Preparatory study for Kettles implementing the Ecodesign Working Plan 2016-2019

Task 6: Design options (final draft)

Request for services N° ENER/C4/FV 2019-467/06/FWC 2015-619 LOT1/05 in the context of the Framework Contract N° ENER/C3/2015-619 Lot 1

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ABOUT THIS DOCUMENT

07.12.2020 - Draft: Task 6 draft for stakeholder consultation based on a consultation document with data and assumptions presented and commented by stakeholders (THIS DOCUMENT)

Please be aware that this draft consultation document is only published for receiving stakeholder comments to the Ecodesign Process. It may still undergo substantial revisions prior to being released as a final report of this study.

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LIST OF ABBREVIATIONS AND ACRONYMS

BAT	Best available technologies
BNAT	Best not-yet available technologies
CO_2	Carbon dioxide
DD	Discount rate
EE	Compound growth rate
EOL	End of life
kWh	kilowatt hour
kWh/a	kilowatt hour per year
LCC	Life cycle costs
LLCC	Least life cycle costs
LED	Light emitting diode
MEErP	Methodology for Ecodesign of Energy-related Products
NPV	Net present value
NN	Product lifetime
OE	Operating expense
PM	Particulate matter
PP	Purchase price
PWF	Present worth factor
SO_2	Sulfur dioxide
VOC	Volatile organic compounds

6. TASK 6: DESIGN OPTIONS

The base cases described in the previous tasks serve as baselines for the assessment of improvement potentials from the use of Best Available Technologies (BAT) or Best Not-yet Available Technologies (BNAT). These potentials are to be analysed using so-called “design options”, i.e. (aggregated clusters of) design measures to increase the performance of electric kettles.

The aim of this task is to identify and describe these options, to assess their quantitative impact on the environmental performance of kettles, to analyse their economic performance and to determine Least Life Cycle Costs (LLCC). For this purpose, this task relies on the calculation models established in the preceding tasks, in particular Task 5, and complements them, where necessary.

6.1. Subtask 6.1 - Design options

The aim of this subtask is to identify and describe the design options that can improve the environmental performance of kettles. According to the underlying methodology[1], typically 4 to 8 design options are considered as a manageable number of design options for Ecodesign preparatory studies. The impact of these individual design options may vary depending on previously implemented ones. An improved sensor, for example, that precisely stops boiling at a selected target temperature may reduce the electricity consumption for boiling the water on the one hand. On the other hand, a water level indicator may cause a user to reduce the amount of excessive water boiled in the kettle. Simply adding up the individual impact of both options will lead to an overestimation of their impact. In this first part of the report, a perspective is taken that considers the design options individually, i.e. independent of each other. In the second part starting from section 6.4, the interaction of the design options is then taken into account.

Table 6-1 provides an overview of the six design options applied to the three base cases of kettles in this study. Not all design options are relevant for all of the base cases. Whether a design option is relevant for a particular base case is indicated in the table by an ‘X’. The design options are based on the technological analysis carried out in the previous tasks, especially Tasks 4 and 5. They can be described as follows:

1. **Water level indicator**: This design options deals with two different measures concerning water level indicators of electric water kettles. Both of them aim to reduce "over boiling", i.e. a situation where the user boils more water that is actually needed for consumption (see also Task 3). The option includes an enlarged of the water level indicator down to a lower minimum volume (e.g. 0.25 litres). In addition to the information in litres, alternative scales for highly intuitive use are covered by this design options, e.g. indicating the filling level in cups.

2. **Heating element**: By this design option, conventional heating elements like immersed or underfloor heating elements are replaced by thick film heating elements. Thick film heating elements operate with a higher efficiency since the have a higher energy density and lower thermal losses, which particularly affects performance in case of low filling levels.

3. **Sensor and controller**: According to the testing procedure described within IEC 60530:1975, electric water kettles shall increase temperature by 80K to a target temperature of 95°C. However, measurements and data from stakeholders show an "over heating" of kettles, i.e. a situation where kettles keep on boiling water beyond 95°C, thus causing additional electricity demand. This design option aims to reduce the time between reaching 95°C (fulfilling standard) and the automatic shut off the kettle. To do so, this design option uses sensor and controller units with higher accuracy.

4. **Insulation of the container**: This design option addresses the container insulation of electric water kettles. According to this design option, containers are equipped with a double shell and a layer of air in between. The focus of this design option is neither on the heating phase nor material substitution (dealt within Task 5), but if reduces heat losses during the cooling phase, i.e. after boiling, and therefore reduces energy consumption, in particular but not limited to keep warm features.

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[1] Kemna R. (2011): Methodology for Ecodesign of Energy-related Products, MEErP 2011, 704 Methodology report, Part 1, methods.

5. **Pre-set temperature**: In some usage scenarios, e.g. brewing teas, temperatures of 95°C are not required. This design option allows users to select temperature levels below 95°C, which results in energy savings.

6. **Keep-warm function:** There is currently no standard or regulation that limits the use of the keep warm function. By setting a maximum duration for keep-warm to 30 minutes, kettles, extensive re-heating of boiled water is avoided.

These design options can be viewed with regard to their impact on heating water, i.e. the boiling phase, and by their effect during the keep warm phase, where relevant. The right part of Table 6-1 shows the upper limits for the expected savings in both phases. These values are based on available documents, additional assumptions and following discussions with stakeholders during the second stakeholder meeting. The specific impact of the design options on energy demand of the specific base cases is provided in Table 6-2 in the next section.

Table 6-1: Overview of the design options and their relevance for the base cases.

		Applies to			Changes energy consumption during	
		Base case 1	**Base case 2**	**Base case 3**	**boiling by up to**	**keep warm by up to**
1	Water level indicator	X	X	X	-10 %	-10 %
2	Heating element	X	X	X	-8 %	-8 %
3	Sensor and controller	X	X	X	-5 %	-5 %
4	Insulation of the container	X	X	X	-1,5 %	-50 %
5	Pre-set temperature		X		-3,5 %	0 %
6	Keep-warm function			X	0 %	-50 %

6.2. Subtask 6.2 - Impacts of the design options

The aim of this subtask is to describe the impacts of the six design options on the environmental performance of the base cases. It should be noted that this analysis is done from a perspective where the design options are directly integrated into new kettles, not from an add-on perspective to existing ones.

