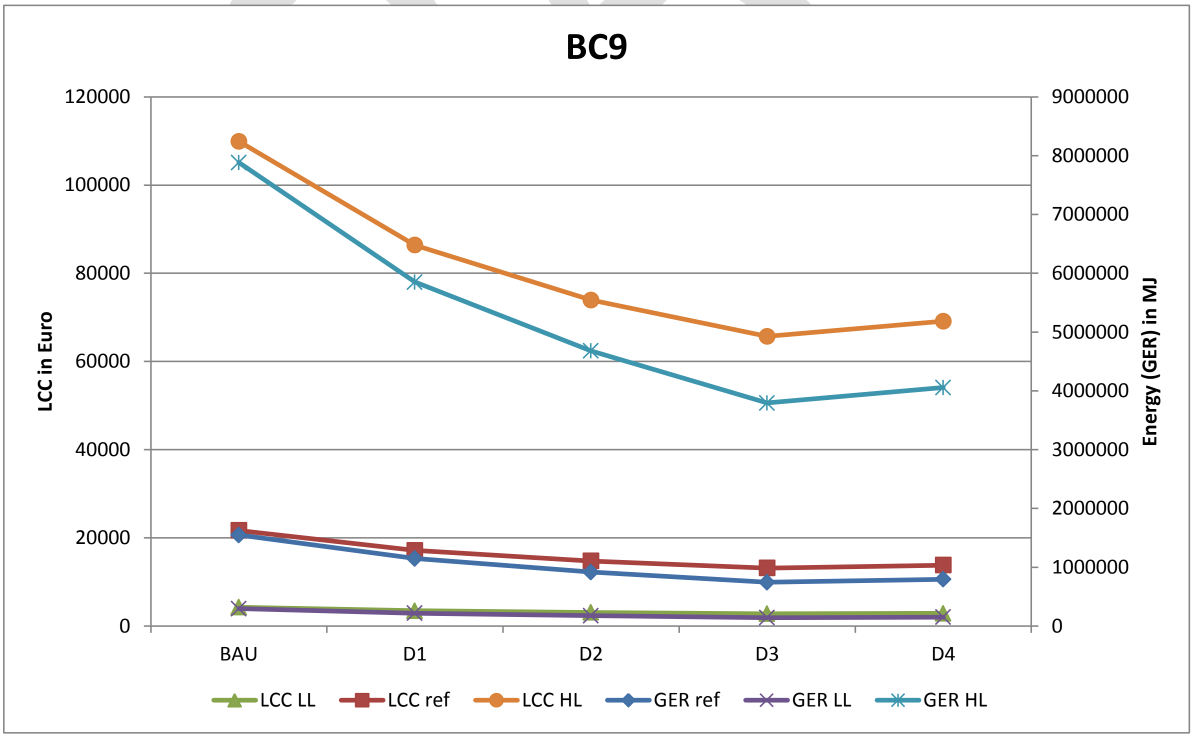


Figure 6-32 BC9 sensitivity to length of circuit

Conclusion:

Table 6-42 summarizes the sensitivity to length of the circuit in terms of design options shifts. In case of BAT, there is no shift in design option to be noticed for all nine base cases. In the graphics in section 6.6.2 one can notice that in absolute terms the energy usage increments when increasing the length of the circuits, but also that the differences between the design options get more pronounced.

Regarding the LLCC, one can notice that in case of BC6 and BC7 a higher length justifies a shift from design option BAU to D1. For the other base cases no shift can be justified.

Table 6-42: design option sensitivity to circuit length

	BAT - length sensitivity			LLCC - length sensitivity		
	low	ref	high	low	ref	high
BC1	D3	D3	D3	D3	D3	D3
BC2	D3	D3	D3	BAU	BAU	BAU
BC3	D2	D2	D2	BAU	BAU	BAU
BC4	D3	D3	D3	D3	D3	D3
BC5	D3	D3	D3	D1	D1	D1
BC6	D3	D3	D3	BAU	D1	D1
BC7	D3	D3	D3	BAU	D1	D1
BC8	D3	D3	D3	D3	D3	D3
BC9	D3	D3	D3	D3	D3	D3

6.6.3 Sensitivity to product lifetime

The basic calculation assumes a circuit product life according the reference values for product life per sector mentioned in Task 3. In order to assess the sensitivity of results compared to circuits with a lower or higher lifetime, the calculations are repeated for a low product lifetime and high product lifetime (see Table 6-43, copied from Task 3).

Table 6-43: Life time parameters per sector

	short product life		Reference		long product life	
Sector	**Replace-ment rate**	**Product life**	**Replace-ment rate**	**Product life**	**Replace-ment rate**	**Product life**
Unit	**%**	**year**	**%**	**year**	**%**	**year**
Residential sector	2.10%	40	1.18%	64	0.80%	84
Services sector	7.08%	13	3.20%	25	1.70%	40
Industry sector	7.08%	12	2.80%	25	1.37%	40

Table 6-44: Sensitivity data BC1

	Base Case Id		BC1				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	952325	1844983	2916173	-48%	+58%
D1	Total Energy (GER)	0.00	788198	1502325	2359277	-48%	+57%
D2	Total Energy (GER)	0.00	671511	1250532	1945358	-46%	+56%
D3	Total Energy (GER)	0.00	565170	1011499	1547094	-44%	+53%
D4	Total Energy (GER)	MJ	565552	1011881	1547476	-44%	+53%
BAU	LCC	€	18905	30389	44171	-38%	+45%
D1	LCC	€	18301	27489	38514	-33%	+40%
D2	LCC	€	18578	26027	34966	-29%	+34%
D3	LCC	€	19984	25726	32617	-22%	+27%
D4	LCC	€	20583	26325	33216	-22%	+26%
GER	D1 compared to BAU		-17%	-19%	-19%		
	D2 compared to BAU		-29%	-32%	-33%		
	D3 compared to BAU		-41%	-45%	-47%		
	D4 compared to BAU		-41%	-45%	-47%		
LCC	D1 compared to BAU		-3%	-10%	-13%		
	D2 compared to BAU		-2%	-14%	-21%		
	D3 compared to BAU		+6%	-15%	-26%		
	D4 compared to BAU		+9%	-13%	-25%		

