POLITECNICO
MILANO 1863

0W
Electric Kettle

Scuola del Design
Corso di Laurea Magistrale
Design & Engineering

Relatore:
Prof. Federico Elli

Candidato:
Carlo Molteni
897234

Anno accademico:
2019/2020

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Abstract

Electric kettles waste large quantities of water and energy when used; often the causes are the careless and improper use of the appliance and also it's design flaws contribute to the problem. Studies have shown how the consistency of use of the electric kettles by million of users leads to worrying datas about the frequency and quantities of wastes.
The purpose of this master thesis project is to reduce the waste of water and with it the energy necessary to heat it. The result will be an electric kettle that heats and pours just the right amount of water flowing through it, minimizing the loss of water and, therefore, the energy needed to heat it.

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01. Design research

Figure 1.1
The need for hot water

01. Design research Hot water consumption

The need for hot water

Heating the water, the process of raising the temperature of water, have always been used by humans for their needs: those could be alimentary needs, hygiene needs or the need for a heated enclosed environment. The earliest method of heating water, was on an open fire. Such a source, along with related methods such as fireplaces, cast-iron stoves, and modern heaters fueled by gas or electricity, is known as direct heating because the conversion of energy into heat takes place at the site to be heated. The evolution of our technologies had made heating water an easy task that we often give for granted. Hot water is used in almost every sector of our economy and in every part of our life, it is an essential and a basic human need, and since the beginning of times hot water is considered to be the minimum basic for a decent developed human condition.
Yet, **heating water, that our home appliances provide, is an energy-intensive consuming process, that requires loads of energy.** That's because water has a very high heat capacity, which is the amount of heat required to raise the temperature of 1 gram by 1°C, or more generally, the resistance to temperature change. Put simple, water can absorb a lot of heat with only a small temperature change. That's why we consume so much energy in water heating systems. Across the centuries these systems for heating water had developed and changed, they have been studied and optimized. These systems and devices can be divided in categories by the amount of water they heat, the fuel they use, the materials involved in the process, their dimensions, their efficiency and their popularity. Nowadays heated water is at our fingertips everytime we need it, whether it comes from an electric boiler unit of our bathroom or from the hot metal pot on an induction stove.
The methods and the devices for providing hot water had specialized for each different type of use, (shower boilers, kettles, radiators, coffee machines, irons, steam-motors etc.) and every kind of device had developed according to its practical use, with the constant aim of improvements both in costs and energy efficiency. What all these devices and methods for heating water have in common is the thesis this study wants to highlight and carry on as project focus. **The amount of water we want to heat is crucial to energy consumption, and if we heat just the right amount of it we can benefit a reduction both in water wastes and in energy demand.**

Sources:
https://www.britannica.com/technology/heating-process-or-system

Hot water usage in dwellings in the United Kingdom

To better understand the current situation of the hot water domestic consumption this thesis research acknowledge other studies conducted in recent years like the report from the british Department of Environment, Food and Rural Affairs, which describes the analysis of data on hot water consumption collected in approximately 120 houses; the study have been conducted in 2008. **The main goal of the study was to understand hot water consumption in dwellings across all United Kingdom and to find out consumption patterns** and a way to interpret the results based on mean results. The study was conducted during the whole year. The mean household consumption has been found to be 122 litres/day, with a 95% confidence interval of 318 litres/day. Statistical analysis of the flow data from each dwelling has considered the impact of geographical region, boiler type, number of occupants, and the number of those occupants who are children. It has revealed that the only one of these factors influencing consumption is the number of occupants. The mean energy content has been found to be 16.8 3 2.2 MJ/day. Energy content of water delivered has been subjected to the same statistical analysis as the flow data, and has also been found to depend only on number of occupants.