6.2.1. Impact on Energy demand

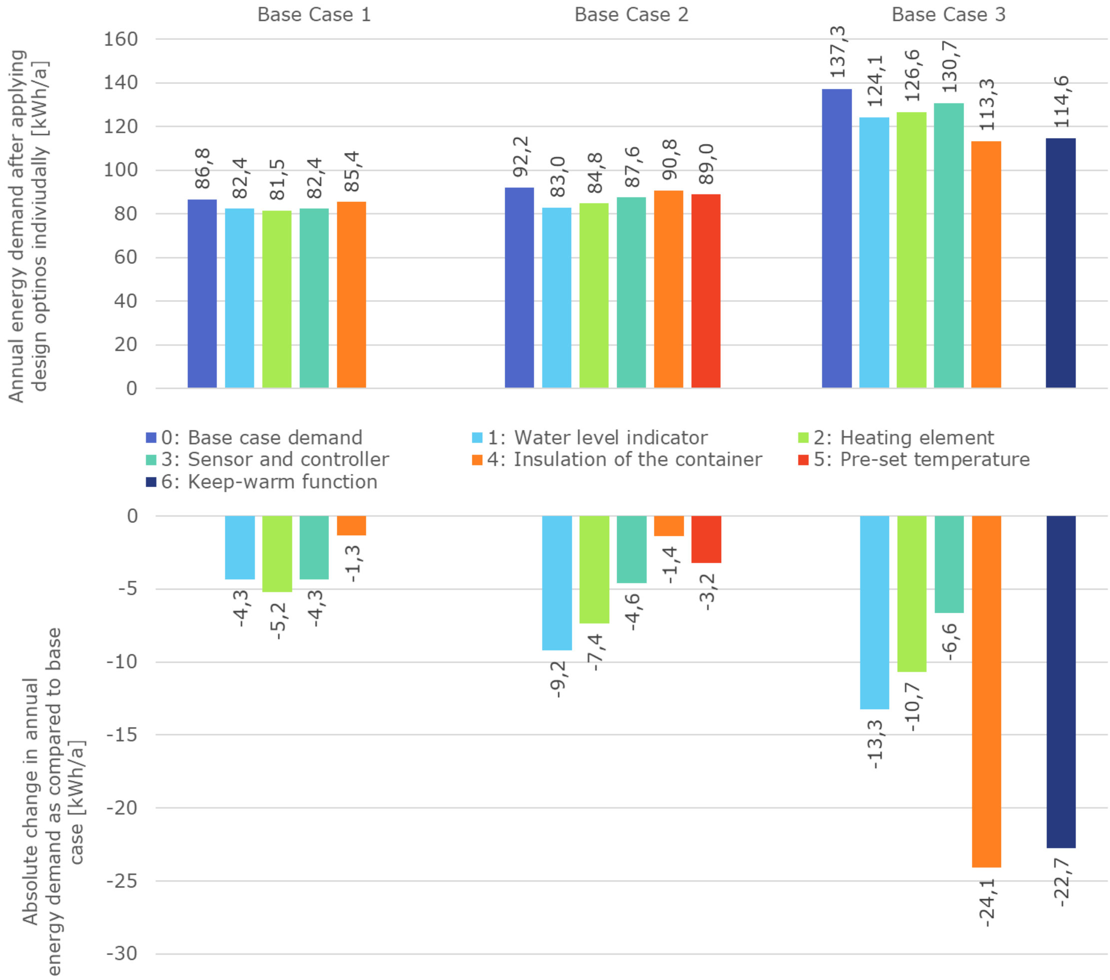
To determine the impact of the design options on energy demand and costs, information on their environmental impact and costs is needed. Table 6-2 gives an overview on the annual electricity consumption of the base cases and the assumed relative impact of the various design options on it.

Table 6-2: Annual direct energy demand of the base case kettles based on Task 5 and assumptions on relative changes due to the implementation of individual design options

		Base case 1	**Base case 2**	**Base case 3**
0	Base case demand	86,8 kWh/a	92,2 kWh/a	137,3 kWh/a
1	Water level indicator	-5,0%	-10,0%	-9,7%
2	Heating element	-6,0%	-8,0%	-7,8%
3	Sensor and controller	-5,0%	-5,0%	-4,8%
4	Insulation of the container	-1,5%	-1,5%	-17,5%
5	Pre-set temperature		-3,5%	
6	Keep-warm function			-16,5%

Figure 6-1 visualizes the impact on the annual overall electricity demand of the base cases (upper part) and the savings in absolute terms as compared to the base case (lower part).

Figure 6-1: Impact on annual energy demand when applying the design options individually (upper part: annual energy consumption; lower part: difference as compared to the respective base case).



6.2.2. Impact on other environmental parameters

Next to the assessment on energy demand, the MEErP methodology also requires an analysis of the impact of the design options on other environmental impact parameters. Changes should be reported if substantial impacts occur due to the design options.

Since some of the design options change the physical setup of the kettles, they affect the input to the bill of materials. Table 6-3 shows the changes associated with the implementation of the design options within this study. As shown in Task 5, the material input only plays a rather small role for most of the environmental indicators. A detailed overview of the combined impact of the changes in the bill of materials combined with the impact of reduced energy consumption can be found in the Annex A (section 6.6) of this report. Across all indicators, the performance values remain unchanged or they are improved, i.e. the environmental impact of the kettles is regularly reduced. This means that any potentially worse performance by using additional material is overcompensated by the additional improvements due to reduced electricity demand.