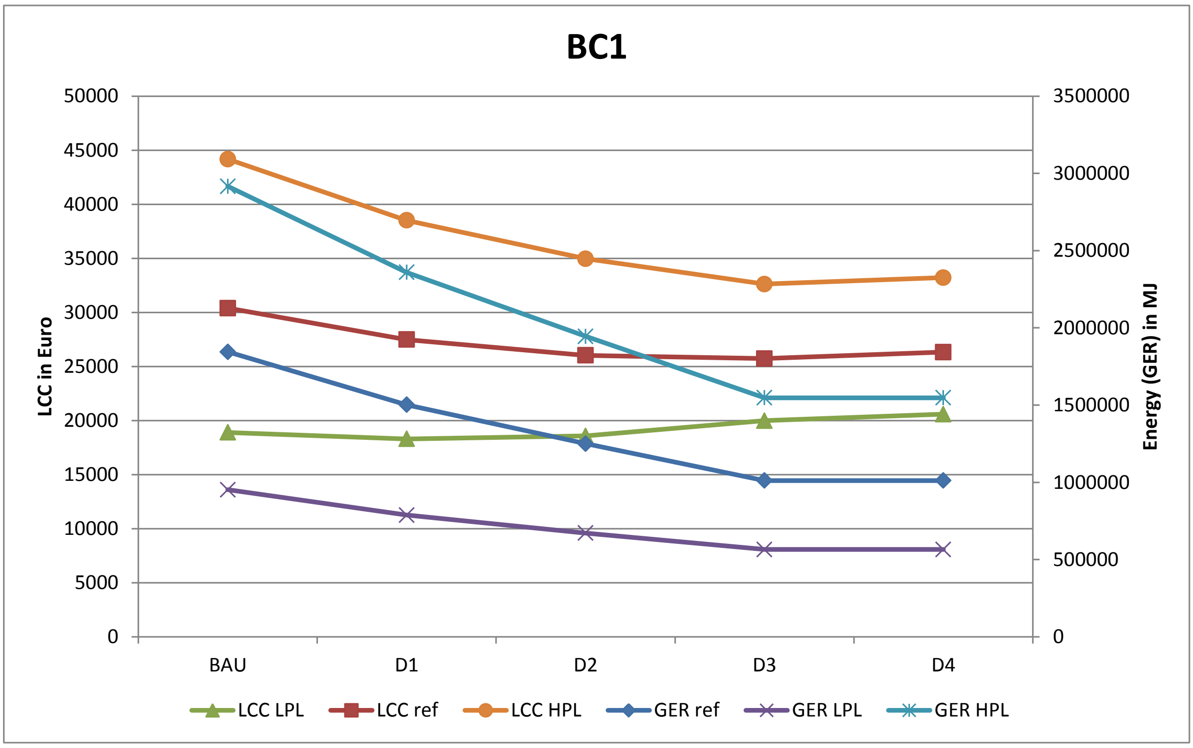


Figure 6-33 BC1 sensitivity to low, reference and high product lifetime

Table 6-45: Sensitivity data BC2

	Base Case Id		BC2				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	4035	7289	11193	-45%	+54%
D1	Total Energy (GER)	0	2948	4900	7243	-40%	+48%
D2	Total Energy (GER)	0	2540	3760	5225	-32%	+39%
D3	Total Energy (GER)	0	2537	3351	4327	-24%	+29%
D4	Total Energy (GER)	MJ	3079	4706	6658	-35%	+41%
BAU	LCC	€	187	229	279	-18%	+22%
D1	LCC	€	213	238	268	-11%	+13%
D2	LCC	€	262	278	297	-6%	+7%
D3	LCC	€	351	361	374	-3%	+3%
D4	LCC	€	311	332	357	-6%	+8%
GER	D1 compared to BAU		-27%	-33%	-35%		
	D2 compared to BAU		-37%	-48%	-53%		
	D3 compared to BAU		-37%	-54%	-61%		
	D4 compared to BAU		-24%	-35%	-41%		
LCC	D1 compared to BAU		+14%	+4%	-4%		
	D2 compared to BAU		+40%	+22%	+6%		
	D3 compared to BAU		+88%	+58%	+34%		
	D4 compared to BAU		+66%	+45%	+28%		

