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

Task 4: Technologies

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

Team:
Contract technical team leader: Antoine Durand (Fraunhofer ISI)
Contractors: VITO (Belgium) and Fraunhofer ISI (Germany)
14.12.2020

EUROPEAN COMMISSION

Directorate-General for Energy
Directorate C - Renewables, Research and Innovation, Energy Efficiency
Unit C4: Energy Efficiency: Buildings and Products

European Commission
B-1049 Brussels

EUROPEAN COMMISSION

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

Task 4: Technologies

Directorate-General for Energy
[Name of the Programme/Activity]
2020 EUR [number] EN

EUROPE DIRECT is a service to help you find answers to your questions about the European Union

Freephone number (*):
00 800 6 7 8 9 10 11

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you)

LEGAL NOTICE

More information on the European Union is available on the Internet (http://www.europa.eu).

Luxembourg: Publications Office of the European Union, 2020

Print	ISBN [number]	ISSN [number]	doi:[number]	[Catalogue number]
PDF	ISBN [number]	ISSN [number]	doi:[number]	[Catalogue number]
EPUB	ISBN [number]	ISSN [number]	doi:[number]	[Catalogue number]

Printed in Belgium

PRINTED ON ELEMENTAL CHLORINE-FREE BLEACHED PAPER (ECF)

PRINTED ON TOTALLY CHLORINE-FREE BLEACHED PAPER (TCF)

PRINTED ON RECYCLED PAPER

PRINTED ON PROCESS CHLORINE-FREE RECYCLED PAPER (PCF)

ABOUT THIS DOCUMENT

29.06.2020 - First draft:	First draft for the first stakeholder meeting
24.08.2020 - Revised draft:	Revised draft of Task 4 after comment from the first stakeholder meeting
14.12.2020 – Final:	Final version of Task 4 report

Author: Marcel Gebele (Fraunhofer ISI)

Contributors: Antoine Durand (Fraunhofer ISI)
Simon Hirzel (Fraunhofer ISI)
Clemens Rohde (Fraunhofer ISI)

Contract management: Mihaela Thuring (VITO)

Study website: https://ec.europa.eu/energy/studies_main/preparatory-studies/ecodesign-and-energy-labelling-preparatory-study-electric-kettles_en

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

BAT	Best Available Technology
BC	Base case
BNAT	Best not yet available technology
BOM	Bill of material
CEN	Comité Européen de Normalisation
CENELEC	European committee for electrotechnical standardization
ErP	Energy-related Products
EN	European Standard
EP	European Parliament
EU	European Union
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LCA	life cycle assessment
MEErP	Methodology for Ecodesign of Energy-related Products
MEPS	Minimum Energy Performance Standard
MS	Member States
NTC	Negative Temperature Coefficient
PTC	Positive Temperature Coefficient

4. TASK 4: TECHNOLOGIES

This task, which is structured in accordance with the MEErP Task 4, presents the processes involved in the functional performance of electric water kettles via a technological description and analysis. This is conducted for technologies that are already on the market and that will become the basis for the base cases, but also for Best Available Technologies (BAT) and state-of-the-art Best Not-yet Available Technologies (BNAT). The analysis addresses both the product level and the component level and briefly assesses improvement potentials.

The aim of this task is also to collect a comprehensive dataset across the whole product life cycle on which to undertake the analysis of the life cycle environmental impact and economics in the subsequent tasks of this preparatory study.

4.1. Technical product description

In this task a comprehensive technical analysis of the products, present in the market, is carried out. Besides the base case technologies, which are intended to represent the average product entering the market today, BAT and BNAT (in terms of environmental improvement potential) are assessed. The assessment of the BAT and BNAT provides the input for the identification of the improvement potentials reported in Task 6.

4.1.1. Different types of kettles (working towards definition of Base Cases)

The work carried out under Task 1 suggested that the scope of the study could be exclusively limited to electric kettles with a volume of up to 10 litres. In order to provide a full information, info, a brief description of hot water dispensers and boiled water heaters is also provided in this document.

4.1.1.1. Electric Water Kettles

When it comes to heating and boiling water (e.g. for cooking, tea or coffee) electric water kettles are the products used the most in households, gastronomy and hotels.

Similar to hot water dispenser, there are multiple types of electric water kettles existing. They vary in terms of

- capacity of the container
- material of the container
- rated input power
- heating element
- base
- features like temperature setting and temperature holding

All these parameters are going to be introduced and analysed within this preparatory study at the component descriptions (see 4.1.2).

<u>Working principle</u>

Despite all variables, there are components all electric water kettles need, to be able to operate in the first place:

- container
- heating element[1]

The working principle of an electric kettle itself is relatively simple. Although it changes slightly depending on the features an electric kettle has (e.g. the kettle with feature of temperature setting requires more electronic parts than other kettles). The water heating/ boiling process can be divided into three steps:

- Step 1: Start of heating/ boiling process

---

[1] see https://www.wasserkocher.net/aufbau-funktion/#gref (last call 15.06.2020)

After filling the container with some water and placing it on the base, dropping a pulser mechanically closes a circuit. The component in charge of the heating is the heating element. A current starts flowing through the element: the boiling process starts.[2]

- Step 2: Heating/ boiling process

The working principle of the heating element is a resistive principle. This means a current flows through an element converting electricity to heat energy due to the components electrical resistance, the resistive heating element heats up.3 As a result, heat flows from heating element to the heating plate. The water temperature rises continuously and reaches the boiling temperature eventually.4

- Step 3: Automatic switch off

All modern electric water kettles possess the feature of an automatic switch-off. One principle behind this feature is that evaporating water generates steam, which heats a bi-metallic thermostat. A kettle switches off, as the bi-metallic element reaches a certain temperature (depending on the metals used in the element) and the element changes its position. As a result, the electric circuit is interrupted and the heating and boiling process stops. Other principles are using thermistors as Negative Temperature Coefficient (NTC) or Positive Temperature Coefficient (PTC).

To summarize there are different types of technologies and kettles, which can fulfil the task to heat and to boil water. For the further input of this preparatory study, the definition of "electric water kettles" used in Task 1 - Scope is used:

"Electric kettles" are stand-alone, unpressurized, electrically powered domestic appliances primarily intended for boiling a batch of up to 10 litres of drinking water, potentially also including a warm-keeping function after heating."[5]

4.1.1.2. Hot water dispenser

Hot water dispensers are known as products to dispense water. There are several types existing, a typical model is an instant hot water dispenser (see Figure 4-1).

Figure 4-1: Hot water dispenser[6]

[2] see https://de.techinfus.com/dlya-kuxni/elektrochajnik/remont-chajnika-svoimi-rukami.html (last call: 15.06.2020)

[3] see https://www.explainthatstuff.com/heating-elements.html last call 23.06.2020

[4] see https://kettleheatingelements.weebly.com/functionality-and-materials.html last call 22.06.2020

[5] see Task 1

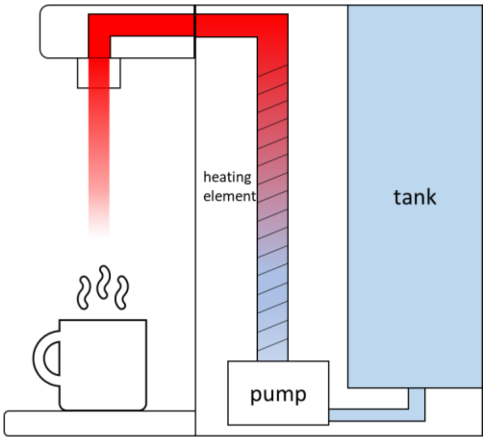
[6] see Task 1

Working principle

Hot water dispenser consists of a tank, usually metal, with rubber tanks also being found in lower-end models, and an electrical coil that is attached to the pipe, quickly and efficiently heating up cold water that goes through the pipe (see Figure 4-2).