Table 6-3: Modification to the bill of materials due to the design options (minus indicates a reduction in usage; plus signs indicate an increase)

		Base case 1	Base case 2	Base case 3
1	Water level indicator	None	None	None
2	Heating element	-47g stainless steel	-105g stainless steel	-105g stainless steel
3	Sensor and controller	None	None	None
4	Insulation of the container	+90g plastic	+129g plastic	+129g plastic
5	Pre-set temperature		+7g stainless steel +2.5g cooper +0.8g aluminium +0.08g tin +10.5g polypropylene +2.3g polyvinyl chloride +4.9g high density poly ethylene +1.4g silicone +0.0022g Silver	
6	Keep-warm function			None

6.3. Subtask 6.3 - Costs

The aim of this subtask is to estimate the price increase due to the implementation of the options and to derive conclusions on their impact on the life cycle costs of kettles. According to the MEErP methodology, this analysis should either be carried out based on an assessment of the market prices of the products, i.e. kettles, and/or by applying a production cost model with sector-specific margins. Here, the market price approach has been chosen since it allows a more direct analysis on the life cycle costs from a user perspective.

To enhance the accessibility of the underlying calculation and their results, an overview of the life cycle model is given first which is underlying the calculations in Task 5, as well. This model from the MEErP distinguishes two different perspective for the life cycle costs: the user and the societal perspective. Preparatory studies are required to assess both types.

The basic equation to determine the life cycle costs from the user perspective (LCC in Euro) covers the following elements: the purchase price (PP in Euro), the annual operating expense (OE in Euro), the dimensionless present worth factor (PWF) and the end-of-life costs (disposal, recycling) or benefits (resale) (EOL in Euro) as follows:

$$\mathrm{LCC} = \mathrm{PP} + \mathrm{PWF} \cdot \mathrm{OE} + \mathrm{EOL}$$

Note, that while the annual operating expense is discounted to the present year, the end-of-life costs are not. This is explained by the experience that disposal costs for many products are already covered during acquisition. The present worth factor, in turn, is calculated using the product lifetime (NN in years) and the discount rate (DD). Furthermore, price increases in operating expenses can be taken into account by DD as an escalation rate expressed as a percentage. Based on this, the calculation of the present worth factor can be written as:

$$\mathrm{PWF} = 1 - \frac{(1+\mathrm{EE})}{(1+\mathrm{DD})} \cdot \left(1 - \left(\frac{1+\mathrm{EE}}{1+\mathrm{DD}}\right)^{\mathrm{NN}}\right)$$

If several different price increases are to be assessed together (e.g. one rate for external damage, one rate for energy costs and one rate for maintenance), they should be aggregated into one compound growth rate (EE) by considering their respective shares in the overall annual costs. In case the discount rate and the overall annual price increases are identical, the previous equation simplifies to the lifetime of the product:

$$\mathrm{PWF} = \mathrm{NN}$$

In the MEErP methodology, it has been argued that the discount rate, the external damage escalation rate and the energy growth rate were all of the order of 3 to 4 % at the time of preparing the MEErP methodology. **We considered a unique rate of 4 %** for the analysis of life cycle costs, allowing for the previous simplification.

Beyond the life cycle costs from the user perspective, societal life cycle costs need to be calculated, as well. These include the costs for external damages of air emissions ($\widetilde{LCC}$) based on a given list of fixed prices as given in Table 6-4. These values are to be multiplied by the total mass of emissions from the EcoReport 2011 and have to be added to the life cycle costs from the user perspective in the respective phases.

Table 6-4: Summary of monetary values attributed to emissions to the air based on the MEErP methodology (source: MEErP methodology)

Emissions	Euro/kg
Global warming potential in CO_2-eq.	0.014
Acidification potential in SO_2-eq.	16.00
Volatile organic compounds VOC	2.80
Particulate matter PM10	37.50

For the kettles with their design options, estimates for increased product prices are indicated in Table 6-5. These values have been derived from available documented evidence and information gained from the stakeholder consultation. These in prices are made under the assumption that a broader utilization of the design options takes places, i.e. that economies of scale apply. Some options such as the water level indicator are rather simple changes in design and are expected to be (nearly) no cost measures.

Table 6-5: Estimates of the marginal prices of the design options by base case based on desk research and stakeholder feedback

		Base case 1	Base case 2	Base case 3
1	Water level indicator	Unchanged	Unchanged	Unchanged
2	Heating element	+3,50 Euro	+2,00 Euro	+2,00 Euro
3	Sensor and controller	+4,00 Euro	+ 4,00 Euro	Unchanged
4	Insulation of the container	+2,00 Euro	+3,00 Euro	+3,00 Euro
5	Pre-set temperature		+2,00 Euro	
6	Keep-warm function			Unchanged

Based on these inputs and the results of the energy and other environmental impacts analysis (section 6.2), the life cycle costs per design option is determined. Table 6-6 to Table 6-8 show the resulting life cycle costs for the different base cases. The category 'purchase' indicates the initial price of the kettles, 'operation (electricity)' covers the expenditures for energy demand and 'operation (non-electricity) incl. EOL' reflects the expenditures related to regular descaling of the kettles. From the results, it can be observed that all design options are cost-effective from a life cycle perspective, i.e. additional costs from the implementation of the design options are lower than the life cycle savings due to electricity costs if applied individually.