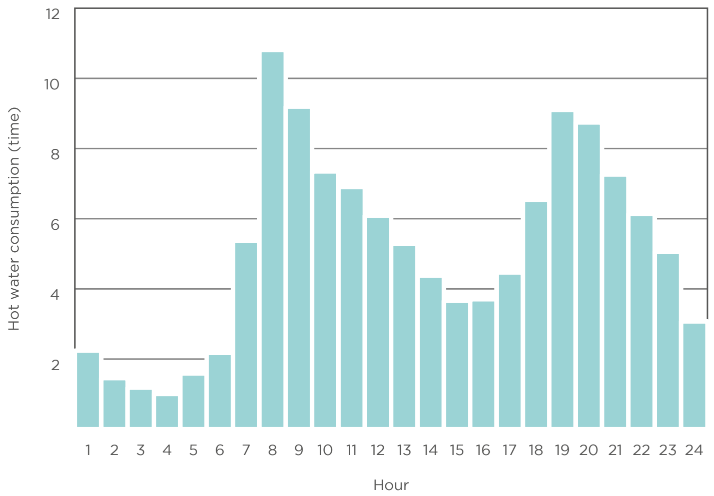


Chart 1.1
Daily runoff profile of whole sample

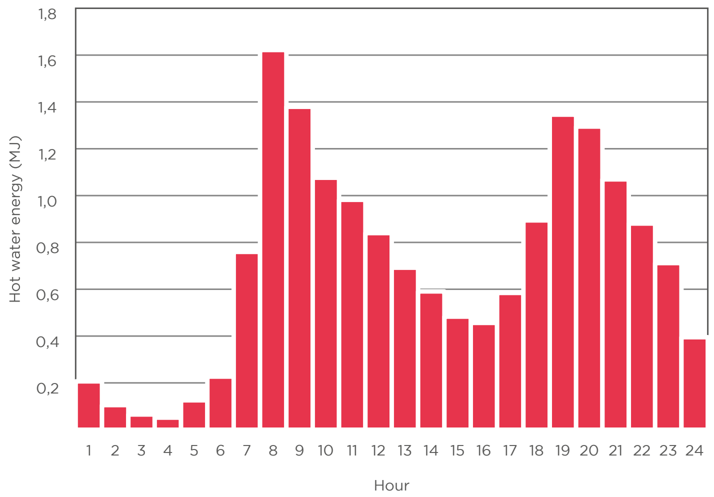


Chart 1.2
Energy delivery profile for whole sample

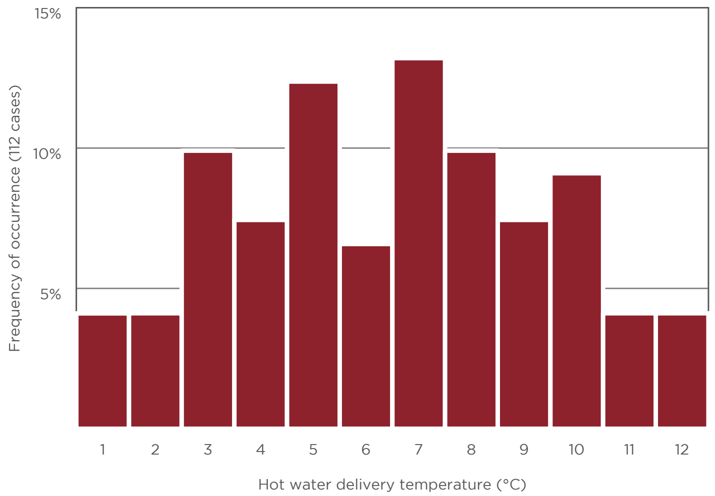


Chart 1.3
Distribution of hot water temperatures

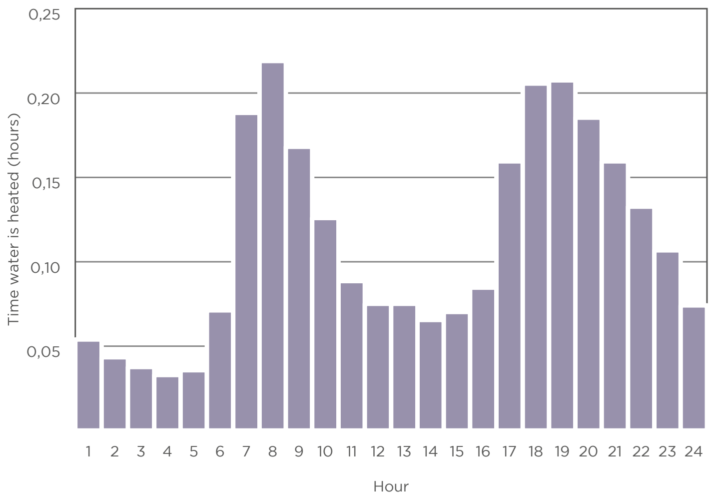


Chart 1.4
Water heating behaviour across whole sample

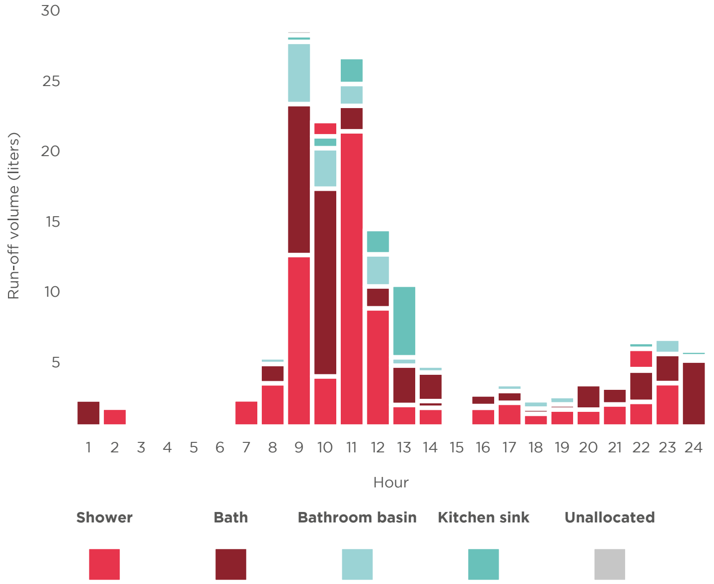


Chart 1.5
Run-off volume profiles at each location in a sample dwelling

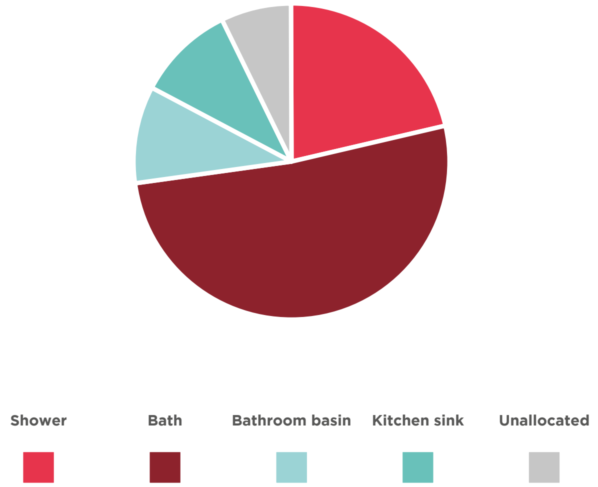


Chart 1.6
Relative runoff volume at each location in a single dwelling

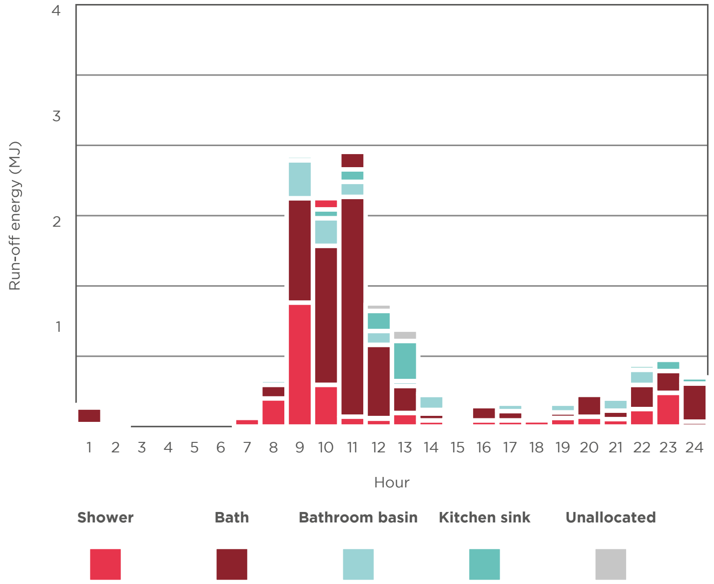


Chart 1.7
Run-off energy profiles at each location in a sample dwelling

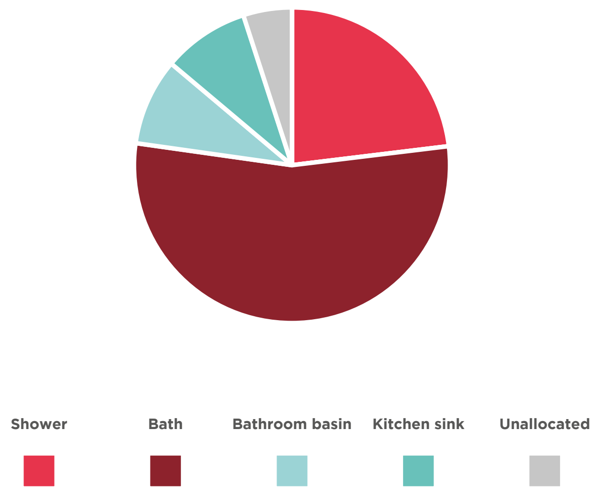


Chart 1.8
Relative run-off energy at each location in a single dwelling

Source:
DEFRA, Department for Environment, Food and Rural Affairs, 2008, Measurement of domestic hot water consumption in dwellings

Hot beverages consumption in the United Kingdom

A study conducted by British adults in 2013 highlighted the importance of drinking hot water in drinks using a survey, conducted with 1724 participants. The primary purpose of this study was to quantify the total intake of water and its relation to beverage consumption patterns. Research in Europe and the USA have reported that around 70 percent -80 percent of the total intake of water comes from various types of drinks (including beer, tea and coffee, milk, soft drinks, juice and alcoholic beverages), with the remainder relating to water in food. In developed societies, where tap water is essentially free, drinks are widely available, but there are concerns that some people may not drink enough fluid for optimal health and some people may be over-consuming. Children, the elderly or the infirm and those working in hot environments are some of the most vulnerable to the effects of dehydration, but at one time many adults may also be insufficiently hydrated. Mean total water intake was 253 L for men and 2.03 L for women, below the "adequate intake" (AI) of 2.5 L and 2 L, respectively, by the European Food Safety Authority. **Beverages made up 75 per cent of the total intake of water. The intake of beverages peaked at 8 A.M., primarily hot drinks and milk, and also at 21 P.M., mostly alcohol**. Total consumption of drinks at weekends