The working principle is quite simple. After activated, the required amount of cold water is pumped from the water tank and heated up to the desired water temperature (max. 94°C). Concerning the heating process, most hot water dispensers have an instantaneous water heater for heating the water (see Figure 4-2). For this purpose, cold water is pumped from a tank through a pipe to the outlet. While going through the pipe, it is heated by an instantaneous water heater to the temperature needed.[7]

Figure 4-2: Source: Working principle of hot water dispenser [Source: following GizTech Review][8]



Characteristically for hot water dispenser is that they just boil the amount of water which is actually needed. Hot water dispenser also copes with the underlying prerequisite to heat water.

4.1.1.3. Boiling water heaters

In comparison to most of hot water dispensers and electric water kettles a Quooker is directly connected with the cold water supply. Boiling water heater systems consist of a vacuum-isolated tank, tap, inlet valve and some minor installation parts (e.g. screws, thread rings, other rings). The system most relevant for this preparatory study is the one that provides hot/ boiling water only, the Quooker PRO3 (see Figure 4-3).

The tank in the kitchen cupboard is connected to the boiling water tap on the worktop, where - depending on the product -a certain amount of hot water is stored at overpressure conditions and 110°C temperatures. The tank itself can be seen as a vacuum flask connected to the cold water supply. The air in the insulated wall is so thin that the heat is unable to escape. It therefore takes very little energy[9] to keep the water at 110°C.

Working principle

As soon as the tap is turned on, the outflowing water starts to boil. Simultaneously, the temperature of the water drops to 100°C. At the same time that the water is flowing out of the tap, cold fresh water is refilling the tank.

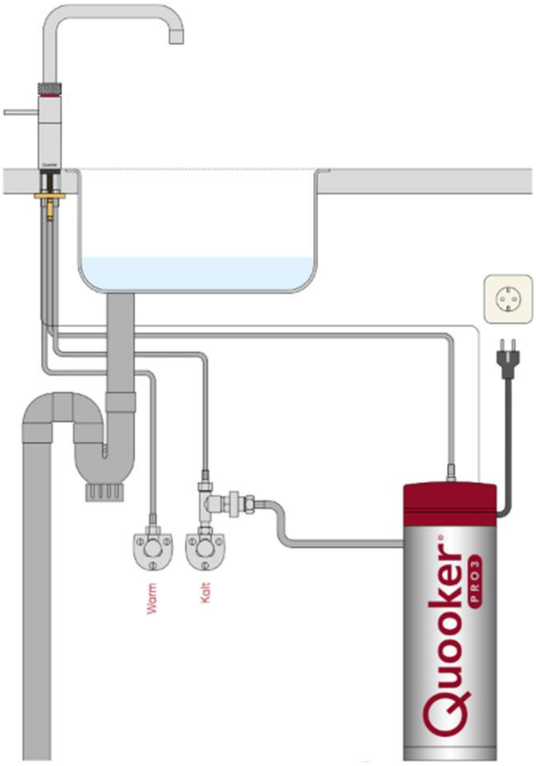
---

[7] See https://de.wikipedia.org/wiki/Wasserkocher (last call 15.06.2020)

[8] See http://giztechreview.com/2018/07/25/s2101-instant-heating-water-dispenser-the-new-water-heater-that-xiaomi-youpin-presents-us/ (last call: 15.06.2020)

[9] According to Quooker just 10 watts (https://www.quooker.co.uk/how-a-quooker-works (last call: 15.06.2020))

Figure 4-3: Installation Quooker PRO3 [Source: Quooker][10]



Quooker fulfils the underlying prerequisite to heat water and due to its insulation, it is relatively efficient. According to Quooker, the stand-by-mode consumes 10W[11] and therefore generates costs up to 0.05 ct€/day.[12]

4.1.2. Components of electric water kettles

Despite all differences, electric water kettles are, generally speaking, simple products with manageable number of component-groups. In the next few chapters, these groups -also considering potential alternative variants or materials- are introduced. Figure 4-4 provides a good overview of built-in components of an electric water kettle.

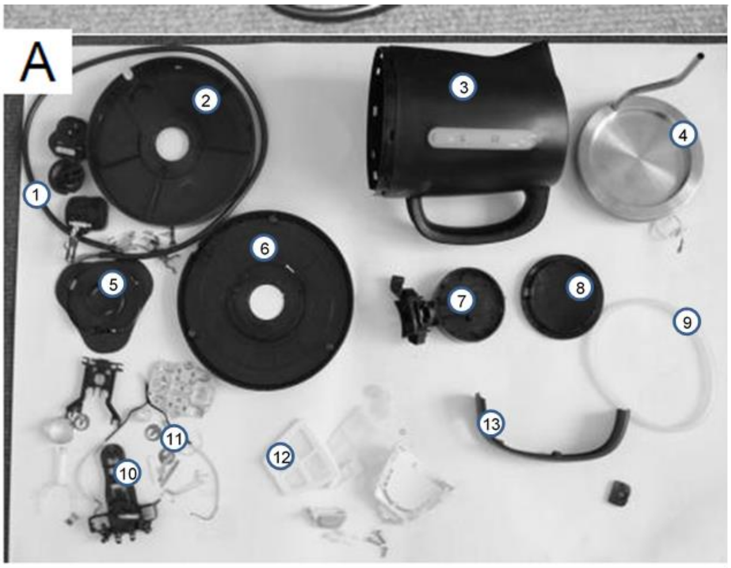
---

[10] see https://www.quooker.de/media/wysiwyg/i/n/installationsanleitung_pro3_de_2.pdf (last call 15.06.2020)

[11] see https://www.quooker.co.uk/media/wysiwyg/i/n/installation_guide_vaq_e_uk.pdf (last call 10.11.2020)

[12] see https://www.quooker.de/media/wysiwyg/Endkundenbrosch_re_DE.pdf (last call 15.06.2020)

Figure 4-4: Dismantled electric water kettle [Source: Alejandro Gallego-Schmid et al. (2018)]



1: Power cable
2: Base moulding
3: Water reservoir
4: Heating plate
5: Wire housing
6: Bottom cover of reservoir
7: Lid release mechanism
8: Lid cover
9: Rubber seal
10: Control unit
11: Bi-metal disk
12: Removable filter
13: Handle cover

4.1.2.1. Power cord and plug

Every electric water kettle has a power cord, connecting mains power with the kettle. The power cord can be mounted on the kettle directly or on a base

Every electric water kettle has a power cord, connecting mains power with the kettle. The power cord can be mounted on the kettle directly or on a base, a differentiation between cordless and corded can be made.

Cordless

Contradicting to the first understanding of the word "cordless" it does not mean that an electric kettle has no power cord at all. In connection with kettles, "cordless" means that the power cord connects the mains power with the base. The container of the kettle itself is not connected to the mains power and therefore is portable. The product offers a two-piece approach.

Corded

Next to cordless products with a two-piece approach, there are one-piece gadgets without a base. The power cord is mounted on the electric kettle directly. This means when filling with fresh water and pouring boiling water the plug should be withdrawn for safety reasons.

There is no causal relation between the way a kettle is connected with the mains power and a certain use of heating element. A cordless product can have either a concealed, underfloor or an immersed heating element.[13]

4.1.2.2. Base

In addition to the differentiation between "cordless" and "corded" explained in the previous subchapter, "cordless" kettles usually have bases, whereas corded models do not.