Table 6-6: Life cycle costs (in Euro) of the design options without considering interaction effects for base case 1 as net present value

		User perspective				Societal perspective
		Purchase	Operation (electricity)	Operating (non-electricity) incl. EOL	Life Cycle Cost	Life Cycle Cost
0	Base case	16	107	20	143	155
1	Water level indicator	16	102	20	138	149
2	Heating element	20	101	20	140	151
3	Sensor and controller	20	102	20	142	153
4	Insulation of the container	18	106	20	144	155

Table 6-7: Life cycle costs (in Euro) of the design options without considering interaction effects for base case 2 as net present value

		User perspective				Societal perspective
		Purchase	Operation (electricity)	Operating (non-electricity) incl. EOL	Life Cycle Cost	Life Cycle Cost
0	Base case	26	114	24	164	176
1	Water level indicator	26	103	24	152	164
2	Heating element	28	105	24	156	168
3	Sensor and controller	30	108	24	162	174
4	Insulation of the container	29	112	24	165	178
5	Pre-set temperature	28	110	24	162	174

Table 6-8: Life cycle costs (in Euro) of the design options without considering interaction effects for base case 3 as net present value

		User perspective				Societal perspective
		Purchase	Operation (electricity)	Operating (non-electricity) incl. EOL	Life Cycle Cost	Life Cycle Cost
0	Base case	62	170	25	257	276
1	Water level indicator	62	154	25	240	258
2	Heating element	64	157	25	246	263
3	Sensor and controller	62	162	25	249	267
4	Insulation of the container	65	140	25	230	246
6	Keep-warm function	62	142	25	229	245

6.4. Subtask 6.4 - Analysis of least life cycle costs and BAT

The aim of this subtask is to determine the least life cycle costs (LLCC) for each base case. The MEErP requires an analysis of the least life cycle costs across several steps both from a consumer as well as from a societal perspective.

6.4.1. Ranking of individual design options

For determining the least life cycle costs, the design options need to be sorted by their economic performance. For the sorting, the difference of the life cycle costs in the case where the design options are applied compared to a situation without any design option, i.e. the pure base case, is considered. This means that economically favourable measures are ranked higher than those that are economically less attractive. The (unaltered) base case always holds the first rank “zero”.

The results of this ranking under the consideration of interaction effects (one options affects the impact of another) is shown in Table 6-9. The results from the ranking analysis show identical results in ranking for the design options and the base cases.

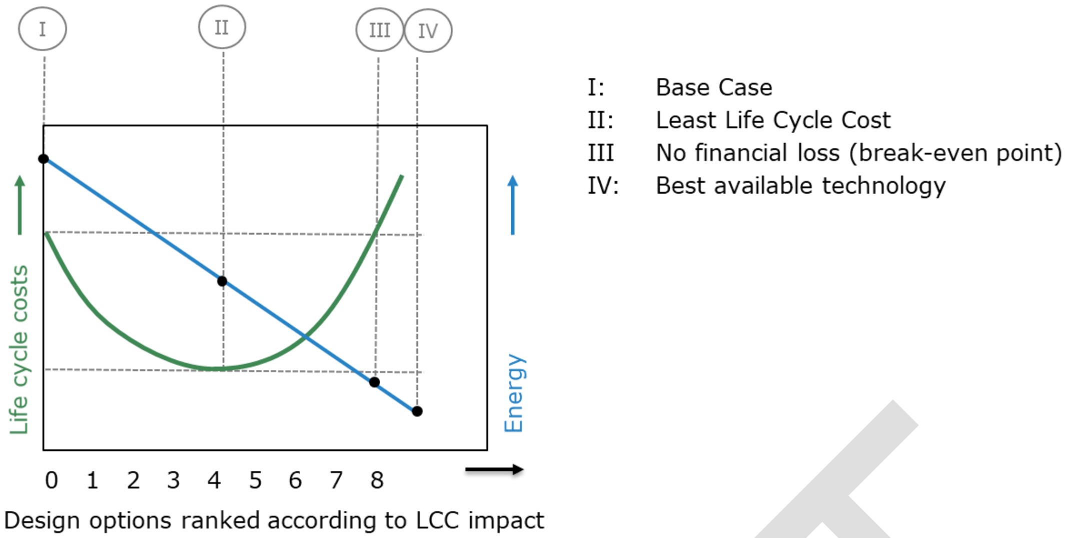
Table 6-9: Ranking of the design options for the different base cases when ordered by the change in the LCC as compared to the base case (both the ranking according to the user perspective and the societal perspective coincide)

		Base case 1	Base case 2	Base case 3
0	Base case	0	0	0
1	Water level indicator	1	1	3
2	Heating element	2	2	4
3	Sensor and controller	3	4	5
4	Insulation of the container	4	5	2
5	Pre-set temperature		3	
6	Keep-warm function			1

6.4.2. Estimation of the cumulative improvement and cost effect

Based on the previous ranking, the cumulative improvement potential and the effect on costs can to be calculated. For this purpose, a least life cycle cost (LCC) curve as shown in Figure 6-2 is needed. To the left of the figure (I), the life cycle costs of the base case are indicated. Then the interacting design options are added by their ranks. According to theory, some design options will reduce the overall life cycle costs while other will then start to increase the costs due to decreasing benefits after applying several design options. As a result, a least life cycle cost (II) will be obtained after applying various design options. Adding further design option will then decrease energy consumption further, but will add to the life cycle costs until a break-even point (III) with the base case situation is reached. At this point, energy consumption is thus lower “at the same life cycle price” as for the base case. Adding further measure to reduce the consumption could increase costs further (IV).

Figure 6-2: Illustration of the least life cycle curve



Following this concept, the life cycle curves for the three kettle base cases with their design options are shown in in Figure 6-3 to Figure 6-5. For improved visibility, vertical axes do not start at zero in all cases.

Figure 6-3: Least life cycle for base case 1 (user perspective)