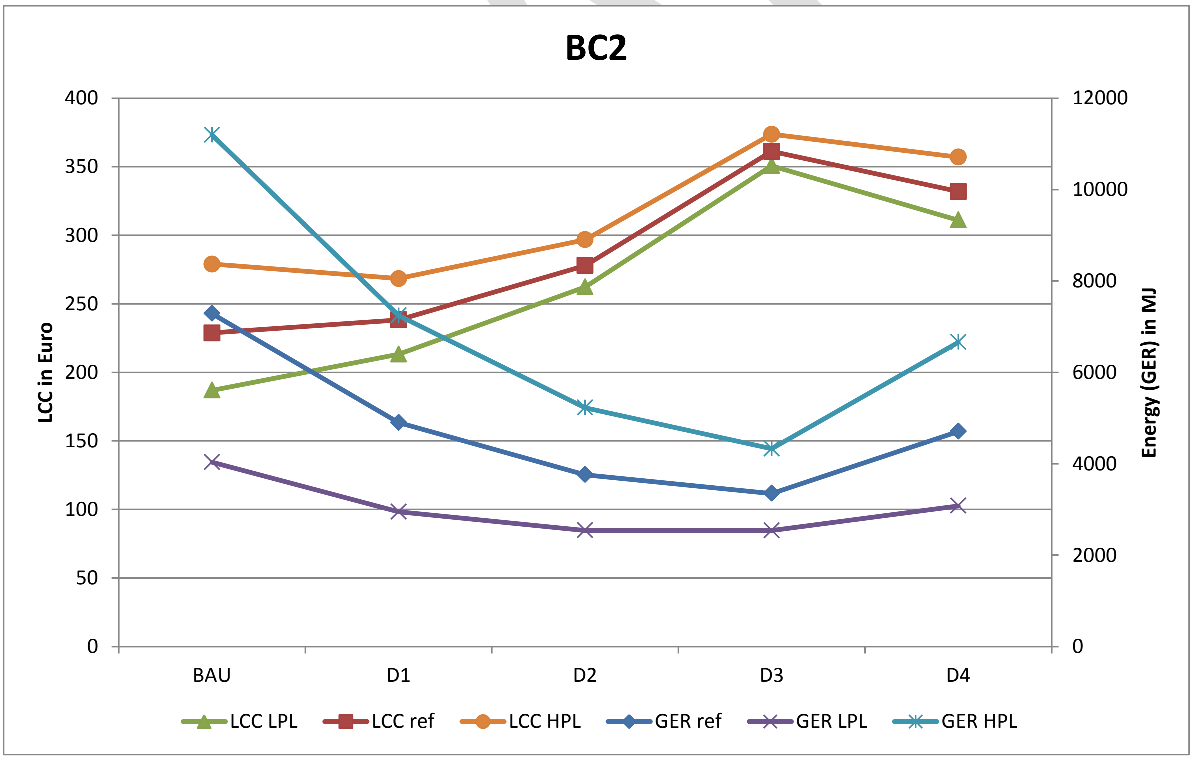


Figure 6-34 BC2 sensitivity to low, reference and high product lifetime

Table 6-46: Sensitivity data BC3

	Base Case Id		BC3				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	3493	5803	8574	-40%	+48%
D1	Total Energy (GER)	0	3020	4464	6196	-32%	+39%
D2	Total Energy (GER)	0	3028	3990	5145	-24%	+29%
D3	Total Energy (GER)	0	3590	4168	4860	-14%	+17%
D4	Total Energy (GER)	MJ	3411	4566	5951	-25%	+30%
BAU	LCC	€	215	245	281	-12%	+15%
D1	LCC	€	267	286	308	-7%	+8%
D2	LCC	€	360	372	387	-3%	+4%
D3	LCC	€	480	487	496	-2%	+2%
D4	LCC	€	386	401	419	-4%	+4%
GER	D1 compared to BAU		-14%	-23%	-28%		
	D2 compared to BAU		-13%	-31%	-40%		
	D3 compared to BAU		+3%	-28%	-43%		
	D4 compared to BAU		-2%	-21%	-31%		
LCC	D1 compared to BAU		+24%	+17%	+10%		
	D2 compared to BAU		+67%	+52%	+38%		
	D3 compared to BAU		+123%	+99%	+77%		
	D4 compared to BAU		+79%	+64%	+49%		