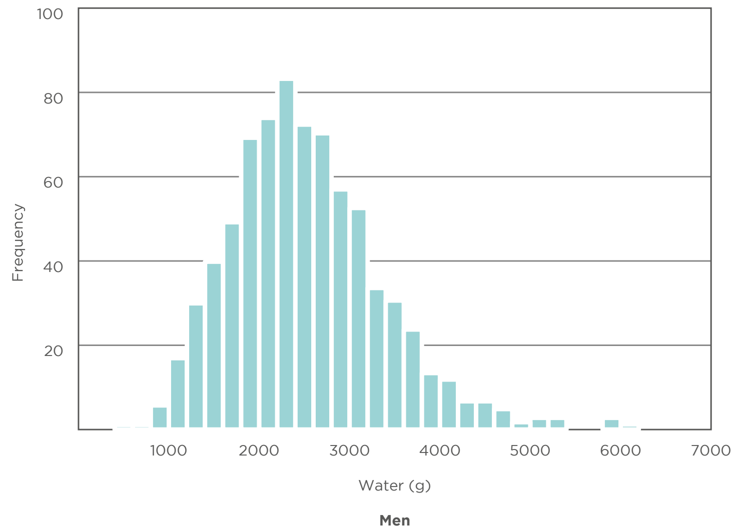


Chart 1.9
Frequency of total water intake g/d over 7 days, by men

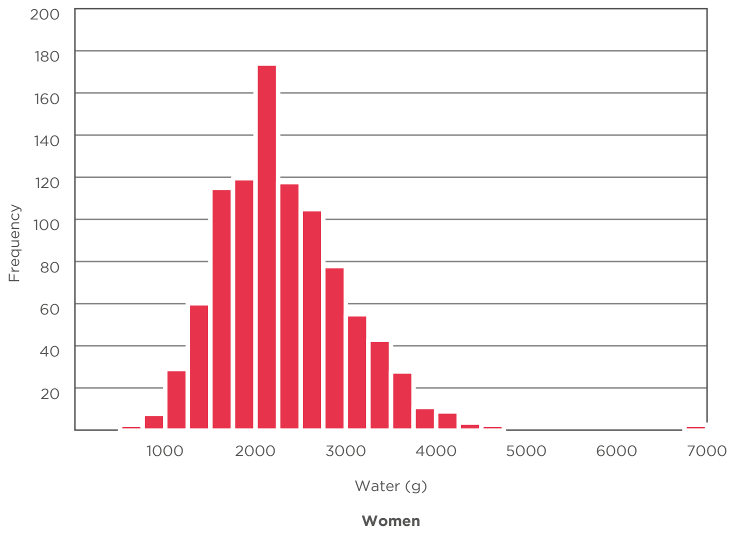


Chart 1.10
Frequency of total water intake g/d over 7 days, by women

was higher, especially among men. Overall, drinks accounted for 16% of the energy intake (men 17%, women 14%), alcoholic drinks accounted for 9% (men) and 5% (women), milk 5-6%, caloric soft drinks 2%, and fruit juice 1%.

Total water intake from all sources averaged 2.5 L and 2.0 L and men and women, respectively (Figure 1.9 and 1.10). Beverages accounted for 75% of total water and 66% of the total weight of food and drink consumed. Mean beverage consumption was 1779 g/d (2012 g/d among men, 1593 g/d among women). **Hot drinks (principally tea and coffee) were consumed by 97% of men and women,** similarly for milk (95-96%) (Figure 2). Among men, alcoholic drinks were more popular than tap water (79% vs. 60% consumed, respectively), while 66% of women consumed alcohol and 73% drank tap water. More than half the sample drank caloric soft drinks at least once during the week, while less than half drank fruit juice, diet soft drinks or bottled water. Tea and coffee accounted for over 40% of the total daily weight of beverages while milk provided an additional 12%. Men consumed much higher quantities of alcoholic drinks and slightly more caloric soft drinks. By contrast, women consumed more tap water and diet soft drinks. Bottled water and fruit juice were consumed in small amounts by both sexes. Younger men and women consumed less hot beverages and milk, but significantly

more soft drinks (both caloric and non-caloric) and alcohol than older adults.
Hot beverages, tap water and alcohol were most highly correlated with the total water intake. Alcoholic drinks, caloric soft drinks and milk had the highest correlation with the energy intake, while for tap water and bottled water the coefficients were essentially zero.

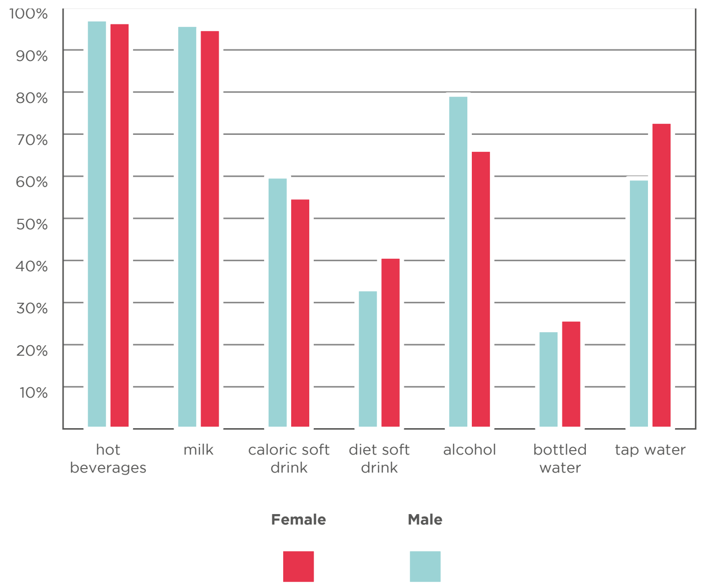
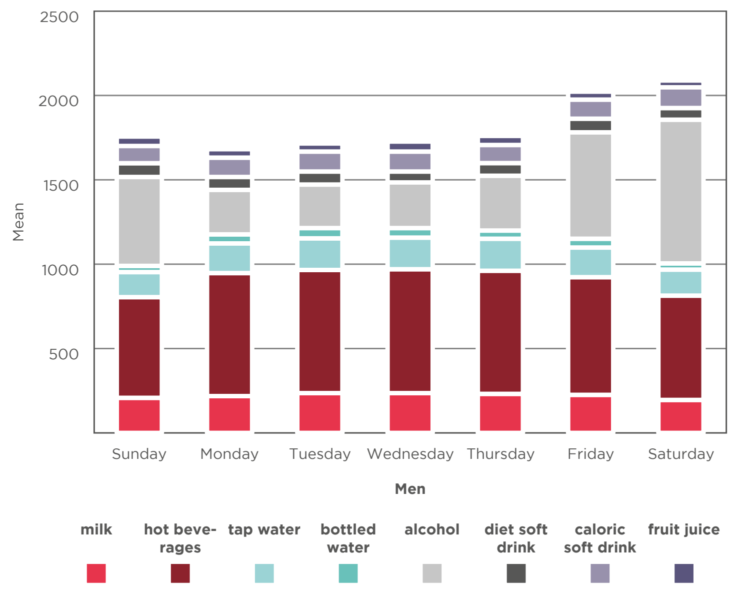


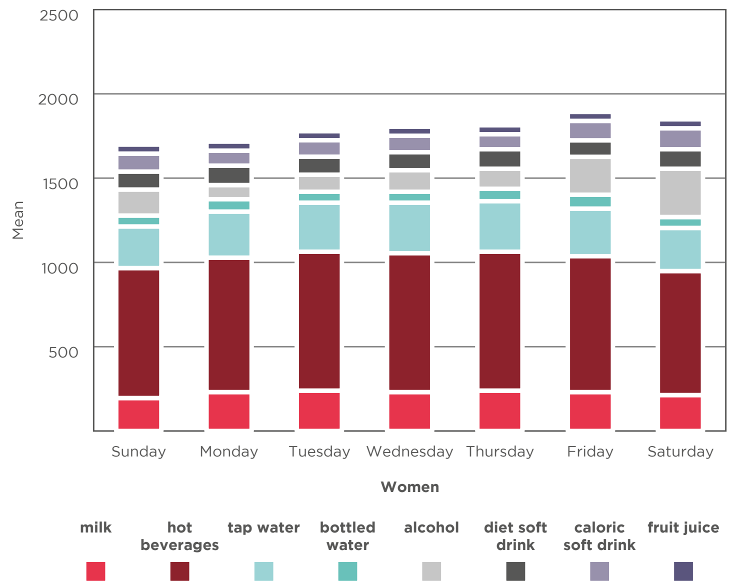
Chart 1.11
Popularity of beverages (% consuming over 7 day period)

Out of a maximum of 8 different types of beverages in our classification, the mean "variety score", averaged over 7 days, was 3.3 for both men and women. Adults consuming fewer than 3 types had a lower total water intake and were less likely to meet the adequate intake of water compared with those drinking 3 types or more. Variety score was positively correlated with the total water intake and with energy intake, suggesting that beverage variety is an indicator of higher consumption of food and drink generally.