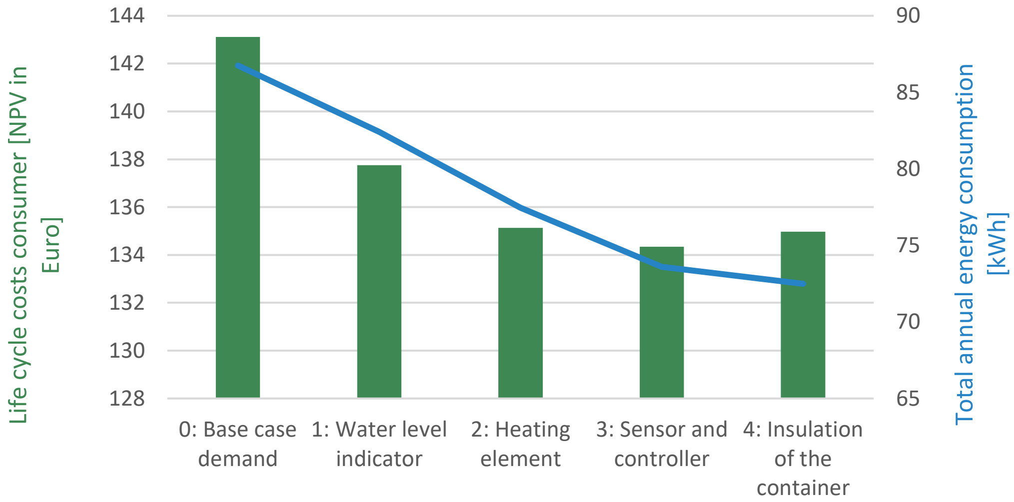


Figure 6-4: Least life cycle for base case 2 (user perspective)

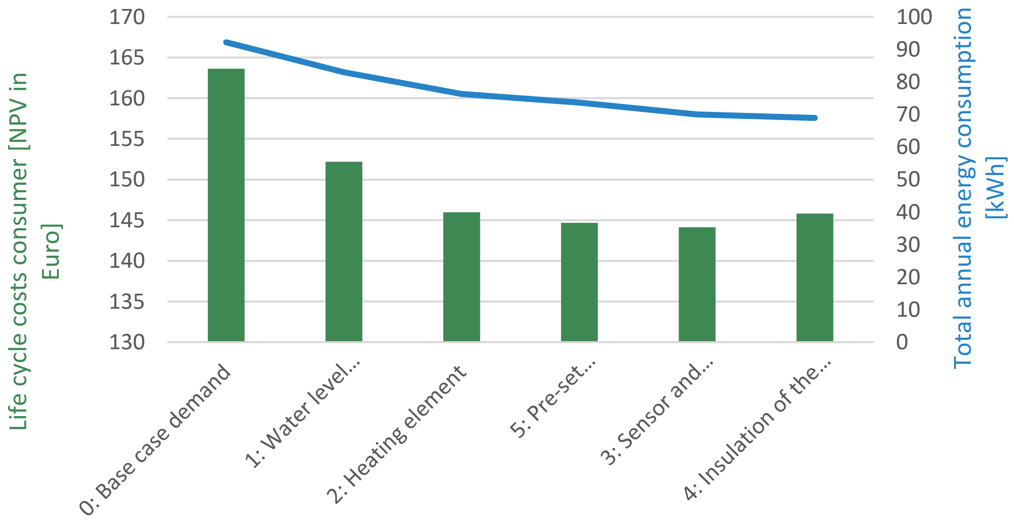
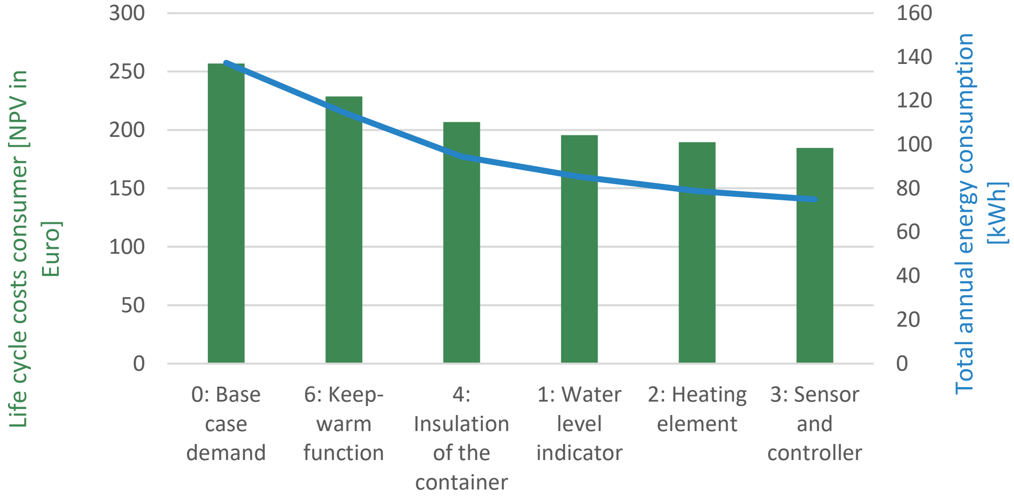


Figure 6-5: Least life cycle for base case 3 (user perspective)



Based on the visualization, these main conclusions follow:

- For base case 1, the least life cycle cost is achieved after applying the first three design options.
- For base case 2, the least life cycle costs is reached after the first four measures in ranking.
- For base case 3, all design options lead to a reduction in overall life cycle costs.
- All design options reduce the overall costs from the user perspective as compared to the base case and lead to additional savings in electricity demand.

The results in numeric terms with further details are given in Table 6-10 to Table 6-12.

Table 6-10: Energy demand and net present value for the ranked and successively combined design options considering interaction for base case 1 (user perspective)

		Annual energy consumption	Purchase price	Operation expense (energy)	Operating expense (non-energy) incl. EOL	Life Cycle Cost (Consumer)
		[kWh]	[Euro]	[Euro]	[Euro]	[Euro]
0	Base case demand	87	16	107	20	143
1	Water level indicator	82	16	102	20	138
2	Heating element	77	20	96	20	135
3	Sensor and controller	74	24	91	20	134
4	Insulation of the container	72	26	90	20	135

Table 6-11: Energy demand and net present value for the ranked and successively combined design options considering interaction for base case 2 (user perspective)

		Annual energy consumption	Purchase price	Operation expense (energy)	Operating expense (non-energy) incl. EOL	Life Cycle Cost (Consumer)
		[kWh]	[Euro]	[Euro]	[Euro]	[Euro]
0	Base case demand	92	26	114	24	164
1	Water level indicator	83	26	103	24	152
2	Heating element	76	28	94	24	146

5	Pre-set temperature	74	30	91	24	145
3	Sensor and controller	70	34	87	24	144
4	Insulation of the container	69	37	85	24	146

Table 6-12: Energy demand and net present value for the ranked and successively combined design options considering interaction for base case 3 (user perspective)

		Annual energy consumption	Purchase price	Operation expense (energy)	Operating expense (non-energy) incl. EOL	Life Cycle Cost (Consumer)
		[kWh]	[Euro]	[Euro]	[Euro]	[Euro]
0	Base case demand	137	62	170	25	257
6	Keep-warm function	115	62	142	25	229
4	Insulation of the container	95	65	117	25	207
1	Water level indicator	85	65	106	25	196
2	Heating element	79	67	97	25	189
3	Sensor and controller	75	67	93	25	185

6.4.3. Possible positive or negative side effects of the individual options

Design options could have additional positive or negative side effects beyond the direct effects captured in the life cycle analysis. The MEErP methodology requires an assessment and discussion of these effects.