The component "base" is directly linked with the power cord and is of pivotal meaning for the whole function and operating mode of an electric water kettle. The base can be seen as the control centre where most of the sensors, thermostats, control units and other safety mechanisms are situated, providing the technology basis for all features a modern kettle offers. For some kettles the hardware for pre-set temperature and temperature holding is also placed on the base.

---

[13] see https://de.wikipedia.org/wiki/Wasserkocher (last call: 15.06.2020)

Besides its importance from a technological point of view, the connector on top of the base ensures -as a preliminary step- the closing of the power circuit through placing the container of the kettle on the base (which is initiated through pushing the pulser at a later stage). Vice versa, removing/ lifting the container from the base interrupts the power circuit and therefore the boiling process. Some but not all kettles offer a feature that prevents the kettle from re-starting the boiling process after the kettle is placed on the base again.[14]

Another distinction can be made in terms of handling the kettle. For cordless kettles, there are bases available which allow

- 360° radius: kettles operate independently of the position on the base
- fixed base: kettles can just be placed in one certain position and therefore solely operate in this position

4.1.2.3. Container

The component in which water kettles vary the most is the container of the kettle. The container comprises the location the actual heating and boiling process takes place, as well as the handle, the lid and the space between these areas (partly used for placing sensors, thermostats and control units, depending on the kettle). A container can differ in following parameters:

- construction
- design
- lid
- material
- capacity
- other components (e.g. water filling indicator, filters)

To give a short and comprehensive overview these parameters are specified in the turn.

Construction

Kettles are constructed in various ways. Some products have a double wall characteristic, which can lead to different qualities of a kettle:

- Cool touch / Insulation

  In its effect, the easiest variation is using two different or one special material(s) for building the wall(s) of the kettle. This double wall measure is aiming for a higher safety standard in handling the kettle (scalding protection).

  Normally, such products go hand in hand with an insulation. Build-in materials provide a certain amount of thermal insulation like a thermos flask. Due to the high price sensitivity of the market, nowadays there is just air, instead of special filling material, between the two layers. A product with the feature cool touch does not necessarily have an insulation, whereas it is most likely that a product with insulation has automatically cool touch feature.

- Vacuum

  Some water kettles go even further and have special approach of insulation. So-called vacuum kettles are vacuum-isolated with a reduced amount of air between two walls of the kettle to prevent heat losses through materials.

Next to the special construction option of the wall, there are products where their hardware for the features pre-set temperature and/or temperature holding are not integrated in the base but in the handle of the container. Therefore, not for every water kettle, all sensors, thermostats and control units are located in the base. Depending on the product, some of those components are built in the spare place in the container, e.g. there are gadgets having the thermostat for providing an auto-switch-off between the tank where the actual heating and boiling process takes place and the handle.

---

[14] see https://de.wikipedia.org/wiki/Wasserkocher (last call: 15.06.2020)

Design

Electric water kettles are sold in different styles and shapes. Most of the kettles are jug-like kettles. However, there are also some products with a traditional -dome/ pyramid- design. Form is not dictated by energy efficiency considerations but by design issues. However, form and design could influence energy consumption of a product. Since kettles are appliances used in households and a visible part of the daily life, they are not just tools to boil water but also products fulfilling special design requirements. As a result, sometimes a higher amount of material is used as it would be actually needed to solely serve the task of heating and boiling water. This has effects on bill of material and the life cycle assessment dealt with at a later stage in this preparatory study.

Lid

Lids of kettles have multiple functions. On the one hand, a closed lid prevents boiling water from spilling out of the container and functions as a scalding protection. On the other hand, it contains - in some cases- sensors, e.g. boiling temperature sensor that is responsible for the auto-off-feature.

Normally lids can be opened via pushing a button, located on the handle. However, the degree to which a lid opens varies from kettle to kettle. For some kettles, the lid can be removed completely, which makes for example cleaning and descaling process easier. Concerning the material: lids of water kettles do not necessarily have the same material as the container of the kettle.[15]

Capacity

In context with this preparatory study, the expression capacity stands for the capacity of the container of the kettle. The volume of water that can be heated and boiled safely.

Looking at the numbers of stock and sales from Task 1, the spectrum of models with different capacities is very broad. To provide a comprehensive overview, three ranges can be made, which comprises the different use-cases the best:

- small kettles

  Small gadgets with a volume up to 1.2l. Mostly used as travel kettles or in hotel rooms. They have the least sophisticated approach and their primarily function is boiling water.

- medium-sized/ standard kettles

  The vast majority of kettles in stock and sales within the European Union concerns medium-sized models with a capacity between 1.5l and 1.7l. This product category exists in all variations with a broad range of features.

- large kettles

  Large kettles are also known under the name "urn". Urns show the widest range of capacity. There are gadgets between 2.5 and 26l. In this study and for a more comprehensive approach, the maximum capacity is limited to 10l.

Material

The material can vary depending on the component of the kettle. The material of the container can differ from the material of the lid, or from the material used for the base. In terms of the material, one can distinguish between materials used for the container, for the lid, for the base. Except for the electrical parts, most kettle components consist of three materials:

- Plastic
- Stainless steel
- Glass

---

[15] see https://de.wikipedia.org/wiki/Wasserkocher (last call: 15.06.2020)

There are products made out of solely one material. Normally, most of the kettles can be stated to have been preliminary made out of one material with components out of other material. Currently in Europe, plastic or stainless steel are the most used materials for manufacturing kettles. However, as Task 2 shows, the share of plastic kettles decreased continuously since 2013, while glass kettles account now for around 10% of the market. Trends show that consumers are getting more sensitive in terms of health and environmental issues.

<u>Other components</u>

- Water level indicator

  For electric water kettles, another distinction can be made in terms of water level indicator. Traditionally the indicator gives information about the amount of water in the kettle in litre. However, alternative systems are existing. Especially regarding energy efficiency, an indicator showing the amount of water needed to be boiled for a number of cups (instead of the amount of water in litres) is a potential energy saver. The so-called minimum fill or one-cup-boil information on the scale informs the user of the kettle about the water level that is required to be boiled for just one cup of tea or coffee (see Figure 4-5):

Figure 4-5: Electric water kettle with 1-cup indicator [Source: Philips][16]

- Limescale filter & other protection elements (vapour etc.)

  Modern water kettles obtain components to prevent limescale deposits from flowing into cups and/or teapots. Such permanent filters are demountable and cleanable.[17]

4.1.2.4. Heating element

Heating elements of water kettles differ regarding their rated input power and the integration of their heating element.

<u>Rated input power</u>

Similar to the capacity of electric water kettles there are multiple ranges of rated input power existing. Looking at the stock and sales data for Europe and in order to get a first overview about the current product distribution, it is possible to divide the kettles into certain clusters of rated input power. Smaller shares concern the low rated input power (lower 1,800W) and high rated input power (above 2,800W). Most of operating kettles are in the range of 2,200W to 2,800W.

As for the heating element, water kettles normally offer two types of built-in heating elements, though both are conventional, tubular electric heater:

<u>Immersed heating element</u>

An immersed heating element is directly integrated in the container of a kettle and stands in immediate and direct heat exchange with the liquid. Due to the unconcealed montage, they are

16 according to permission of Philips in telco from 17th of June 2020

17 see https://de.wikipedia.org/wiki/Wasserkocher (last call: 15.06.2020)

more difficult to clean and descale compared to the concealed versions. They are often built-in less expensive water kettles though.

Their shapes vary from horizontal and flat to a vertical approach (see Figure 4-6). To operate a kettle with such a heating element a minimum amount of water needs to cover the heating element completely on grounds of safety issues. This has an impact on the aspect of over-boiling (vs. heating/ boiling the amount of water that is actually required) and can be mentioned as energy efficiency potential.