Total water intake and beverage consumption was significantly higher on Fridays and Saturdays than on other days of the week, especially among men. This appeared to be attributable to higher consumption of alcoholic drinks at weekends, especially

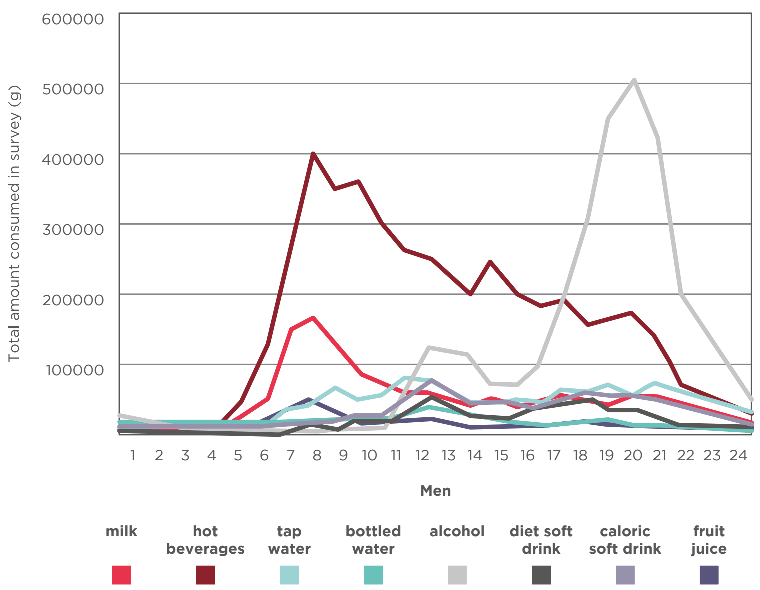
Saturday (Figure 1.11). Women showed weaker trends, but consumption on weekend days was still twice that on other days of the week. Saturday consumption of alcoholic drinks averaged 262 g among women and 949 g among men. Smaller differences in the opposite direction were observed for hot beverages and water. Consumption of soft drinks and fruit juice did not vary greatly by day of the week.
Older adults consumed more beverages in the morning, young adults in the evening.. For example, men aged 50y + consumed on average 30% of their beverages before 10 A.M., while young men (19-35y) consumed less than 22%; older men consumed 30% after 18 P.M. compared to 36% among younger men. Similar trends were observed among women. Evening consumption appeared to be driving the higher total beverage consumption on Fridays and Saturdays.

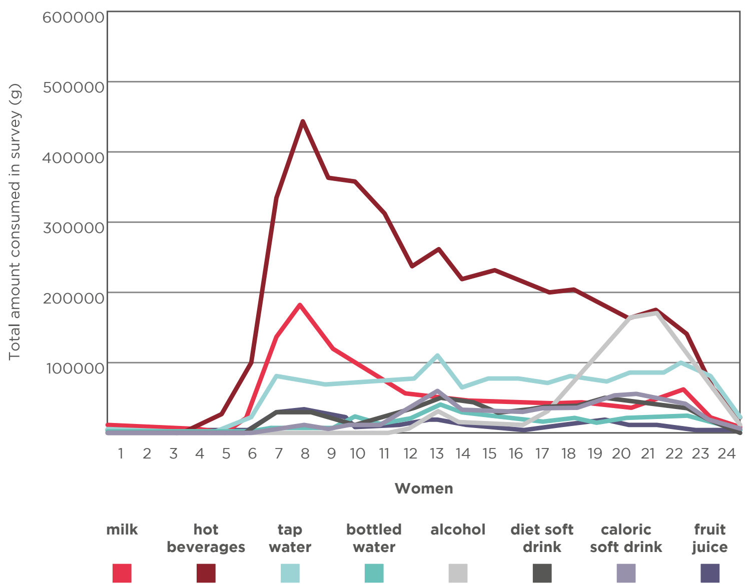




Source:
S. Gibson, S. M. Shirreffs, 2013, Beverage consumption habits "24/7" among British adults: association with total water intake and energy intake, Gibson and Shirreffs Nutrition Journal

Charts 1.12 and 1.13
Time of consumption by beverage type





Charts 1.14 and 1.15
U.S. hot drinks market size, by product, 2015-2025 (USD Billion)

Hot beverages market analysis (global)

The global market size for hot drinks was estimated at USD 250.7 billion in 2018 and is expected to grow over the forecast period at a CAGR of 6.8 percent (“Compound Annual Growth Rate”). **Health-related awareness raising has increased demand for quality goods. The demand for drinks, including green tea, lemon tea, and detox coffee and tea, is growing as a result of increasing awareness of this product’s health benefits**, which in turn drives the market for hot drinks over the forecast period. A key factor driving market growth is the launch of hot drinks with varying health benefits.Increasing installation of coffee vending machines is expected to fuel the demand for hot drinks mostly in offices and corporate locations over the forecast period. Consumers have started to opt for hot drinks over carbonated drinks because of increased awareness about the possible harmful effects of carbonated drinks. The market is expected to see significant growth due to increased awareness among the young population about the health benefits of drinking hot drinks like coffee and tea in reducing unhealthy diseases such as diabetes, blood pressure and obesity.
Manufacturers are using various products and ingredients, which are certified by GRAS, Kosher, HACCP, USDA Organic, and GMP, in order to improve product offering and expand their consumer base. Several manufacturers are developing creative tea and coffee flavors with added health benefits that may enable the hot beverage market to grow in the coming years. Consumers are changing their choice to de-stress and detox beverages because of the hectic lifestyle and rising cigarette consumption, which is expected to increase the market for green tea over the forecast period. In addition, manufacturers are introducing innovative products like instant coffee, which can be easily prepared just by adding hot water, milk, and sugar.
The key hot drink players concentrate on rebuts and comprehensive supply chain as well as growing their market presence through retailers such as dollar shops, mass merchandisers, retail stores, grocery stores, and supermarkets. This is expected to fuel hot drink demand over the forecast period.

Coffee dominated the market among all hot beverages, representing 42.7 per cent of global sales in 2018. The segment is expected to maintain their lead over the forecast period. Growing popularity of organic coffee is one of the key factors in coffee growth over the forecast period. Organic and natural coffee is free of pesticides and chemicals, and thus fueling health conscious people’s demand.Growing demand for organic coffee has driven many producers to produce new and innovative varieties and flavors. In addition, cafe chains and coffee shops

concentrate on fast and natural coffee, thereby fueling growth in the industry. Most young generations prefer coffee because it contains a high amount of caffeine that helps the body charge up, which can contribute to market growth in the years to come. **Tea is the fastest growing category, rising over the forecast period at a CAGR of 7.6 per cent**. Increase in tea production and consumption in Asia Pacific is a major driving factor for the market over the forecast period. High tea consumption has been observed in Asia Pacific countries such as India, China, Thailand and Pakistan. To boost their sales, producers focus on different premiumization and exclusive tea flavours.Organic India Company, for example, has made masala tea packs which help improve metabolism and the immune system. Premiumisation has increased new ideas in various countries like Japan, India and Singapore, such as subscribing. The sector is also driven by the luxury tea lounge and on-line delivery. Tea capsules have been launched recently in many regions, but the attitude of the consumer toward the drug has been a bit negative.The Asia Pacific market dominated the market in 2018 and is expected to grow by 7.9 percent at the fastest CAGR over the forecast period due to the increasing number of retail and franchise outlets in the country. In addition, heightened brand awareness is a major reason for the region's market growth. Increasing Millennial population will be a key audience over the forecast period for the global hot drinks industry. **Millennials are willing to spend on hot drinks because organic hot drinks reach more and more. In addition, increasing product visibility of high quality product and flavors and aromas is driving the market for hot drinks over the forecast period.** Consumers are looking for unique and different flavors of tea that are of authentic taste and high quality. This has led to an increase in sales and premiumization across many countries of Asia. People from many places of Asia are consuming and preferring premium tea. It may fuel the growth of the market for hot drinks in this region.
In 2018 Europe held the second largest share. Since the last few years the region has witnessed an increase in demand for coffee pods. What's more, U.K. Has a massive demand for ready-to-drink or instant coffee products which, in turn, is expected to fuel hot drinks market growth in the coming years. In the case of tea, ready-to-drink tea such as tea bags and capsules are becoming widely popular in regions such as North America. In the U.S., one in six people suffer from obesity which can lead to serious health problems. This may be one of the reasons why people shift their tastes from soda-related beverages to hot drinks like coffee or tea, and this can drive the growth of the industry.
Some of the key market players of hot drinks are Tazo Tea Company; Tata Global Beverages; Keurig Green Mountain (KGM); Costa Coffee; Starbucks; Celestial seasoning Inc.; Caffe Nero; Ajinomoto General Foods Inc.; Associated British Foods