The impact of the design options of life cycle costs on electricity demand, environmental performance and costs is already covered by the previous steps. Major areas of potential impacts could related to the durability of the products or user behaviour. No particular side effects have been identified for the design options, yet the following items should be mentioned:

- Concerning design option 3 'sensor and controller', one stakeholder pointed out that users might perceive a kettle as defective if there is no 'bubbling sound' when boiling. Experience from kettle testing indicates, however, that kettles emit noise well below the 95°C threshold. As a positive side effect of the earlier switch-off from the user perspective, the time for 'completing boiling' decreases. In addition, the calcification process is not linear, so that heating water to 95°C instead of the physical boiling point will reduce the formation of limescale deposit.

- In case of design option 4 'insulation of the container', the temperature of the outer shell of the boiler will be decreased due to a lower heat transfer. As a positive side effect, this might improve the safety of operation since the container will be less hot to touch.

- In case of design option 6 'keep-warm function', users could expect the kettle to hold the temperature beyond a 30 minutes threshold. Yet this function is currently not (yet) very common in kettles on the one hand and existing models with this functionality have different keep-warm settings. In consequence, there does not seem to be an established expectation among users concerning the 'keep-warm function'. Furthermore, a limitation of this function could be an additional safety feature, helping to avoid the kettle to run dry if the function is used for a long time.

6.5. Subtask 6.5 - Long term targets and system analysis

The aim of this final subtask within Task 6 is two-fold. It shall look beyond the specific design options that are available as BAT in the long term. First, the long-term technical potentials as best not yet available technologies (BNAT) are to be discussed based on the assessment of applied and fundamental research, which still address the context of the present product archetype. Second, the long-term potential based on changes to the total system to which the present archetypal product belongs shall be discussed.

6.5.1. Long-term technical potentials based on BNAT

With regard to long-term technical potentials, it should be noted that electric kettles already come close to the theoretical minimum for the boiling process (excluding warm-keeping). Thus, from a physical perspective, no major break-through BNAT to reduce energy demand, for example similar to the change from the incandescent lamps to LED technology, can be expected.

Major levers concerning boiling (beyond the suggested design options) lies mainly in developing solutions to help users make better use of kettles to more adequately cover their actual boiled water demand, especially by avoiding over-heating (too high temperatures) and over-boiling (too much water). Digital innovations (e.g. alert functions) may assist here, but they might also cause additional consumption. One the one hand due to their own energy consumption and on they other hand if they act as independent agents and start boiling water based on predicted user behaviour in future scenarios. First kettles moving in this direction are already being advertised (Figure 6-6).

Figure 6-6: Excerpt of a smart kettle advertisement

„A brand new iOS and Android App, re-designed from the ground up packs in many new features in a simple and intuitive way to control your [kettle]. Using the latest Blink-Up technology, your connection is now even more secure, giving you that extra peace of mind. The customisable water temperature feature allows you to select any temperature between 20-100c. […] The water level sensor tells you exactly how much water is in your kettle directly on your App, so you know how many cups you can make. The new formula mode makes night feeds even easier, with the ability to connect to your Nest cam with IFTTT, it will boil the water and then notify you when it is at your desired temperature. Schedule the [kettle] to start heating at any time with Wake Up Mode, to make sure you get your day off to the best start possible. [It] also welcomes you home as soon as you walk in the door, select your normal time of arrival and the [kettle] will ask if you would like to boil the kettle."

(Excerpt of smart kettle description on www.amazon.co.uk)

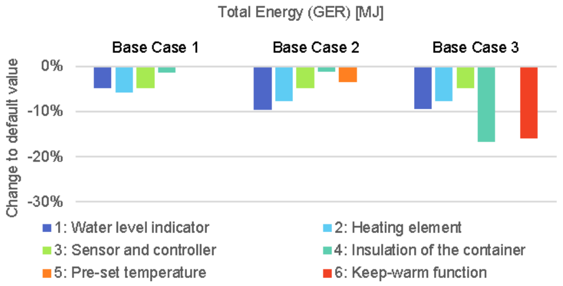
6.5.2. Long-term changes to the total system

There are no evident long-term changes to the demand of hot water. However, based on available evidence, modern induction heating cooktops using traditional kettles to boil water seem to be able to compete with electric kettles in terms of both performance and time. If such cooktops become broadly used, this might affect the need for stand-alone electric kettles unless they offer additional services to the users.