Figure 4-6: Different shapes of immersed heating elements [Source: Thermoer][18]

Underfloor heating element

Conventional, underfloor, heating elements are not directly integrated in the container. They are concealed and attached under a metallic plate, which builds the bottom of the container. The heat exchange works indirectly. In comparison to immersed heating elements, concealed heating elements are easier to clean and to descale. They also can be designed to be able to operate with a relatively low minimum water level (e.g. one-cup-indicator, boiling approx. 200-300 ml water), resulting in the potential to operate more application-specific.

Both immersed and conventional underfloor heating elements vary within their cross-section area according to their rated power input; the higher the wattage the larger the cross-sectional area.

Composition - conventional, tubular

To be precise, a standard heating element can be divided into several sub-components (see Figure 4-7). A central function has the heating wire (as the original resistance heating element), often comprising a nickel-based, nichrome heating element (NiCr), magnesium oxide powder and an outer casing. The heating wire itself is coiled. Forming a ring increases the resistance value, enhances the durability and improves heat generation speed and efficiency.

The most common mixture of nichrome heating element consists of 80 percent nickel and 20 percent chromium. Its benefits are high melting point, no oxidization, no significant expansion and relatively stable resistance qualities in terms of increasing temperatures.[19] The magnesium powder filled around the coiled wire guarantees electrical insulation and good heat transfer (thermal conductivity) within the heating element. Whereas the outer casing (often stainless steel alloys) is heat-resistant and conducting and provides both protection and form.[20]

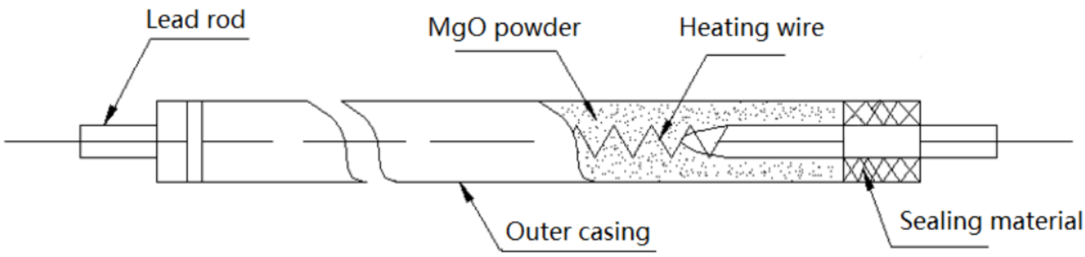
---

[18] see https://thermoer.com/products/kettle-heating-element-supplier/ (last call 16.06.2020)

[19] see https://www.explainthatstuff.com/heating-elements.html (last call 23.06.2020)

[20] see http://www.ottercontrols.co.uk/x6-series.html#gsc.tab=0 (last call 26.06.2020)

Figure 4-7: Composition of a tabular heating element [Source: Thermoer][21]

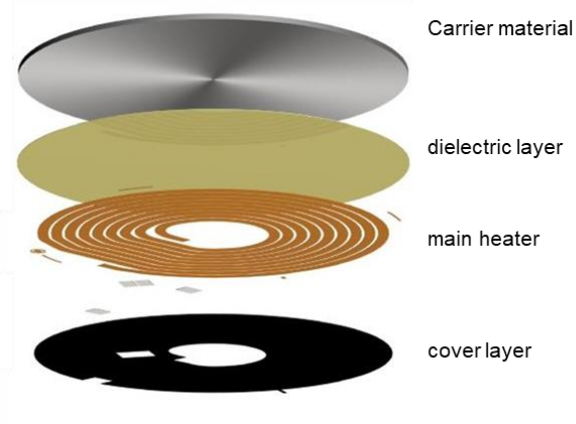


<u>Thick film heating element</u>

Besides the common tubular heating elements mentioned above there are also thick film heating elements.

Thick film heating elements follow another approach and composition (see Figure 4-8). They generally consist of a metal core. The core is coated with a glass-ceramic lining, which ensures electrical insulation and carries conductive, screen printed heater tracks.[22]

Figure 4-8: Composition thick film heating element [Source: following ferro techniek][23]



Currently, thick film heating elements are more expensive than conventional, tubular one. These elements are able to transfer a higher amount of energy/ heat per surface (average over the printed area 50 W/cm²)[24]. Additionally, such elements offer a lower thermal mass, therefore heat losses to the surrounding material are lower.

4.1.2.5. Other mechanical & electrical parts, sensors and control units

Hand in hand with the heating elements, go mechanical and electrical parts as sensors/thermostats and control units, that enable features like auto-switch-off, pre-set temperature, temperature keeping and boil-dry protection.

---

[21] see https://thermoer.com/how-to-make-a-heating-element/ (last call 23.06.2020)

[22] see http://www.ferrotechniek.com/thick_film_heaters/technology.aspx (last call 24.06.2020)

[23] see http://www.ferrotechniek.com/thick_film_heaters/technology.aspx (last call 24.06.2020)

[24] see http://www.ferrotechniek.com/thick_film_heaters/technology.aspx (last call 24.06.2020)

Basic definition

To be able to bring features of a modern water kettle in line with the underlying technology, some basic definitions and understandings have to be made. The expression of temperature sensors is misleading, since these sensors do not measure the actual temperature themselves. Elements providing a certain water temperature are either mechanical bi-metal switches or thermistors. Therefore, an auto-switch-off feature bases always on the same technology as pre-set temperature features. How and with which technology these features are guaranteed are dealt with within the next subchapters.

Bi-metal switch (mechanical)

Boiling water creates steam. Continuous generated steam is led to a mechanical sensor, a bi-metallic disk. This sensor can be placed on various locations (base, handle, lid). The working principle though does not change: once water boils long enough, steam hits the bi-metallic sensor and heats it up. Reaching a certain temperature (e.g. 100°C) the bi-metallic disk snaps its position and cuts off the power circuit. Such a bi-metal switch can be mounted in several ways. Integrated in the control unit or remote in other areas in base or product (e.g. lid or handle). Bi-metal switches are working with tolerances of +/- 5 to 7 K.[25]

Additional to the auto-switch-off feature, the working principle of a bi-metal switch can provide boil-dry protection. When the temperature soars beyond what would be expected in presence of water, a second bi-metal switch would open, cut off the circuit and not reset until the disk is close to room temperature as an infinite on-off-cycle.[26]

Thermistor (electrical)

The word thermistor is the short form of thermally-sensitive resistor. Thermistors are elements that change their electrical resistance in response to a change in their body temperature. For electric water kettles two different types of thermistors are used: PTC (Positive Temperature Coefficient) and NTC (Negative Temperature Coefficient).