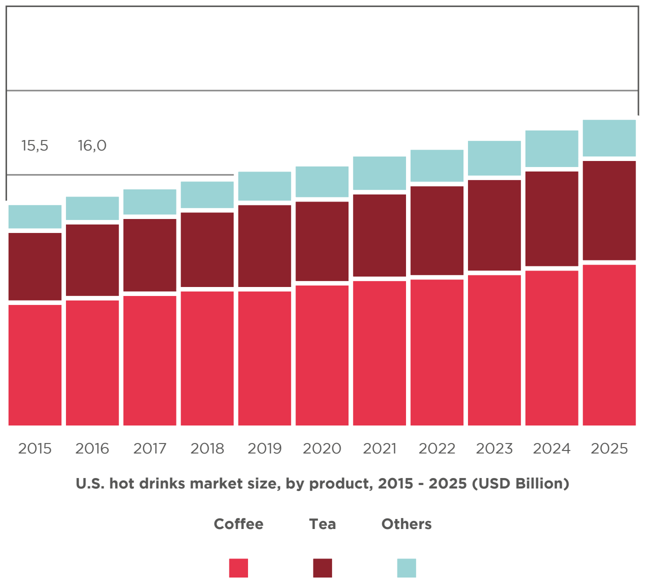


Chart 1.16
U.S. hot drinks market size, by product, 2015-2025 (USD Billion)

(ABF). Companies have been launching new products and knowing consumer preferences and behavior in order to meet customer needs. Moreover, the comfort of consumers is taken into consideration while making a new product. For instance, in 2017, Hotshots, U.S. based coffee company, launched Hotshot hot can coffee, which is driving the coffee market in U.S.
Other important players are Jacobs Douwe Egberts (JDE), Keurig Dr Pepper, Tchibo, J.M. Smucker and Lavazza. Out of home, Starbucks, Tim Hortons, Panera Bread, Costa Coffee, Peet's Coffee, Dunkin' Donuts and Caribou Coffee are the most important players. An important company in the background of both at-home and out-of-home coffee is the Luxembourg-based JAB Holding which has built a sizable portfolio in retail and coffee shop brands and owns at least partially both Jacobs Douwe Egberts and Keurig Dr Pepper as well as Panera Bread, Peet's Coffee and Caribou Coffee among others. In the Tea segment, Unilever (Lipton), Associated British Foods (Twinings) and Tata Global Beverages (Tetley) are the biggest players by revenue while Nestlé is the most important player in the Cocoa realm.
The market for Hot Drinks is structured into retail sales for at home consumption and on-premise or foodservice sales for out-of-home consumption. The at-home market, also called off-

trade market, covers all retail sales via super- and hypermarkets, convenience stores or similar sales channels. The out-of-home market, also called on-trade market, away-from-home market or HORECA encompasses all sales to hotels, restaurants, catering, cafés, bars and similar hospitality service establishments. Both the at-home and the out-of-home market are valued at retail selling prices including all sales and consumption taxes. The price per unit in the out-of-home market always references the total price over the kg amount of coffee, tea or cocoa consumed, regardless of the other components of the finished beverage. The valuation of the out-of-home segment at retail prices means a significant change of the market definition in comparison to earlier iterations of the Consumer Market Outlook, as out-of-home consumption was valued at wholesale prices before. This means, market totals are not comparable to published data from prior years. The price per unit always references liters as a base unit for both at-home and out-of-home consumption. One liter of beverage represents typical serving sizes of 2 to 5 glasses (0.2 to 0.5 liters).

Chart 1.17
Revenue in the Hot Drinks market amounts to US$165,909m in 2020.

Source:
https://www.grandviewresearch.com/industry-analysis/hot-drinks-market

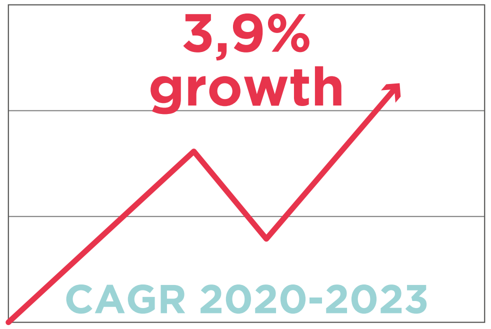


Chart 1.18
The market is expected to grow annually by 3.9% (CAGR 2020-2023)

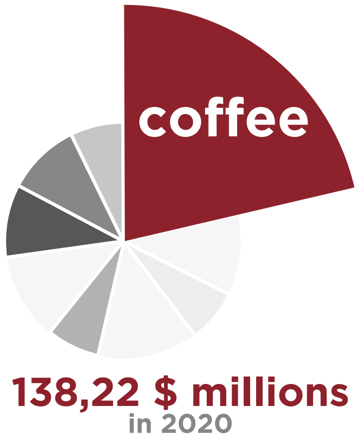


Chart 1.19
The market's largest segment is Coffee with a market volume of US$138,222m in 2020

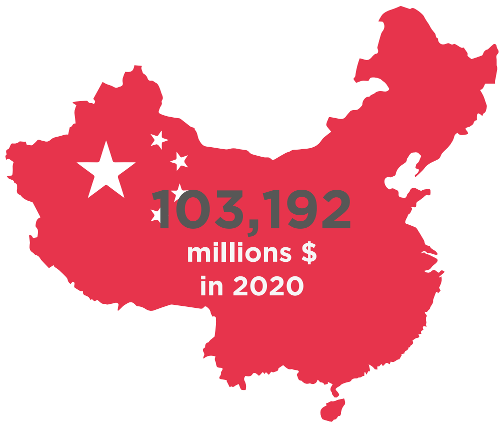


Chart 1.20
In global comparison, most revenue is generated in China (US$103,192m in 2020)

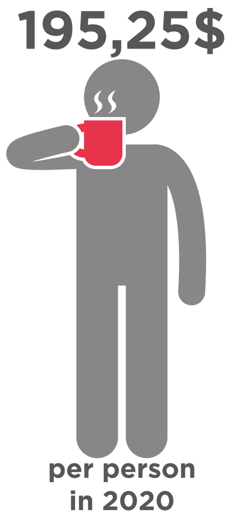


Chart 1.21
In relation to total population figures, per person revenues of US$195.25 are generated in 2020

Figure 1.2
Hot beverage market forecast

Hot beverages market forecast

The global market for hot beverages (coffee and tea) in terms of volume is projected to exceed 19 million tons by 2024 driven by a wealth of **factors encouraging increased frequency of consumption such as improving publicity surrounding the health benefits of coffee and tea drinking;** convenience of instant coffee and RTD tea innovations and launch of single cup brewers (RTD states for “Ready To Use”), all of which tend to influence behavioural frequency of consumption. Other important factors that are expected to benefit market prospects include innovative packaging formats that are portable, easy-to-use and easy-to-consume; launch of weight loss gourmet coffee, protein fortified coffee and slimming tea targeted at the growing base of obese and health conscious population. rise of iced tea as a mainstream RTD beverage product; chilled addiction among consumers and the ensuing popularity of cold brewed coffee. Innovations ranks as key to market growth right from kid-friendly coffee drinks, bubbly (carbonated) coffee drinks, tea infused dishes, Matcha powdered green tea leaves as a more potent source of nutrients that steeped green tea, speciality iced teas with exotic ingredients such as sweet condensed milk or coconut milk, all promising to give a fresh twist to consumer demand and consumption patterns. Noteworthy innovative launch of speciality coffee in regional tastes include Thai/Vietnamese iced coffee; Greek frappès, Vienna, Greek, Giorgian, Turkish and irish coffee, Italian Espresso, among others. Also helping drive consumption patterns are flavored tea and beverages brewed to perfection to capitalize on the indulgence trend. Noteworthy flavor innovations in coffee include maple walnut coffee, rosemary latte, honey cinnamon latte, iced caramel latte, tart flavored coffee etc. The success of flavors in the coffee segment is leading to the rise of coffee-inspired teas with lattes and mochas making their way into tea flavors. Asia-Pacific represents the largest and the fastest growing market with a volume CAGR of 5.0% over the analysis period. Presence of two of the leading producers and consumers of coffee and tea, China and India; rise of the coffee culture among the burgeoning middle class population; rising income levels; rapid urbanization, growing brand awareness; Westernization and preference for lifestyle products; improving retail infrastructure and availability of premium and speciality coffee and tea varieties and mushrooming speciality coffee outlets, represent key growth drivers in the region. Through 2024 coffee will remain the largest market, followed by tea. Mental health, cardiovascular well-being and fitness and appearance benefits to spur the emergence of tea as the fastest growing segment.