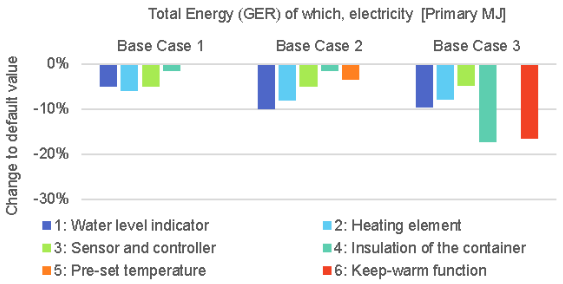
6.6. Annex A: Detailed impact of the design options on the environmental performance

Energy, water and waste

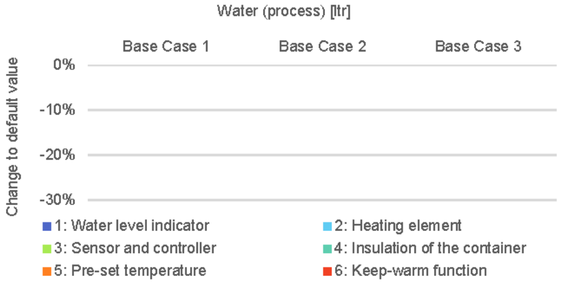
Total Energy (GER) MJ	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	4.898	5.239	7.687
1: Water level indicator	4.663	4.742	6.971
2: Heating element	4.614	4.835	7.104
3: Sensor and controller	4.663	4.991	7.329
4: Insulation of the container	4.836	5.180	6.402
5: Pre-set temperature		5.063	
6: Keep-warm function			6.460



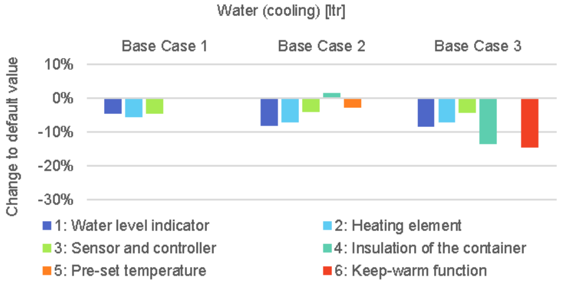
Total Energy (GER) of which, electricity Primary MJ	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	4.726	5.030	7.469
1: Water level indicator	4.492	4.533	6.753
2: Heating element	4.445	4.631	6.890
3: Sensor and controller	4.492	4.782	7.111
4: Insulation of the container	4.659	4.960	6.173
5: Pre-set temperature		4.856	
6: Keep-warm function			6.242



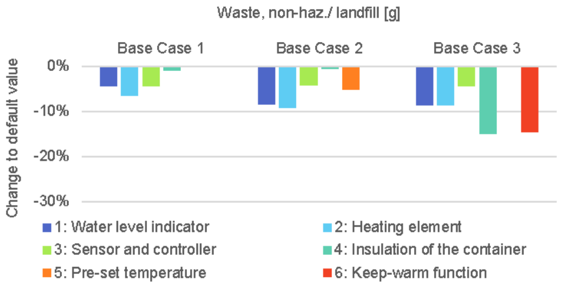
Water (process) ltr	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	5.438	5.453	5.453
1: Water level indicator	5.438	5.453	5.453
2: Heating element	5.435	5.448	5.448
3: Sensor and controller	5.438	5.453	5.453
4: Insulation of the container	5.438	5.453	5.454
5: Pre-set temperature		5.448	
6: Keep-warm function			5.453



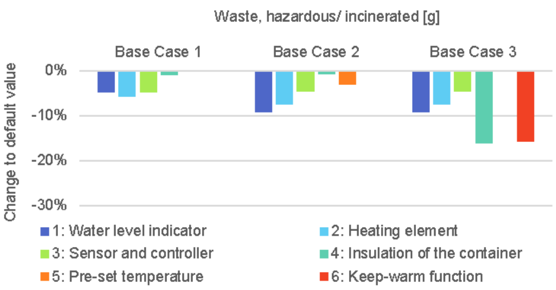
Water (cooling) ltr	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	238	269	379
1: Water level indicator	228	247	347
2: Heating element	225	250	352
3: Sensor and controller	228	258	363
4: Insulation of the container	239	273	327
5: Pre-set temperature		262	
6: Keep-warm function			324



Waste, non-haz./ landfill g	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	2.764	3.056	4.327
1: Water level indicator	2.643	2.801	3.958
2: Heating element	2.585	2.775	3.953
3: Sensor and controller	2.643	2.930	4.142
4: Insulation of the container	2.740	3.041	3.678
5: Pre-set temperature		2.901	
6: Keep-warm function			3.694

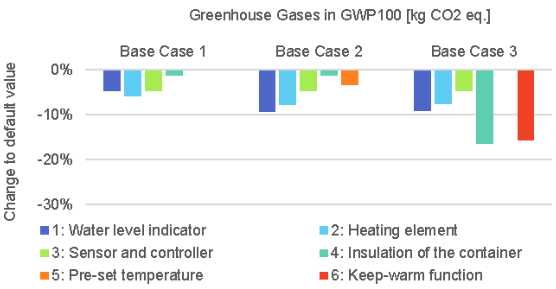


Waste, hazardous/ incinerated	g		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	79	85	123
1: Water level indicator	75	77	112
2: Heating element	74	78	114
3: Sensor and controller	75	81	118
4: Insulation of the container	78	84	103
5: Pre-set temperature		82	
6: Keep-warm function			104

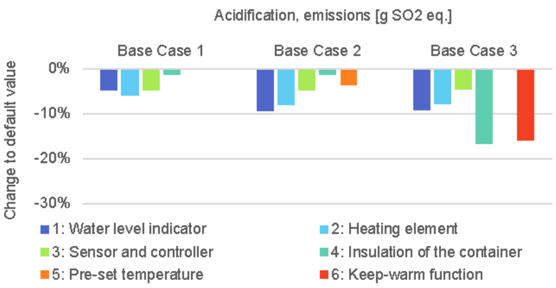


Emissions (Air)

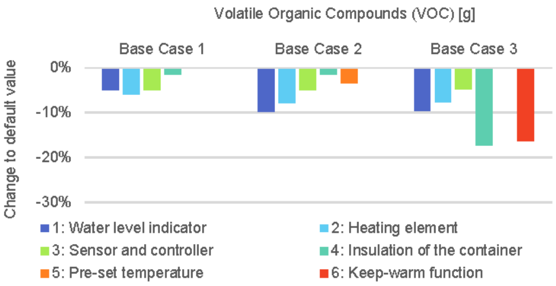
Greenhouse Gases in GWP100	kg CO2 eq.		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	213	228	333
1: Water level indicator	203	207	302
2: Heating element	201	211	308
3: Sensor and controller	203	218	317
4: Insulation of the container	211	226	278
5: Pre-set temperature		220	
6: Keep-warm function			280