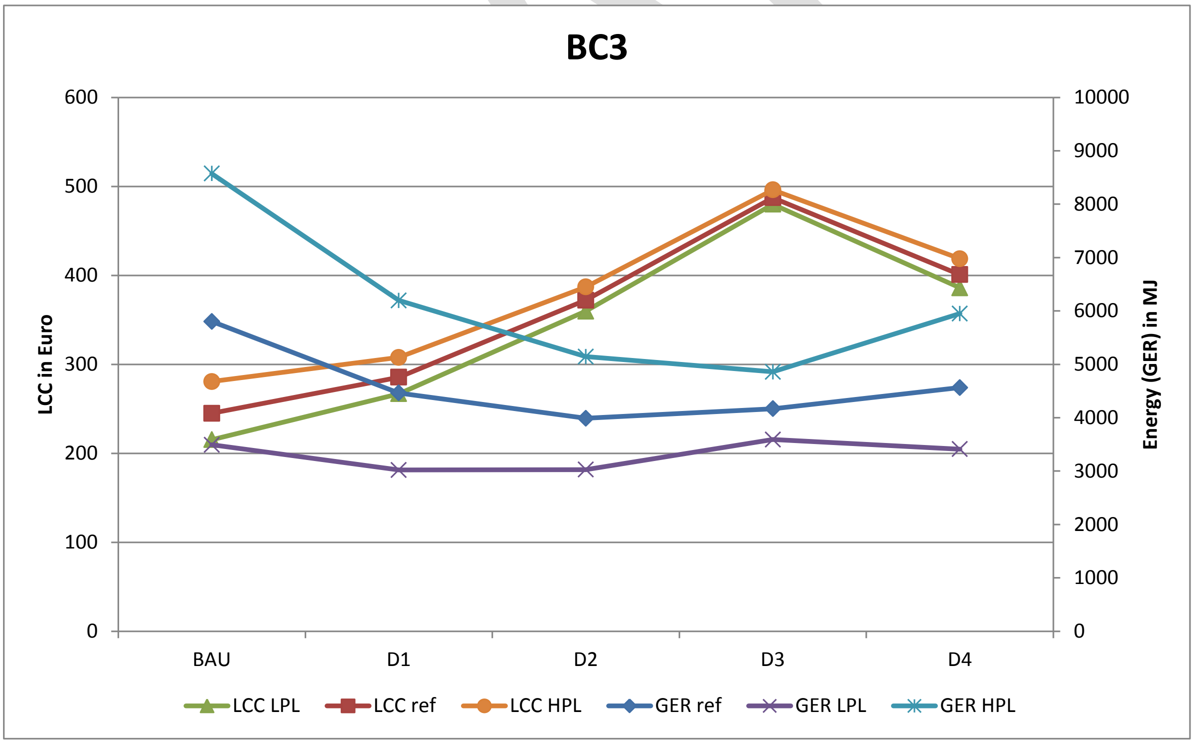


Figure 6-35 BC3 sensitivity to low, reference and high product lifetime

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Table 6-47: Sensitivity data BC4

	Base Case Id		BC4				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	225406	447921	714939	-50%	+60%
D1	Total Energy (GER)	0	143260	282332	449219	-49%	+59%
D2	Total Energy (GER)	0	95282	184289	291096	-48%	+58%
D3	Total Energy (GER)	0	71941	135517	211808	-47%	+56%
D4	Total Energy (GER)	MJ	116928	228186	361695	-49%	+59%
BAU	LCC	€	3255	6117	9553	-47%	+56%
D1	LCC	€	2352	4141	6288	-43%	+52%
D2	LCC	€	1959	3104	4478	-37%	+44%
D3	LCC	€	1926	2744	3725	-30%	+36%
D4	LCC	€	2215	3646	5364	-39%	+47%
GER	D1 compared to BAU		-36%	-37%	-37%		
	D2 compared to BAU		-58%	-59%	-59%		
	D3 compared to BAU		-68%	-70%	-70%		
	D4 compared to BAU		-48%	-49%	-49%		
LCC	D1 compared to BAU		-28%	-32%	-34%		
	D2 compared to BAU		-40%	-49%	-53%		
	D3 compared to BAU		-41%	-55%	-61%		
	D4 compared to BAU		-32%	-40%	-44%		