There are two main varieties of coffee, coffee arabica and coffee robusta, which have the highest share in the world’s commercial coffee market. The processing method, altitudes of growth, size, density of the bean and age of the bean have an influence on the flavour of the coffee beans, and based on these factors, the two varieties can be further classified commercially. Tea is a beverage, which is almost 2000 years old. There are 3000 varieties of tea available worldwide. The characteristics of tea are dependent on its growth environment; it's processing and blending. There are basically three main categories of tea: green tea, black tea and oolong tea.

Major players:

Costa Limited

Luigi Lavazza S.p.A.

Nestlè S.A.

Starbucks

TATA Global Beverages

Celestial Seasonings, Inc.

R. Twinings and company Limited

Figures 1.3
Major players

Source:
https://www.strategyr.com/MarketResearch/market-report-infographic-hot-beverages-coffee-and-tea-forecasts-global-industry-analysts-inc.asp

Hot beverages Trends

Latest market forecasts extending to the year 2020 are also now available. **Consumers showed a growing preference for premium hot drinks and health-positioned beverages in 2015.** In foodservice and retail channels, growing consumer sophistication contributed to growth in fresh coffee beans and premium tea as shoppers looked for higher-quality products and attractive environments. Many consumers are also seeking out health benefits from their beverages. Sales of tea and malt-based hot drinks grew in 2015 as producers marketed their drinks as offering antioxidant and nutritional properties. At the same time, certain shoppers are looking for convenience, aiding sales of coffee pods and instant coffee. Given the weak global economy, the global hot drinks industry did well, as it achieved a slight improvement over growth in 2014. Growth reached 7% in off-trade current value terms, with tea the fastest growing category – followed by a strong performance for other hot drinks and coffee (the overall volume leader). Off-trade volumes in hot drinks grew by 2%.

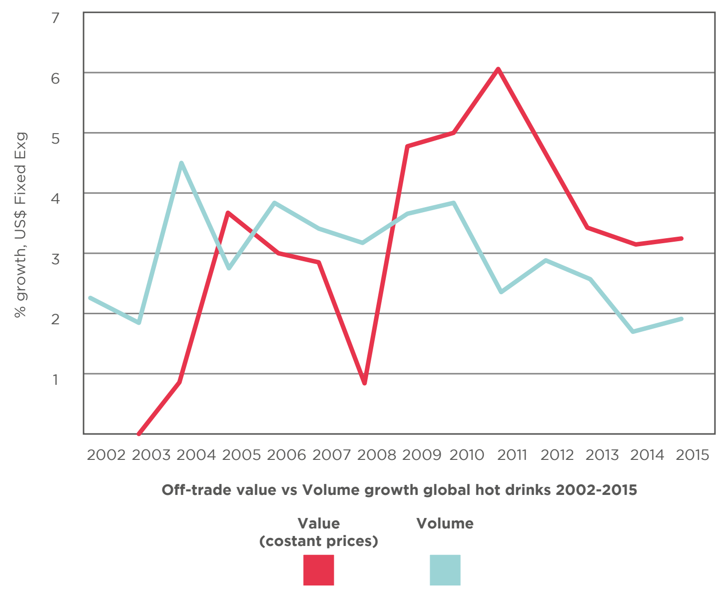


Chart 1.22
Off trade value vs volume growth global hot drinks 2002-2015

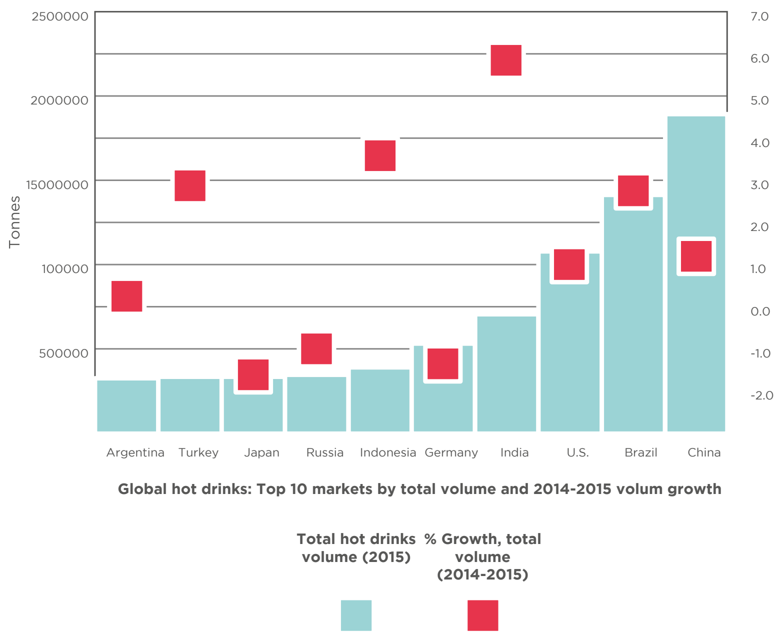


Chart 1.23
Global hot drinks: top 10 markets by total volume and 2014-2015 volume growth

2015 was characterised by weakness in key emerging markets for consumer goods but the hot drinks industry was less impacted than other industries, as hot drinks are still viewed by many consumers as affordable necessities. Among the BRICs, India was a success story with 6% total volume growth for hot drinks in 2015, up from 4% in 2014. India's economy and demand for hot drinks have been less impacted by the slowdown in the global economy because its GDP is less reliant on exporting of manufactured goods and raw materials than Brazil, China, or Russia. Though Brazil's economy slowed in 2015, the country was able to achieve 3% volume growth for hot drinks in both 2014 and 2015. As one of the world's largest producers of coffee, Brazil grows most of the coffee consumed domestically, making coffee affordable to all economic groups. Looking over the next five years, Brazil is expected to lead all nations in terms of forecast growth in absolute terms. Top line volume consumption of hot drinks is expected to remain stable over the forecast period, with a 3% CAGR expected over 2015-2020.

"Tea benefits from consumer perception as a healthy beverage"

Tea outperformed coffee and other hot drinks in total volume terms in 2015 with 3% growth. Volume sales of packaged tea are benefiting from a number of reasons. In developed markets such as US and Norway, tea's perceived health benefits and the expansion of premium tea specialists are driving higher consumption. In emerging markets such as China and India, the move from buying unpackaged tea (not tracked by Euromonitor International) in local markets to purchasing packaged tea in retail outlets is driving volume growth. **Consumers increasingly view tea as a beverage with multiple health benefits as tea producers tout tea's high levels of flavonoids, an antioxidant.** Companies are now touting that theanine, an amino acid found in green tea, heightens mental alertness. As tea producers in developed countries launch more teas, they are focusing on health and wellness by introducing teas with Ayurvedic positioning, organic certification, and detox properties. The expansion of tea specialists providing a wide range of different tea products in certain countries is also boosting tea sales. In Norway, total volume sales of tea grew by 5% in 2015, the highest among the Western European countries. The growth of tea specialists such as Black Cat Kaffe og Tehus and Le Palais des Thés that target young, urban women with a selection, variety and quality that is much higher than supermarkets has generated renewed interest in tea and resulted in stronger growth for premium tea. Total volume sales of tea grew by 4% in the US in 2015 for similar reasons to Norway. Tea specialists such as Starbucks-owned Teavana, DAVIDsTEA, and Argo Tea have created attractive environments with knowledgeable staff where affluent consumers can learn more about and sample different teas. The premium nature of the teas and decoratively packaged gift boxes offered in tea specialists also allow tea to become a gift item, much like a box of chocolates. The migration of many Asia Pacific consumers from rural to urban areas, combined with increasing incomes, has created high demand for packaged and branded teas. Fewer consumers are going to wholesale markets nowadays and instead shop in supermarkets, hypermarkets or other grocery stores where packaged tea prevails. The movement from unpackaged to packaged teas has contributed to volume growth for tea in China and India despite competition from newer beverages such as coffee and packaged juices. India saw its total volume sales of tea grow by 4% in 2015 while sales of tea grew by 2% in China.