- PTC

  PTC thermistor's resistance increases as temperature rises.[27] Inversely when temperature decreases, so does the resistance. As a result, the conductivity is higher as temperatures stay low. PTCs often have a transition temperature and reaching this temperature leads to an abrupt rise of resistance. They are often used in self-regulating heating elements or commonly installed in series with a circuit and used to protect against overcurrent conditions as resettable fuses.[28]

  As for water kettles, PTCs are for example beneficial for products with several pre-set temperatures (step-approach). To realize this feature different PTCs have to be mounted on the same spot. In combination with a step switch and depending on the pre-set temperature, circuits are closed or cut off.[29]

- NTC

  NTC thermistor's resistance decreases as temperature rises.[30] Whereas resistance increases as temperature decreases,[31] resulting in a better conductivity at higher temperatures, which means the higher the temperature, the higher the current. In comparison to PTCs, NTCs do

---

[25] based on Expert interview BSH (19.06.2020)

[26] based on Expert interview BSH (19.06.2020)

[27] see https://en.wikipedia.org/wiki/Thermistor (last call 24.06.2020)

[28] see https://www.teamwavelength.com/thermistor-basics/ (last call 24.06.2020)

[29] see http://wasserkocher-test24.de/woher-weiss-der-wasserkocher-wann-das-wasser-kocht/ (last call 24.06.2020)

[30] see https://en.wikipedia.org/wiki/Thermistor (last call 24.06.2020)

[31] see https://www.teamwavelength.com/thermistor-basics/ (last call 24.06.2020)

not have transition temperatures and their resistance decreases linear with temperature.[32] NTCs are commonly used as a temperature sensor, or in series with a circuit as an inrush current limiter.[33]

As for water kettles, NTCs are beneficials of different approaches (step, stepless). In combination with a control unit the kettle continuously detects the resistance and therefore the water temperature, resulting in either close or cut off the circuit. To illustrate this on an example (keep warm feature):

After switching on the keep warm feature, the control unit will detect the water temperature via NTC. If the temperature is lower than the pre-set temperature, the heating element will switch on to heat the water to the pre-set temperature again. Especially for the keep warm feature, it is worth mentioning that there is no special additional sensor used. Already existing devices are supplemented by a timer, which runs for maximum 30 minutes.

Depending on price sensitivity, aspired price segment and product group, target group and corresponding control unit, both NTCs and PTCs can provide features like auto-switch-off, boil-dry (PTC), pre-set temperature, temperature keeping and work with an accuracy of +/- 2 to 5 K.[34]

<u>Control unit & Connector</u>

A control unit is the "brain" of each kettle, where individual elements as bi-metal disk(s), PTCs and NTCs run together. The product portfolio ranges from rather basic control units to high-end products -including all safety and steering functions as e.g. sensors and switches. Therefore, control units play a pivotal role in the daily operation of electric water kettles, especially in combination with thermistors, where the unit permanently detects and controls the resistance and therefore the temperature of the kettle. This results in starting and stopping the heating and boiling process.

However, control units do not only differ in terms of the grounds of the sensors built in a kettle, but also on the type of kettle itself

- Corded - immersed heating element

  In terms of control unit there is -theoretically- just one difference between corded and cordless kettles; the area one can carry the kettle without unplugging it: the base. However, corded kettles do not need one component that the cordless kettles need: a connector that acts as an extended arm of the control unit, establishing a connection between heating element (container) and control unit (base). Depending on the heating element there are different connectors built. As for a immersed heating element the heating element is physically integrated inside the container

- Corded - underfloor heating element

  In comparison to the corded immersed heating element, an underfloor heating element is built in directly under the bottom of the container.

- Cordless – immersed heating element

  Since an immersed heating element is mounted on the container wall, the connector cannot be placed directly under the container. This is also the reason why such kettles mostly require a fixed base and the connectors look different. They partly offer the possibility to place the steam detector integrated in the control unit or remote (e.g. in the lid of the container, or the handle)

- Cordless – underfloor heating element

---

[32] see http://wasserkocher-test24.de/woher-weiss-der-wasserkocher-wann-das-wasser-kocht/ (last call 24.06.2020)

[33] see https://en.wikipedia.org/wiki/Thermistor (last call 24.06.2020)

[34] based on Expert interview BSH (19.06.2020)

Control units of underfloor heating elements are in most cases leaner than the immersed ones and offer usually 360° movable use of the kettle.

Noteworthy, that there are two world-market suppliers for (micro) control units- Otter Controls LTD and Strix Ltd- which play a pivotal role not just in producing and supplying control units but also in developing, constructing and other services.35

4.1.2.6. Other small parts

As in every other product there are also other small parts built in electric water kettles. Screws, buttons (rubber, protective), a rubber seal of the central switch "ON/OFF", its corresponding lamp (LED) various fixed rings.

In comparison to the other components mentioned above, those parts play an underlying role.

4.1.3. Products with standard improvement (design options)

Environmental impact of electrical products -as electrical products in households- has been intensifying over the last few years, recognizable on various ecodesign preparatory studies and regulations on these subjects. As one field of environmental impact, the energy consumption can be named. On the basis of analysing components of an electric water kettle, potential for improvements can be identified as so called design options, which are going to be specified within Task 6.

Besides energy efficiency measures, there are other potentials that have influence on real life energy consumption. As showed in Task 3, user behaviour is one of them. Prevention of over-boiling and an easy to clean and descale container have an impact. The package of potential improvements (see Table 4-1) also includes solutions to support a change in behaviour of users. *Considering the scope of the preparatory study, only water kettles are going to analysed further*

[35] see http://www.ottercontrols.co.uk/kettleservices.html#gsc.tab=0 (last call 24.06.2020)

Table 4-1: Summary of potential standard improvements (design options)

Topic	Option	Component	Measure
Thermal optimization	1	Material	Material substitution
Thermal optimization	2	Design	Energy efficient design
Thermal optimization	3	Construction	Insulation
Technical optimization	4	Rated input power	Seizing
Technical optimization	5	Heating element	Immersed heating element
Technical optimization	6	Heating element	Heating element substitution
Technical optimization	7	Other mechanical & electrical parts, sensors and control units	Temperature control
Technical optimization	8	Other mechanical & electrical parts, sensors and control units	Sensors
Technical optimization	9	Other mechanical & electrical parts, sensors and control units	Boil-dry protection
Usage behaviour	10	Construction	Double chamber A double chamber approach means that there are two chambers in one kettle. One for containing the cold water, one where the actual boiling process takes place.
Usage behaviour	11	Water level indicator	Water usage
Usage behaviour	12	Heating element	Cleaning /Limescale

4.1.4. Best Available Technology – BAT (e.g. the best products on the market)

Concerning electric water kettles there is no single technology, which pushes energy efficiency of the products. Characteristically for the European market of electrical water kettles is a major intersection of features offered by each kettle. However, this intersection comprises not only technology- or energy-related topics but also user behaviour. Therefore, it is hard to say from which point, a technology can be considered as Best Available Technology (BAT). Significant distinguishing features are for example pre-set temperature and keep warm. An additional differentiation cannot be made by features or technologies themselves but by the quality of the single components. Hence, best products on the market are also considered.

4.1.4.1. Water dosing

Over-boiling is the most significant reason for energy waste during the use phase of electric water kettles. Reducing the excess of boiled water, decreases the waste of energy by more than 30 %.[36] There are two BATs dealing with this issue, initiating not just a reduction of energy waste but also a potential change in user behaviour.

Two-chamber water kettles

Products following a two-chamber approach help to heat and boil just the amount of water that is actually needed. For this purpose, water is poured in a smaller separate tank inside the actual container of the kettle where the heating/ boiling process takes place. Pushing a button, a valve opens and water enters the actual container of the kettle, where the heating/ boiling process takes place. Large windows allow easy checking of the current water level, resulting in a rather well scalable filling process, enabling to heat/ boil just the amount of water that is actually needed.

Despite being logical from an energy efficiency perspective, there are no such products on the market currently.

Downsize water level indicator

Based on the same reason, but with a different approach, this feature aims to reduce the excess energy resulting from boiling too much water.

Most water level indicators start at 0.5l. Especially, for single cups of coffee or tea, a smaller amount would be sufficient. This feature is aiming for both enhancing the usability and influencing the behaviour of users. Therefore, the water level indicator is enlarged both by scale (smaller numbers) and by window surface. The users shall be enabled to just fill to the amount of water they need. Particularly interesting are alternative scales, e.g. indicators not solely with numbers, but with corresponding numbers of cups (see Figure 4-9).