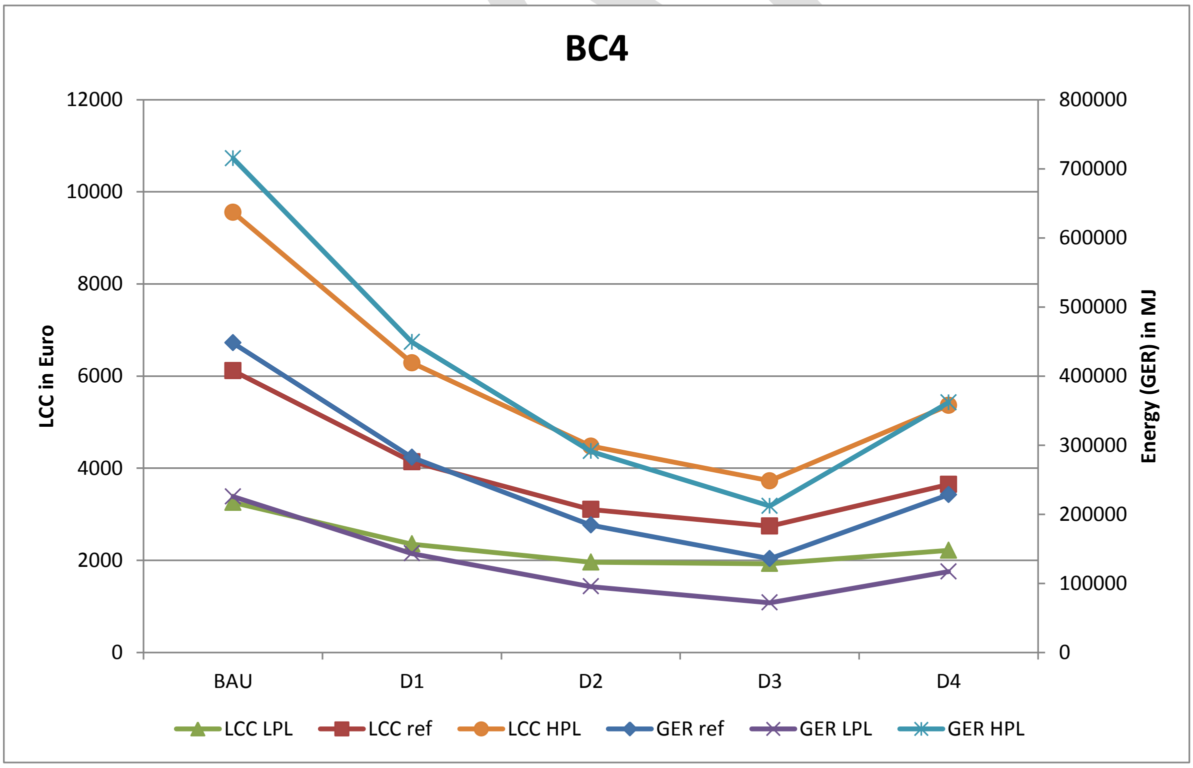

Figure 6-36 BC4 sensitivity to low, reference and high product lifetime

Table 6-48: Sensitivity data BC5

	Base Case Id		BC5				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	3921608	7509255	11814432	-48%	+57%
D1	Total Energy (GER)	0	3125188	5815923	9044806	-46%	+56%
D2	Total Energy (GER)	0	2647705	4800293	7383399	-45%	+54%
D3	Total Energy (GER)	0	2328487	4036890	6086974	-42%	+51%
D4	Total Energy (GER)	MJ	2461634	4255457	6408046	-42%	+51%
BAU	LCC	€	87965	134122	189510	-34%	+41%
D1	LCC	€	89880	124498	166039	-28%	+33%
D2	LCC	€	97645	125339	158572	-22%	+27%
D3	LCC	€	110047	132027	158402	-17%	+20%
D4	LCC	€	106695	129773	157467	-18%	+21%
GER	D1 compared to BAU		-20%	-23%	-23%		
	D2 compared to BAU		-32%	-36%	-38%		
	D3 compared to BAU		-41%	-46%	-48%		
	D4 compared to BAU		-37%	-43%	-46%		
LCC	D1 compared to BAU		+2%	-7%	-12%		
	D2 compared to BAU		+11%	-7%	-16%		
	D3 compared to BAU		+25%	-2%	-16%		
	D4 compared to BAU		+21%	-3%	-17%		

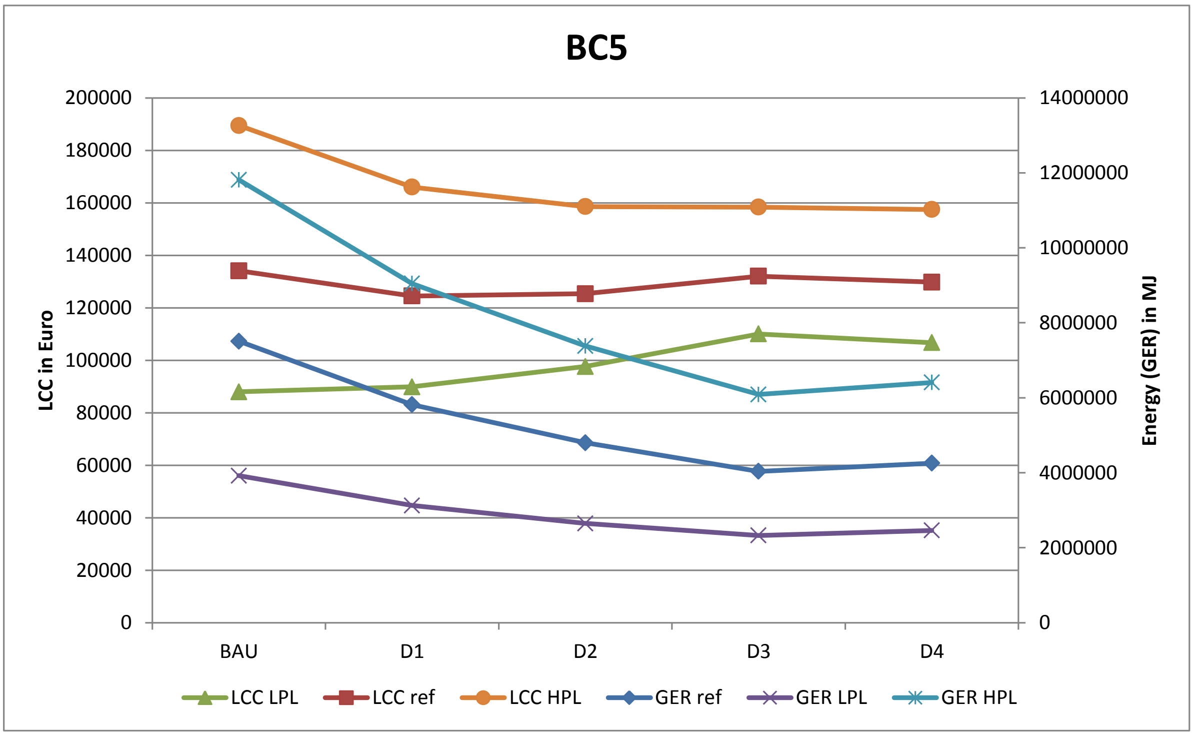

Figure 6-37 BC5 sensitivity to low, reference and high product lifetime

Table 6-49: Sensitivity data BC6

	Base Case Id		BC6				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	3921608	14563	22611	26828%	+55%
D1	Total Energy (GER)	0	3125188	9530	14359	32692%	+51%
D2	Total Energy (GER)	0	2647705	7015	10033	37642%	+43%
D3	Total Energy (GER)	0	2328487	5964	7976	38943%	+34%
D4	Total Energy (GER)	MJ	2461634	8896	12920	27570%	+45%
BAU	LCC	€	87965	369	472	23767%	+28%
D1	LCC	€	89880	362	424	24726%	+17%
D2	LCC	€	97645	408	446	23855%	+10%
D3	LCC	€	110047	520	546	21070%	+5%
D4	LCC	€	106695	478	530	22208%	+11%
GER	D1 compared to BAU		-20%	-35%	-36%		
	D2 compared to BAU		-32%	-52%	-56%		
	D3 compared to BAU		-41%	-59%	-65%		
	D4 compared to BAU		-37%	-39%	-43%		
LCC	D1 compared to BAU		+2%	-2%	-10%		
	D2 compared to BAU		+11%	+11%	-5%		
	D3 compared to BAU		+25%	+41%	+16%		
	D4 compared to BAU		+21%	+30%	+12%		