Source:
https://blog.euromonitor.com/key-global-trends-in-hot-drinks-from-2015/

Google hot beverages report insights

Three main trends in beverages:

- Process becomes primary
- Flavors go earthy
- More water, more premium

In Spain and Mexico, hot infusions are most likely to be searched at night. As demonstrated in top associations, both markets strongly associate infusions with health benefits - and time of day could play a role in activating the beverage's benefits. Not all infusions are created equal. **Consumers associate a hot water process with enabling certain benefits or flavors. Temperature is a new dimension to consider in dialing up positive health associations with brands.** In Mexico and Spain, hot infusions are searched by functionality and consumed as part of a night-time ritual. Reach consumers when they are looking to foster healthy rituals, at the right moments in the day. As evidenced mainly in the US and the UK, the tea process is strongly associated with experiences. The key insight to better improve brands sales is to connect with consumers when they want to connect with others; turn your beverage into an experience, in or out of home. **Based on Google Search data, growth in water is being fueled by interest in a more enhanced hydration experience. Consumers are thirsty for water**. We see growing interest in safe, clean and accessible water options. We also see increased consumer demand for more premium water, elevated via process or container. More water: demand is being driven by filtered and bulk water across all four markets. Consumers are trying to drink more water and want it to be accessible in and out of home. Re-imagine how to make safe, clean water more accessible in people's lives. The growth of interest in water is also being fueled by the premiumization of water. Many of the top trending water searches are related to enhancing water by boosting alkalinity, adding carbonation or using premium water bottles.

Source:
Google, 2017 , Think with Google, Bevarage Trends Report 2017, US, UK, ES, MX.

Process becomes primary

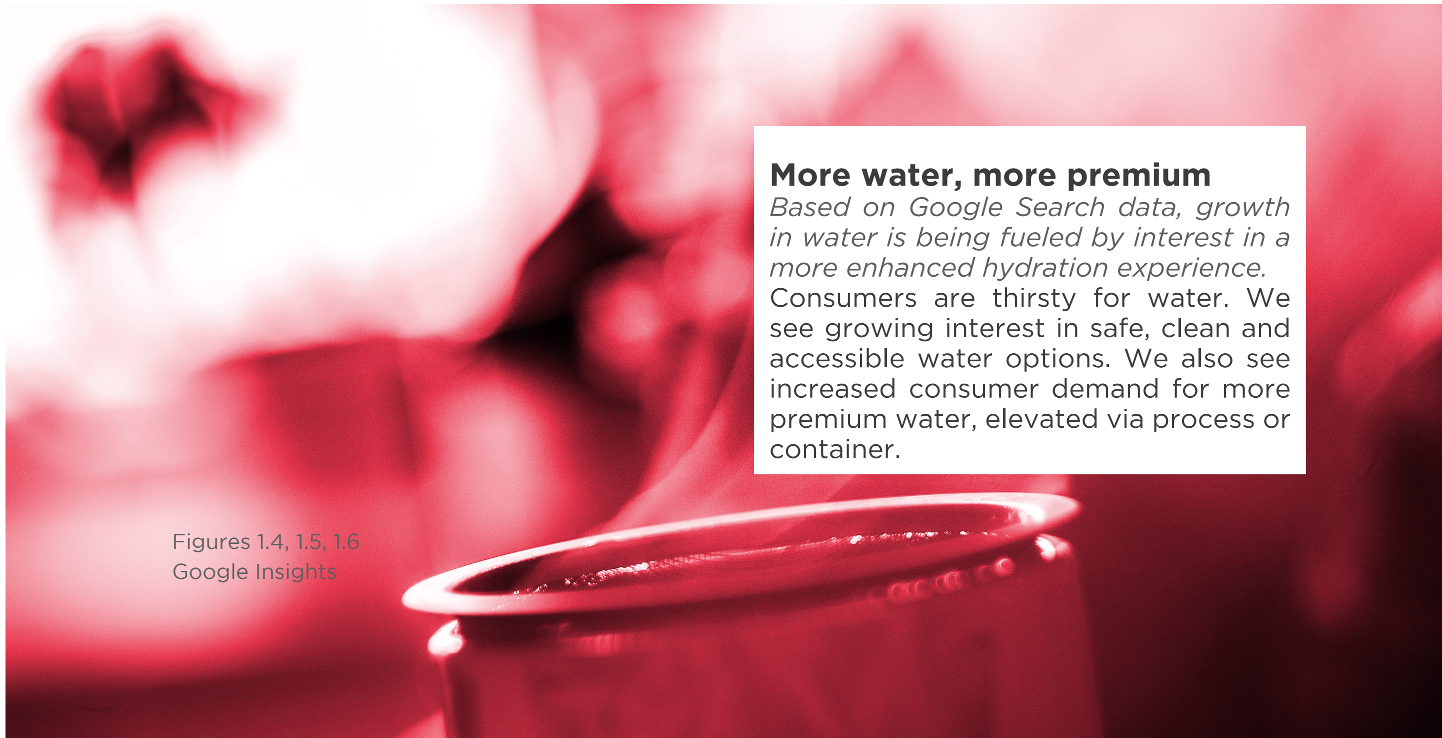
How a drink is made is just as important as what's in it.

Whether it's driven by health, taste or connoisseurship, there is a growing interest in beverages that are defined by the key process through which they are made.

Flavors go earthy

Plant-based ingredients are bringing bold new flavor notes to the beverage equation.

As we look at the most prominent trending searches in the beverage category, we see that earthy flavors are taking off in all four of our markets and that a wide variety of botanical based beverages are in demand.