Figure 4-9: Example of an alternative scale indicating the volume in number of cups [Source: Philips][37]

That fact that alone a water level indicator with up to one cup can save up to 18 % has been demonstrated in a study commissioned from Philips and conducted in 2008. For this study over a four-week period, 70 consumers were asked to use their own electric kettle. After that period a second period of four-weeks started, where the consumers were asked to use a kettle with a one-cup indicator. The selected consumers represented broadly typical English and Welsh households.

[36] see Gallego Schmid, A, et al., Life cycle environmental evaluation of kettles: Recommendations for the development of eco-design regulations in the European Union, DOI: 10.1016/j.scitotenv.2017.12.262

[37] according to permission of Philips in telco from 17th of June 2020

4.1.4.2. *Monitoring temperature*

Another feature is a digital display of temperature on the surface of the container of the kettle. The possibility to monitor the temperature potentially saves re-boiling procedures (see Figure 4-10). For example, if the person who wants to boil water, leaves and returns after the kettle finished the boiling process, not knowing if the temperature is still sufficient, he will start the boiling process again.

Figure 4-10: Electric Water Kettle with digital display [Source: own picture]

4.1.4.3. *Thick film heating elements*

Currently, and in comparison with resistance heating elements, thick film heating elements are more expensive. However, their benefits are obvious.

Having high power density in combination with a low thermal mass[38], they are able to heat direct and efficient, with lower amount of energy "wasted" to heat the surrounding mass of kettles. Particularly interesting is to observe the development of stand-by mode for kettles -either in relation with WiFi-connected gadgets or kettles with keep warm feature, since the energy use of thick film heating elements for providing such a mode is rather low.[39]

4.1.4.4. *Permanent cut off power circuit*

There are different technologies used in electric water kettles to provide boil-dry-protection. No matter if the feature is implemented mechanically via a bi-metallic switch or electronically via a thermistor, both solutions can result in a permanent switch-on, switch-off cycle after detection of lack of water.

Both solutions fulfil the requirements of the relevant safety standard. However, there are technologies that avoid endless on/off triggering and cut off the power circuit permanently, which can lead to additional energy savings (in case of occurrence).

4.1.4.5. *Electric kettles with WiFi-connection*

Electric kettles with WiFi-connection are already on the market. However, studies show that their handling and steering via App is not working smoothly yet.[40] Regarding increasing level of digitalization and smart home concepts of other product groups and appliances (heating system, ventilations system, fridge, etc.) it is most likely that electric water kettles are going to be integrated in such systems at some point.

---

[38] see http://www.ferrotechniek.com/thick_film_heaters/technology.aspx (last call 26.06.2020)

[39] see http://www.ferrotechniek.com/thick_film_heaters.aspx (last call 26.06.2020)

[40] see https://www.techstage.de/ratgeber/Wasserkocher-mit-App-Optimale-Temperatur-ab-35-Euro-4686998.html?hg=2&hgi=2&hgf=false (last call 26.06.2020)

The question about the energy demand for a permanent operation in stand-by mode to be accessible for Apps is a question, which needs to be further investigated.

4.1.4.6. Sensors and Control Units

Sensors used in water kettles can be divided into mechanical and electrical sensors. However, both possess a certain tolerance in determining the actual temperature of the water. Mechanical sensors as bi-metallic switches tend to have a higher inaccuracy than for instance thermistors. However, technology is evolving, and sensors offer a lower tolerance. A close interaction between sensors and control unit enables narrower detecting and checking schemes and potentially leads to an earlier cut of the circuit and therefore to a reduction in energy consumption.

4.1.5. Best Not yet Available Technology (BNAT)

After reviewing patents for heating liquids, heating technologies and control mechanisms in relation with heating and boiling liquids, it appears that electric water kettles are rather mature products. Characteristically for kettles are not their innovation potential but the intensive price sensitivity of customers and the pressure of low production and distribution costs of producers.

Also worth of mentioning, not just for the BNAT chapter of this preparatory study but also for implementing measures or potential regulation, is that there is a high market concentration in the supplying segment of control units of two major producers. These producers cannot be seen as conventional suppliers but as full-service providers from planning and developing to the realisation of the steering and controlling unit (incl. sensors and safety applications). This circumstance could influence further activities and measures according to Article 15, 5(e) related to "Implementing measures"[41] of the Ecodesign Directive 2009/125/EC, which should be considered carefully. However, there are two trends worth mentioning on this stage.

4.1.5.1. Induction heating

Repeatedly, alternative heating principles occur. So does the principle of induction. Induction is seen as the heating technology of the 21st century for more than one product area.

However, there has always been a lack of additional "user benefit" or "more convenience" for induction technology as criteria for generating customer needs. Addressing this issue, one innovative product entering the market was a heating application with two components, an induction plate and a metal rod / a disk-like ending.[42]

Induction is an electric heating method. Usually, a planar copper coil is supplied by electrical power via a frequency inverter (~20 to 200 kHz). Alternating current induces eddy current in nearby metallic objects such as the disk-like ending of the metal rod.[43]

Therefore, in order to heat or boil water, a cup filled with water is placed on the induction plate. The metal rod will be immersed in the liquid and the plate will be switched on. Since the liquid is directly heated in its vessel, the topic of over-boiling is not present with this technology. Such technology does not just heat or boil water but various other liquids, e.g. milk and soups.[44] Despite all advantages, the product lacks technological maturity and has not succeeded on the market yet.

---

[41] see Articel 15, 5, (e): implementing measures shall meet all the following criteria: in principle, the setting of an ecodesign requirement shall not have the consequence of imposing proprietary technology on manufacturers;

[42] see https://www.gruenderszene.de/allgemein/miito-kickstarter-insolvenz?interstitial (last call 26.06.2020)

[43] see Lot 23, Domestic and commercial hobs and grills included when incorporated in cookers, Task 4: Technical analysis of existing products, Preparatory Studies for Ecodesign Requirements of EuPs (III) [Contract N° TREN/D3/91-2007-Lot 23-SI2.521661]

[44] see https://www.kickstarter.com/projects/747044530/miito-the-sustainable-alternative-to-the-electric (last call 26.06.2020)

4.1.5.2. *Kippit Water kettles*

Another potential BNAT can be identified not in developing or using new technology but in improving the reparability and durability of electric water kettles. The product follows the approach, that every part of the kettle can be changed easily and is available for life. Stressing that repairing is not just financially advantageous but also from a circular economy point of view.[45]

There are products entering the market, which not just aim to boil water but broaden the application portfolio. Such kettle-like appliances do not just heat or boil water but do offer several different inlets that can be used to heat soup, cook noodles.[46]

4.2. Production, distribution and end of life

Following the MEERP methodology, this study requires an analysis by using base cases (BC). Base cases represent standard electric water kettles, reflecting the average product of the market. As a result of the tasks carried out so far, three base cases can be defined. The values are derived from stakeholder input, product catalogues and product data from GfK (see Task 2), existing environmental product declarations and other LCA studies for electric water kettles components or products.

4.2.1. *Definition of Base Cases*

Analysing the European market in stock and sale as well as using other relevant data, the project team suggest defining three Base Cases (BC), as follows:

- Base Case 1: simple plastic kettle with no special specifications such as temperature setting and temperature holding. The rated input power as well as the capacity of the container is relatively low. The base itself is fixed and the container has an immersed heating element. Those kinds of kettles are typically used as travel kettles.
- Base Case 2: simple plastic kettle. In terms of both capacity of the container and rated input power, this Base Case represents the average electric water kettle -highest number of kettles in stock and sale- used in Europe. The kettle has a concealed, underfloor heating element and 360° moveable base.
- Base Case 3: plastic as container material. In comparison to BC 2 special specifications, namely temperature setting and temperature holding, are considered.