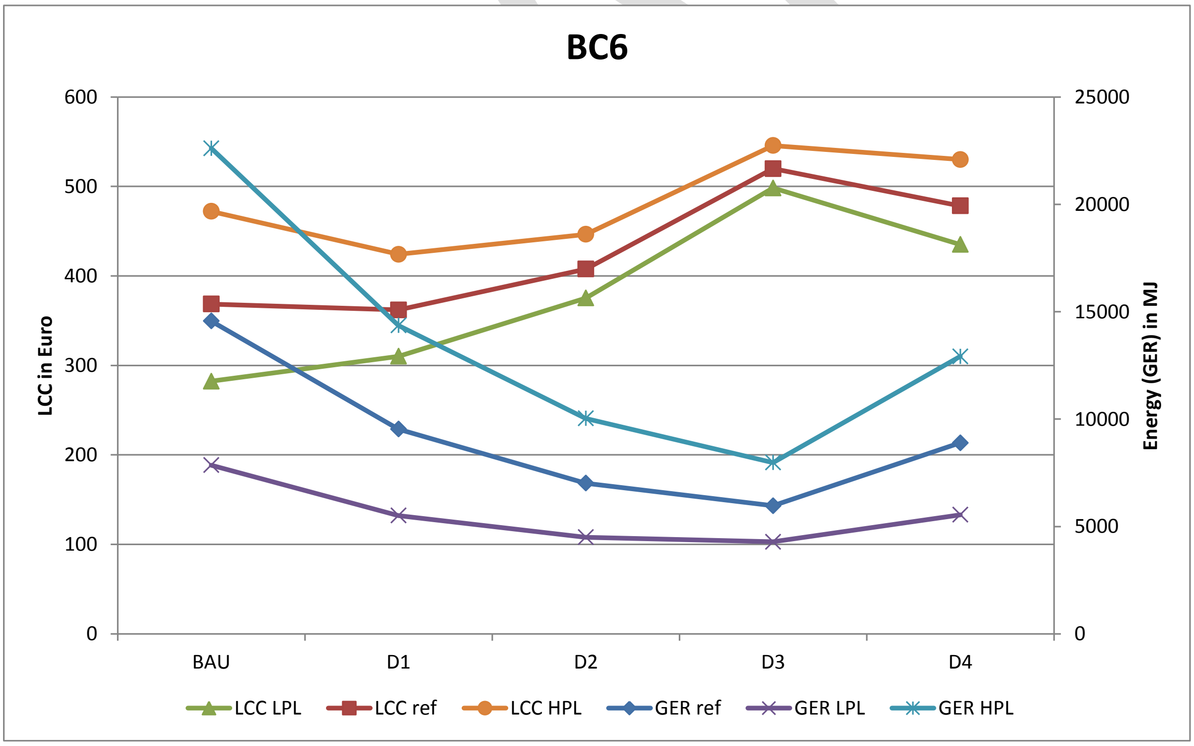

Figure 6-38 BC6 sensitivity to low, reference and high product lifetime

Table 6-50: Sensitivity data BC7

	Base Case Id		BC7				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	9945	18316	28361	-46%	+55%
D1	Total Energy (GER)	0	7342	12574	18852	-42%	+50%
D2	Total Energy (GER)	0	6265	9753	13939	-36%	+43%
D3	Total Energy (GER)	0	6162	8255	10767	-25%	+30%
D4	Total Energy (GER)	MJ	7223	11408	16431	-37%	+44%
BAU	LCC	€	324	432	561	-25%	+30%
D1	LCC	€	362	430	511	-16%	+19%
D2	LCC	€	462	507	561	-9%	+11%
D3	LCC	€	608	635	667	-4%	+5%
D4	LCC	€	487	540	605	-10%	+12%
GER	D1 compared to BAU		-26%	-31%	-34%		
	D2 compared to BAU		-37%	-47%	-51%		
	D3 compared to BAU		-38%	-55%	-62%		
	D4 compared to BAU		-27%	-38%	-42%		
LCC	D1 compared to BAU		+12%	-0%	-9%		
	D2 compared to BAU		+43%	+17%	-0%		
	D3 compared to BAU		+88%	+47%	+19%		
	D4 compared to BAU		+50%	+25%	+8%		