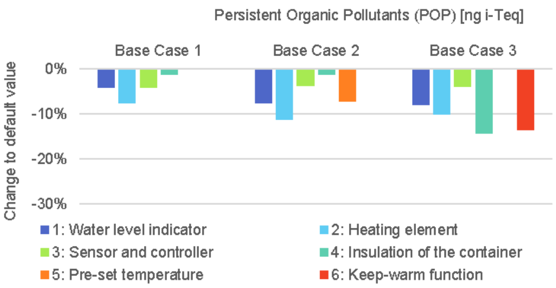
Acidification, emissions	g SO2 eq.		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	933	1.000	1.462
1: Water level indicator	889	906	1.327
2: Heating element	878	920	1.349
3: Sensor and controller	889	953	1.395
4: Insulation of the container	921	988	1.219
5: Pre-set temperature		964	
6: Keep-warm function			1.231



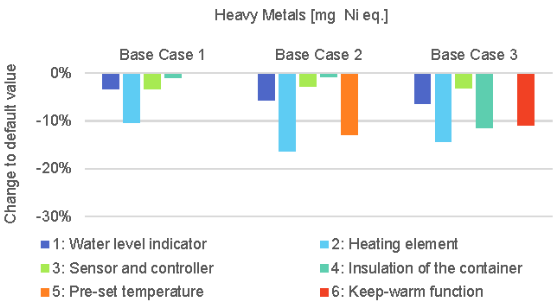
Volatile Organic Compounds (VOC)	g		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	106	112	167
1: Water level indicator	100	101	151
2: Heating element	99	103	154
3: Sensor and controller	100	107	159
4: Insulation of the container	104	111	138
5: Pre-set temperature		108	
6: Keep-warm function			140



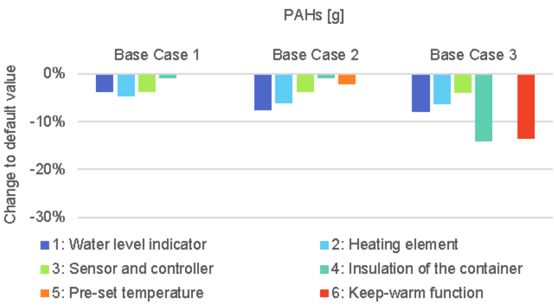
Persistent Organic Pollutants (POP)	ng i-Teq		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	13	15	21
1: Water level indicator	13	14	19
2: Heating element	12	14	19
3: Sensor and controller	13	15	20
4: Insulation of the container	13	15	18
5: Pre-set temperature		14	
6: Keep-warm function			18



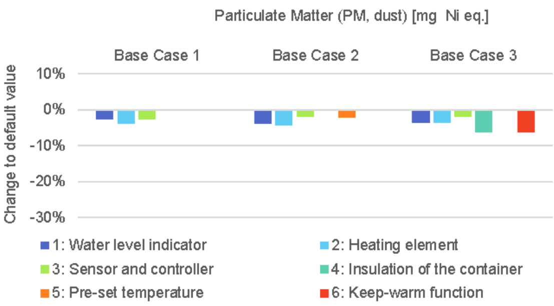
Heavy Metals	mg Ni eq.		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	73	88	114
1: Water level indicator	71	83	107
2: Heating element	66	74	98
3: Sensor and controller	71	86	110
4: Insulation of the container	72	88	101
5: Pre-set temperature		77	
6: Keep-warm function			101



PAHs	g		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	14	15	21
1: Water level indicator	14	14	20
2: Heating element	14	14	20
3: Sensor and controller	14	15	20
4: Insulation of the container	14	15	18
5: Pre-set temperature		15	
6: Keep-warm function			18

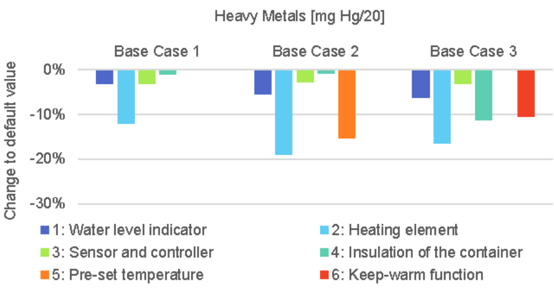


Particulate Matter (PM, dust)	mg Ni eq.		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	37	51	79
1: Water level indicator	36	49	76
2: Heating element	36	49	76
3: Sensor and controller	36	50	78
4: Insulation of the container	37	51	74
5: Pre-set temperature		50	
6: Keep-warm function			74

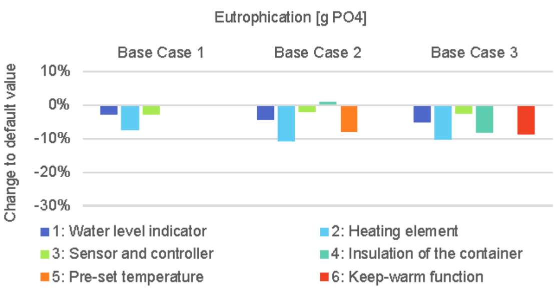


Emissions (Water)

Heavy Metals	mg Hg/20		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	31	39	50
1: Water level indicator	30	37	47
2: Heating element	27	32	42
3: Sensor and controller	30	38	49
4: Insulation of the container	31	39	44
5: Pre-set temperature		33	
6: Keep-warm function			45



Eutrophication	g PO4		
	Base Case 1	Base Case 2	Base Case 3
0: Base case demand	2	2	3
1: Water level indicator	2	2	3
2: Heating element	2	2	2
3: Sensor and controller	2	2	3
4: Insulation of the container	2	2	2
5: Pre-set temperature		2	
6: Keep-warm function			2



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