Table 4-2 shows all main characteristics and basic parameters of the base cases:

Table 4-2: Overview - Base Cases

Base Case	Heating element	Material of the container	Capacity of the container[l]	Rated power input [W]	Features	Shape	Base & 360°
1	Non-concealed	Plastic	1.0	1,000-1,400	-	Jug	No
2	Concealed	Plastic	1.7	2,200 – 2,400	-	Jug	Yes
3	Concealed	Plastic	1.7	2,200 – 2,400	Temperature-setting, keep warm	Jug	Yes

[45] see https://www.kippit.fr/pourquoi-kippit/ (last call 26.06.2020)

[46] see https://www.kippit.fr/boutique/ (last call last call: 23.06.2020)

4.2.2. Bill of materials

Since the three BCs are intended to represent the average products on the current market, the bill of materials allow a scaling up of materials used and required for electric water kettles within Europe. The three BOMs were elaborated based on data provided in the valuable work of Alejandro Gallego-Schmid et al. (2018). Within this paper kettles have been dismantled and BOMs have been generated. One BOM represents a kettle out of plastic with similar features like the BCs.

Further remarks:

- If a material is occurring just once in the list of materials as well as in the list of components, no scaling and calculations have been undertaken, since it can be assumed that this material is necessary for operating the kettle.
- In comparison to BC2, BC3 has the features of pre-set temperature and temperature keeping. Therefore, BC2 acts as a reference model in terms of components and material. However further electronic components have been added. Information about the additional components are derived from a BOM of an Eco-Kettle listed in Alejandro Gallego-Schmid et al. (2018)

Table 4-3 shows a summary of the BOM of the three base cases. Further detailed explanations about the proceeding about these calculations are attached in Appendix.

Table 4-3: Summary of bill of materials

Name	BC 1	BC 2	BC 3
Description	Simple plastic kettle, low capacity, no special specifications, medium power	Simple plastic kettle, medium capacity, no special specifications, higher power	Simple plastic kettle, medium capacity, no special specifications, higher power
Capacity of the container [litre]	1.0	1.7	1.7
Material of the container	Plastic	Plastic	Plastic
Rated input power [W]	1,000 - 1,400	2,200 - 2,400	2,200 - 2,400
Temperature setting	no	no	yes
Keep warm	no	no	yes
Weight [g]	723.00	1,166.00	1,195.47
Weight incl. packaging [g]	860.80	1,433.00	1,462.47

The aggregated BOMs representing the BCs are shown in the following tables. For each BC a detailed BOM is attached in the Appendix. Whereas the BOM is presented according to the EcoReport template in Task 5.

Table 4-4: Bill of material - Overview

Name	Base Case 1	Base Case 2	Base Case 3
Description	Simple plastic kettle, low capacity, no special specifications, medium power	Simple plastic kettle, medium capacity, no special specifications, higher power	Simple plastic kettle, medium capacity, no special specifications, higher power
Stainless steel (g)	186,00	299,97	306,93
Brass (g)	20,25	32,66	32,66
Copper (g)	15,00	24,19	26,73
Aluminium (g)	-	-	0,82
Tin (g)	-	-	0,08
Silver (g)	-	-	-
Polypropylene (PP) (g)	350,25	564,86	575,32
Polyvinyl chloride (g)	43,50	70,15	72,49
Nylon (g)	49,50	79,83	79,83
Polyoxymethylene (POM) (g)	9,75	15,72	15,72
Polycarbonate (g)	6,75	10,89	10,89
Acrylonitrile butadiene styrene (g)	30,00	48,38	48,38
High density polyethylene (g)	-	-	4,88
Silicone (g)	12,00	19,35	20,75
Ag (g)			0,00
Sum	723,00	1,166.00	1,195.47

Table 4-5: Bill of material - Power Supply Base

		Base Case 1	Base Case 2	Base Case 3
BC-Component	Material	Weight	Weight	Weight
POWER SUPPLY BASE				
Plug + Cord	Polypropylene (PP) (g)	33.75	54.43	54.43
	Copper (g)	10.33	16.67	16.67
	Brass (g)	15.75	25.40	25.40
	Polyvinyl chloride (g)	42.98	69.31	69.31
Screws	Stainless steel (g)	2.25	3.63	3.63
Base	Polypropylene (PP) (g)	56.25	90.72	90.72
base centerpiece	Copper (g)	2.21	3.57	3.57
	Nylon (g)	12.75	20.56	20.56
Electronic switch (elements on the top)	Stainless steel (g)			6.96
	HDPE			4.88
	Copper (g)			0.07
	Polyvinyl chloride (g)			0.69
Electronic switch (base)	Polypropylene (PP) (g)			2.26
	Copper (g)			0.29
	Tin (g)			0.03
	Ag (g)			0.00
Keypad (cables)	Copper (g)			0.72
	Polyvinyl chloride (g)			0.71
Keypad (itself)	Polypropylene (PP) (g)			3.96
	Copper (g)			0.51
	Tin (g)			0.05
	Ag (g)			0.00
Interior cables	Copper (g)			0.96
	Polyvinyl chloride (g)			0.94
Bottons control temperature	Al (g)			0.82
Protective buttons	Polypropylene (PP) (g)			4.25
Rubber bottons	Silicone (g)			1.39

Table 4-6: Bill of material - Electronic Base-Container Kettle

		Base Case 1	Base Case 2	Base Case 3
BC-Component	Material	Weight	Weight	Weight
ELECTRONIC BASE-CONTAINER KETTLE				
connections	Brass (g)	3.00	4.84	4.84
Spiked base	Brass (g)	1.50	2.42	2.42
	Stainless steel (g)	4.50	7.26	7.26
basic electronic support	Copper (g)	1.48	2.38	2.38
	Nylon (g)	15.75	25.40	25.40
Additional element supporting base electronics	Nylon (g)	5.25	8.47	8.47
Transparent element	Polycarbonate (g)	6.75	10.89	10.89
Base extraible	Acrylonitrile butadiene styrene (g)	26.25	42.33	42.33
Base cover	Polypropylene (PP) (g)	11.25	18.14	18.14
Discs	Stainless steel (g)	0.75	1.21	1.21
Lamp cables	Polyvinyl chloride (g)	0.52	0.84	0.84
	Copper (g)	0.97	1.57	1.57
Screws + washers	Stainless steel (g)	2.25	3.63	3.63
Spring	Stainless steel (g)	0.75	1.21	1.21
Supports	Stainless steel (g)	0.75	1.21	1.21
Fixed ring	Nylon (g) (PA)	15.75	25.40	25.40
POM Parts	Polyoxymethylene (POM) (g)	2.25	3.63	3.63

Table 4-7: Bill of material - Container

		Base Case 1	Base Case 2	Base Case 3
BC-Component	Material	Weight	Weight	Weight
CONTAINER				
Handle, accessories and container				
	Polypropylene (PP) (g)	153.00	271.43	271.43
Handle	Polypropylene (PP) (g)	40.00	60.00	60.00
Accessories	Polypropylene (PP) (g)	41.75	47.15	47.17
Base metal body	Stainless steel (g)	173.25	279.40	279.40
Base target coverage	Silicone (g)	12.00	19.35	19.35
Pulser	Acrylonitrile butadiene styrene (g)	3.75	6.05	6.05
Filter and housing	Polypropylene (PP) (g)	14.25	22.98	22.98
POM Parts	Polyoxymethylene (POM) (g)	7.50	12.10	12.10
Screws	Stainless steel (g)	1.50	2.42	2.42

Table 4-8: Bill of material - Packaging

		Base Case 1	Base Case 2	Base Case 3
BC-Component	Material	Weight	Weight	Weight
Packaging				
Packaging foil	Low density polyethylene (g)	6.30	11.90	11.90
Cardboard boxes	paper (g)	131.50	255.10	255.10

4.3. Recommendations

In this task, three base cases for electric water kettles were suggested. Table 4-9 shows some design options for components and areas of the BCs where improvements would be applicable. Within Task 6 further relevant combinations are going to be investigated.