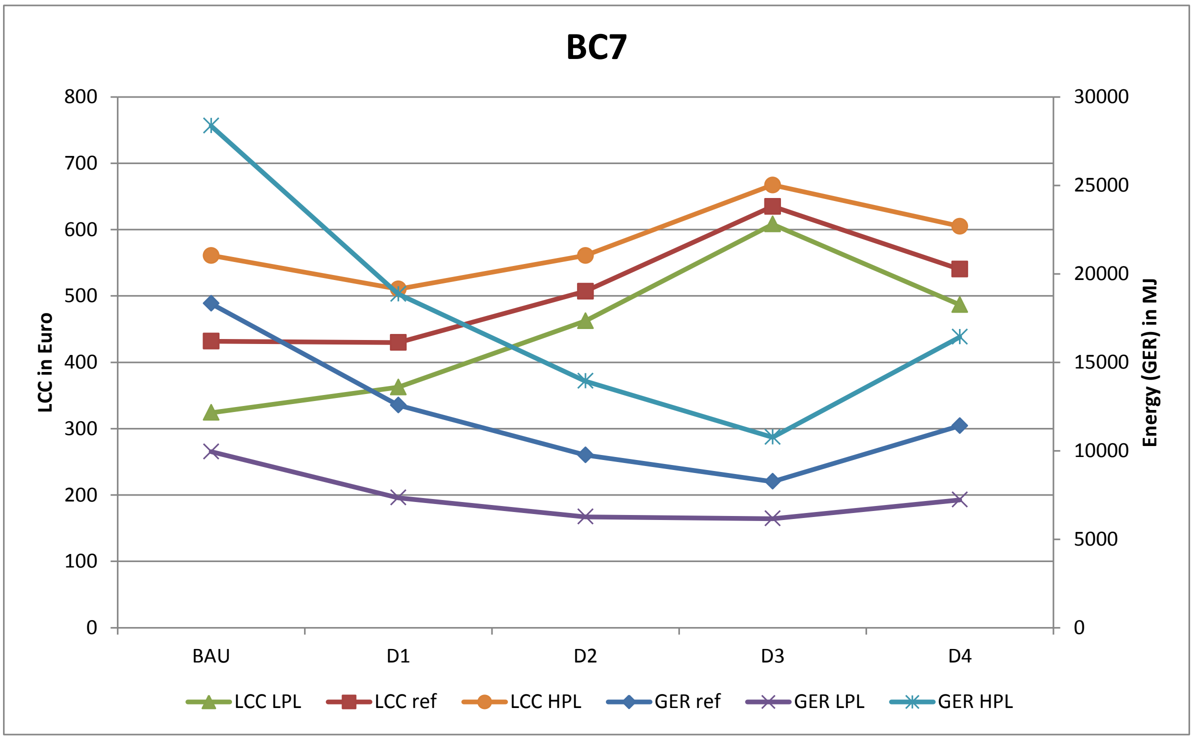

Figure 6-39 BC7 sensitivity to low, reference and high product lifetime

Table 6-51: Sensitivity data BC8

	Base Case Id		BC8				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	977584	1943151	3101831	-50%	+60%
D1	Total Energy (GER)	0	692058	1367955	2179031	-49%	+59%
D2	Total Energy (GER)	0	505677	988460	1567801	-49%	+59%
D3	Total Energy (GER)	0	387162	742897	1169779	-48%	+57%
D4	Total Energy (GER)	MJ	506707	989490	1568831	-49%	+59%
BAU	LCC	€	14096	26519	41426	-47%	+56%
D1	LCC	€	10953	19649	30083	-44%	+53%
D2	LCC	€	9327	15538	22992	-40%	+48%
D3	LCC	€	8748	13325	18817	-34%	+41%
D4	LCC	€	9559	15770	23224	-39%	+47%
GER	D1 compared to BAU		-29%	-30%	-30%		
	D2 compared to BAU		-48%	-49%	-49%		
	D3 compared to BAU		-60%	-62%	-62%		
	D4 compared to BAU		-48%	-49%	-49%		
LCC	D1 compared to BAU		-22%	-26%	-27%		
	D2 compared to BAU		-34%	-41%	-44%		
	D3 compared to BAU		-38%	-50%	-55%		
	D4 compared to BAU		-32%	-41%	-44%		