Table 4-9: Potential standard Improvements – suggestions for Task 6

Topic	Component		BC1	BC2	BC3
Thermal optimization	Material	Material substitution	X	X	X
Thermal optimization	Design	Energy efficient design	X	X	X
Thermal optimization	Construction	Insulation	X	X	X
Technical optimization	Rated input power	Seizing	X	X	X
Technical optimization	Heating element	Immersed heating element	X	n/a	n/a
Technical optimization	Heating element	Heating element substitution	X	X	X
Technical optimization	Other mechanical & electrical parts, sensors and control units	Temperature control	X	X	n/a
Technical optimization	Other mechanical & electrical parts, sensors and control units	Sensors	X	X	X
Technical optimization	Other mechanical & electrical parts, sensors and control units	boil-dry protection	X	X	X
Usage behaviour	Construction	Double chamber	X (x)	X	X
Usage behaviour	Water level indicator	Water usage	X	X	X
Usage behaviour	Heating element	Cleaning	X	n/a	n/a

<u>Legend:</u>
X = yes
(x) = yes, desirable but with restrictions

References for Task 4

BIO Intelligence Services (2011): Preparatory Studies for Ecodesign Requirements of EuPs (III) [Contract N° TREN/D3/91-2007-Lot 23-SI2.521661] Lot 23, Domestic and commercial hobs and grills included when incorporated in cookers, Task 4: Technical analysis of existing products,

Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products

Gallego Schmid, A., Jeswani, H., Fernandez Mendoza, J. M., & Azapagic, A. (2018). Life cycle environmental evaluation of kettles: Recommendations for the development of eco-design regulations in the European Union. Science of the Total Environment, 625. https://doi.org/10.1016/j.scitotenv.2017.12.262

Appendix - BOM

Since the three BCs are intended to represent the average products on the market nowadays, the bill of materials allow a scaling up of materials used and required for electric water kettles within Europe. For generating the three BOMs (see Table 4-10) following approach has been chosen:

Basic input is delivered from a paper by Alejandro Gallego-Schmid et al. (2018). Within this paper kettles have been dismantled and BOMs have been generated. One BOM represents a kettle out of plastic with similar features of the BCs. Based on this paper some calculations can be made:

- relations of materials to the total weight of the kettle
- relations of materials per component to total weight of one material

In a second step, three kettles have been identified representing the characteristics of each BC. Knowing the total weight of each of three kettles, the results of the calculations can be scaled on the total weight of the three BC-representative kettles.

For this calculation, the same approach as for calculating the relations is applied, but vice versa. In a first step, relations of materials to total weight of the BC-kettles are used to calculate the share of materials per BC.

Second step, relations of materials per component to total weight of one material are used to calculate the materials per component.

Further remarks:

- If a material is occurring just once in the list of materials as well as in the list of components, no scaling and calculations have been undertaken, since it can be assumed that this material is necessary for operating the kettle.
- Alejandro Gallego-Schmid et. al (2018) dealing with casing, handle and lid of the container of the kettle as one component. With regard to task 6, a sub-calculation has been carried out calculating the amount of the casing. On the share of handle and lid assumptions have been made.
- In comparison to BC2, BC 3 has the features of pre-set temperature and temperature keeping. Therefore, BC2 acts as a reference model in terms of components and material. However further electronic components have been added. Information about the additional components are derived from a BOM of an Eco-Kettle listed in Alejandro Gallego-Schmid et al. (2018).

Table 4-10: Overview of the BoM

		BC 1	BC 2	BC 3
BC-Component	Material	Weight	Weight	Weight
POWER SUPPLY BASE				
Plug + Cord	Polypropylene (PP) (g)	33.75	54.43	54.43
	Copper (g)	10.33	16.67	16.67
	Brass (g)	15.75	25.40	25.40
	Polyvinyl chloride (g)	42.98	69.31	69.31
Screws	Stainless steel (g)	2.25	3.63	3.63
Base	Polypropylene (PP) (g)	56.25	90.72	90.72
base centerpiece	Copper (g)	2.21	3.57	3.57
	Nylon (g)	12.75	20.56	20.56
Electronic switch (elements on the top)	Stainless steel (g)			6.96
	HDPE			4.88
	Copper (g)			0.07
	Polyvinyl chloride (g)			0.69
Electronic switch (base)	Polypropylene (PP) (g)			2.26
	Copper (g)			0.29
	Tin (g)			0.03
	Ag (g)			0.00
Keypad (cables)	Copper (g)			0.72
	Polyvinyl chloride (g)			0.71
Keypad (itself)	Polypropylene (PP) (g)			3.96
	Copper (g)			0.51
	Tin (g)			0.05
	Ag (g)			0.00
Interior cables	Copper (g)			0.96
	Polyvinyl chloride (g)			0.94
Bottons control temperature	Al (g)			0.82
Protective buttons	Polypropylene (PP) (g)			4.25
Rubber bottons	Silicone (g)			1.39
ELECTRONIC BASE-CONTAINER KETTLE				
connections	Brass (g)	3.00	4.84	4.84
Spiked base	Brass (g)	1.50	2.42	2.42
	Stainless steel (g)	4.50	7.26	7.26
basic electronic support	Copper (g)	1.48	2.38	2.38
	Nylon (g)	15.75	25.40	25.40
Additional element supporting base electronics	Nylon (g)	5.25	8.47	8.47
Transparent element	Polycarbonate (g)	6.75	10.89	10.89
Base extraible	Acrylonitrile butadiene styrene (g)	26.25	42.33	42.33
Base cover	Polypropylene (PP) (g)	11.25	18.14	18.14
Discs	Stainless steel (g)	0.75	1.21	1.21
Lamp cables	Polyvinyl chloride (g)	0.52	0.84	0.84
	Copper (g)	0.97	1.57	1.57
Screws + washers	Stainless steel (g)	2.25	3.63	3.63
Spring	Stainless steel (g)	0.75	1.21	1.21
Supports	Stainless steel (g)	0.75	1.21	1.21
Fixed ring	Nylon (g) (PA)	15.75	25.40	25.40
POM Parts	Polyoxymethylene (POM) (g)	2.25	3.63	3.63
CONTAINER				
Handle, accessories and containe	234.75			
Container	Polypropylene (PP) (g)	153.00	271.43	271.43
Handle	Polypropylene (PP) (g)	40.00	60.00	60.00
Accessories	Polypropylene (PP) (g)	41.75	47.15	47.15
Base metal body	Stainless steel (g)	173.25	279.40	279.40
Base target coverage	Silicone (g)	12.00	19.35	19.35
Pulser	Acrylonitrile butadiene styrene (g)	3.75	6.05	6.05
Filter and housing	Polypropylene (PP) (g)	14.25	22.98	22.98
POM Parts	Polyoxymethylene (POM) (g)	7.50	12.10	12.10
Screws	Stainless steel (g)	1.50	2.42	2.42
SUM		723.00	1,166.00	1,195.47

GETTING IN TOUCH WITH THE EU

In person

All over the European Union, there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact/meet-us_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by Freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 2 299 96 96, or
- by email via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from: https://publications.europa.eu/en/publications.

Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

Open data from the EU

The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

[Catalogue number]

Publications Office
of the European Union

doi:[number]
ISBN [number]