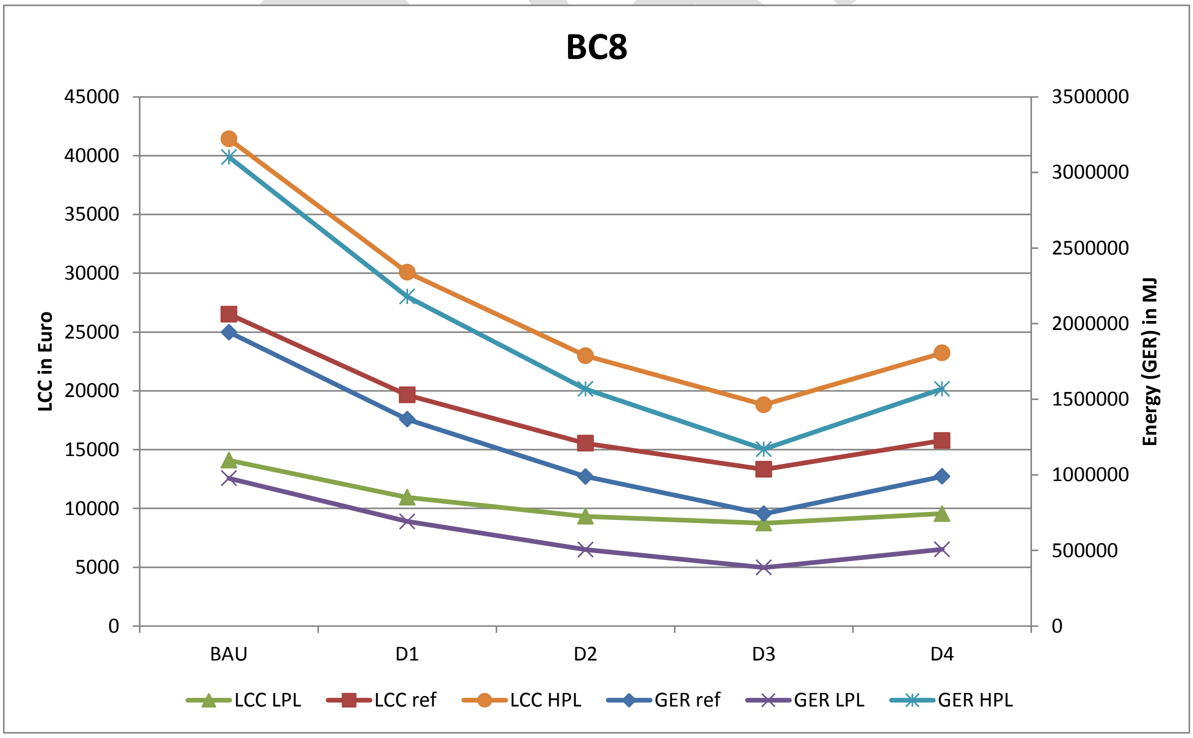

Figure 6-40 BC8 sensitivity to low, reference and high product lifetime

Table 6-52: Sensitivity data BC9

	Base Case Id		BC9				
		Unit	LPL	Ref	HPL	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	781194	1547287	2466600	-50%	+59%
D1	Total Energy (GER)	0	583607	1148097	1825485	-49%	+59%
D2	Total Energy (GER)	0	471683	918571	1454837	-49%	+58%
D3	Total Energy (GER)	0	387119	744630	1173642	-48%	+58%
D4	Total Energy (GER)	MJ	413136	796183	1255839	-48%	+58%
BAU	LCC	€	11834	21690	33518	-45%	+55%
D1	LCC	€	9896	17158	25873	-42%	+51%
D2	LCC	€	9015	14765	21664	-39%	+47%
D3	LCC	€	8566	13166	18685	-35%	+42%
D4	LCC	€	8884	13812	19726	-36%	+43%
GER	D1 compared to BAU		-25%	-26%	-26%		
	D2 compared to BAU		-40%	-41%	-41%		
	D3 compared to BAU		-50%	-52%	-52%		
	D4 compared to BAU		-47%	-49%	-49%		
LCC	D1 compared to BAU		-16%	-21%	-23%		
	D2 compared to BAU		-24%	-32%	-35%		
	D3 compared to BAU		-28%	-39%	-44%		
	D4 compared to BAU		-25%	-36%	-41%		

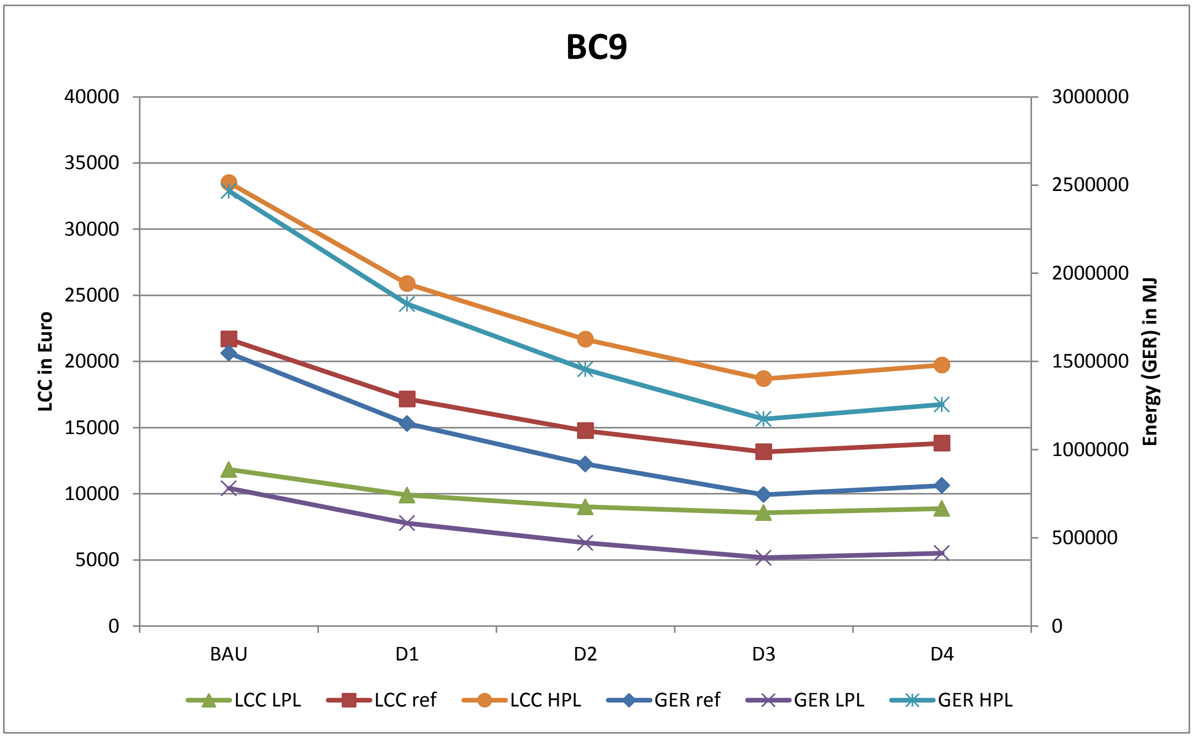

Figure 6-41 BC9 sensitivity to low, reference and high product lifetime

Conclusion:
Table 6-53 summarizes the sensitivity to product lifetime in terms of design options shifts. In case of BAT design option D3 stays the best option for low, ref and high values, except for BC3. In case of BC3, a longer product life will justify a shift from D2 to D3 design option, meaning the lesser electricity consumption in the use phase can compensate the higher energy usage at the production and distribution.

Having a smaller lifetime will make it more difficult to compensate the investment costs by the gains made during the use phase due to the lesser electricity consumption. Overall it appears that lengthening the product lifetime is favourable for the LCC of more costly design options, as to be expected.

Table 6-53: Design option sensitivity to product lifetime

	BAT - lifetime sensitivity			LLCC - lifetime sensitivity		
	low	ref	high	low	ref	high
BC1	D3	D3	D3	D1	D3	D3
BC2	D3	D3	D3	BAU	BAU	D1
BC3	D1	D2	D3	BAU	BAU	BAU
BC4	D3	D3	D3	D3	D3	D3
BC5	D3	D3	D3	BAU	D1	D4
BC6	D3	D3	D3	BAU	D1	D1
BC7	D3	D3	D3	BAU	D1	D1
BC8	D3	D3	D3	D3	D3	D3
BC9	D3	D3	D3	D3	D3	D3