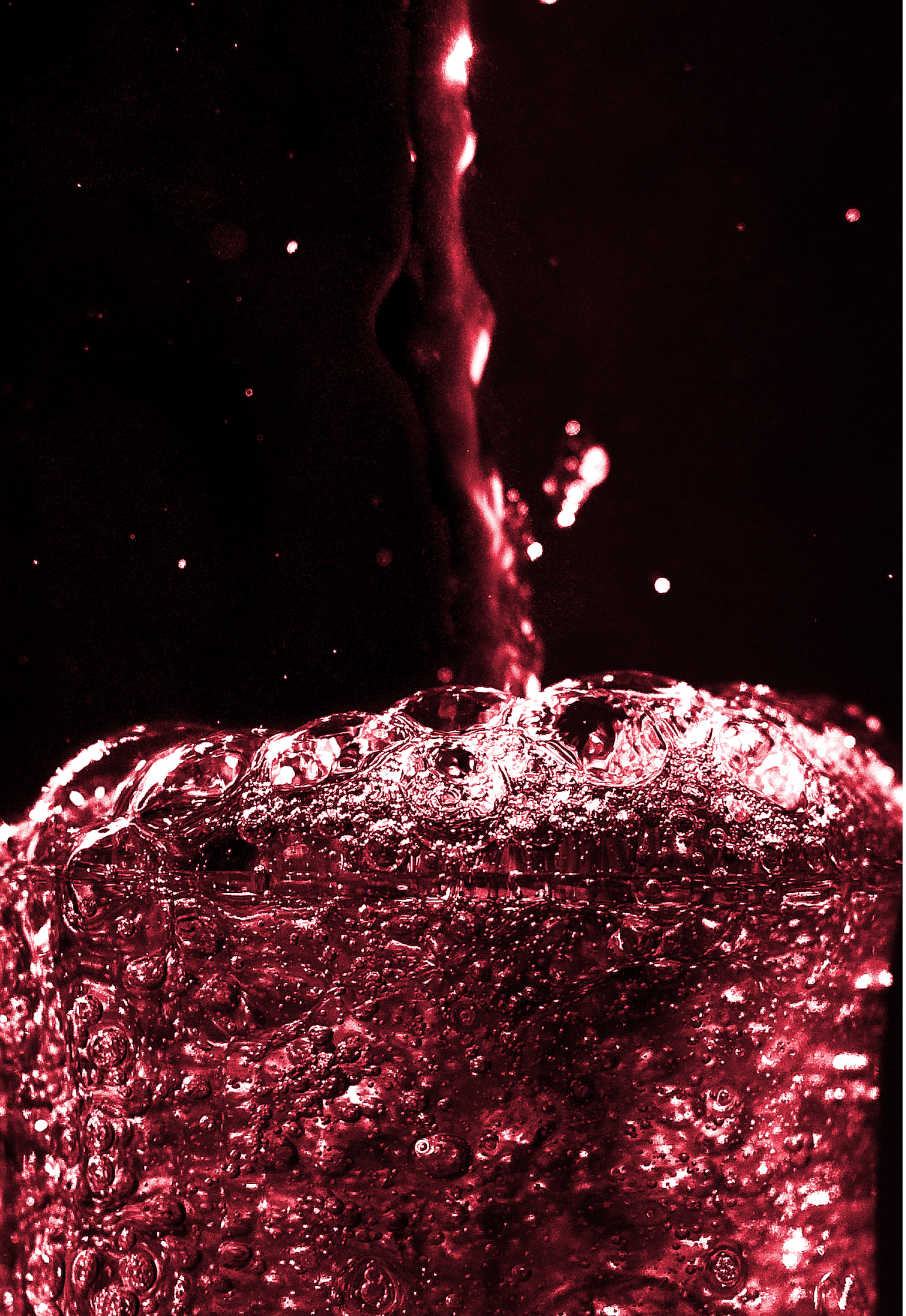


More water, more premium

Based on Google Search data, growth in water is being fueled by interest in a more enhanced hydration experience.

Consumers are thirsty for water. We see growing interest in safe, clean and accessible water options. We also see increased consumer demand for more premium water, elevated via process or container.

Figures 1.4, 1.5, 1.6
Google Insights



Heating the water

General physics

What is heat?
In science, thermodynamic equations, in particular, heat is defined as the flow of energy between two systems by means of kinetic energy. This can take the form of transferring energy from a warm object to a cooler object. More simply put, heat energy, also called thermal energy or simply **heat, is transferred from one location to another by particles bouncing into each other.** All matter contains heat energy, and the more heat energy that is present, the hotter an item or area will be.

Heat and temperature
Heat refers to the transfer of energy between systems or bodies, whereas temperature is determined by the energy contained within a singular system or body. In other words, heat is energy, while temperature is a measure of energy. Adding heat will increase a body's temperature while removing heat will lower the temperature, thus changes in temperature are the result of the presence of heat, or conversely, the lack of heat. Particles have more energy at higher temperatures, and as this energy is transferred from one system to another, the fast-moving particles will collide with slower moving particles. As they collide, the faster particle will transfer some of its energy to the slower particle, and the process will continue until all the particles are operating at the same rate. This is called thermal equilibrium.

Units of heat
The International System of Measurements unit for heat is a form of energy called the joule (J). Heat is frequently also measured in the calorie (cal), which is defined as "the amount of heat required to raise the temperature of one gram of water from 14.5 degrees Celsius to 15.5 degrees Celsius." Heat is also sometimes measured in "British thermal units" or Btu.

Ways of transferring heat
There are three basic ways to transfer heat: **convection,** conduction, and radiation. Many homes are heated through the convection process, which transfers heat energy through gases or liquids. In the home, as the air is heated, the particles gain heat energy allowing them to move faster, warming the cooler particles. The conduction process is the transfer of heat energy from one solid to another, basically, two things that are touching. We can see an example of this can be seen when we cook on the stove. When we place the cool pan down on the hot burner, heat energy is transferred from the burner to the pan, which

Figure 1.7
General physics

in turn heats up. Radiation is a process in which heat moves through places where there are no molecules, and is actually a form of electromagnetic energy. Any item whose heat can be felt without direct connection is radiating energy.

Electrical heating elements
An electrical heating element is normally a detachable part of a furnace, an appliance, or a heater consisting of one or more electric circuits. In each circuit heat is generated by passage of electric current through a resistor that is joined to a terminal in each end. The two terminals are connected to an available voltage by means of copper leads. The terminals are designed in such a way that the temperature at the joint between them and the leads is low enough to avoid oxidation of the leads or damage to their insulation. In electrical heating elements for appliances the assembly of resistor(s) and terminals is often mechanically supported by electric insulation that is part of the element.
Heat is transferred by conduction, convection, or radiation or a combination of them. Through solid and opaque bodies heat is transferred by conduction only. The most important formula for the conduction in a thermal steady state is:

$$\mathbf{p = -A\ \Delta T/dx}$$

p = surface load or rating per unit cross section
A = thermal conductivity
T = temperature

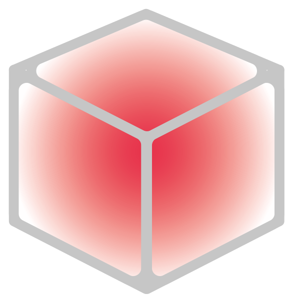


Figure 1.8
Heating element

Heating up a streaming fluid
When streaming air or fluid is heated by the rating P, the following equation for the temperature increase of the fluid may be useful:

$$\mathbf{T = P\ /\ (\ c \cdot\ y \cdot Q\ )}$$

$$°C = W\ /\ (\ KJ/Kg \cdot K) \cdot (Kg/m^3) \cdot (m^3/s\ )$$

Q = volume of fluid transported per time unit (m3 /s)
For water:
c = 4.18 J/g · K (Specific heat)
y = 1000 kg/m3 (density)

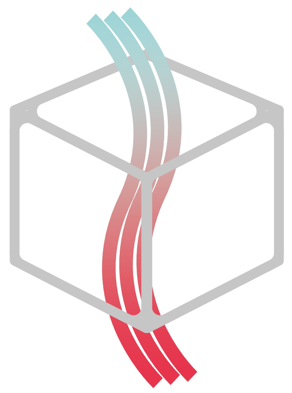


Figure 1.9
Streaming fluid

Flow is defined as the quantity of fluid (gas, liquid or vapour) that passes a point per unit time. Definition of Q and its unknown values:

$$\mathbf{Q = m^3\ /\ s}$$

$$m^3 = x$$

(t) s = Distance (mm) / velocity

The average speed will be given by the final speed of the liquid divided by two. We assume that the initial speed of the water is zero and that the liquid falls into the coil only thanks to the force of gravity. Potential initial gravitational energy is equal to the chinetic final energy of the liquid. Therefore:

$$\mathbf{Uin = m \cdot g \cdot h = \tfrac{1}{2} \cdot m \cdot \bar{u}^2}$$
$$= m \cdot g \cdot h = \tfrac{1}{2} \cdot m \cdot \bar{u}^2$$
$$= g \cdot h = \tfrac{1}{2} \cdot \bar{u}^2$$

Inversed formula:

$$\mathbf{\bar{u} = \text{frazione di } (2 \cdot g \cdot h)}$$
$$\mathbf{\bar{u} \text{ media} = (\sqrt{2 \cdot g \cdot h}\,) / 2}$$
$$\textit{Distance} = h$$
$$\textit{gravity force} = 9{,}8 \, m / s^2$$

Our initial formulas with the units:

$$\mathbf{P = c \cdot \ y \cdot Q \cdot \Delta T}$$
$$\mathbf{P = c \cdot \ y \cdot (h / \bar{u} \text{ media}) \cdot \Delta T}$$
$$W = (KJ/Kg \cdot K) \cdot (Kg/m^3) \cdot (m^3/s) \cdot \Delta C°$$

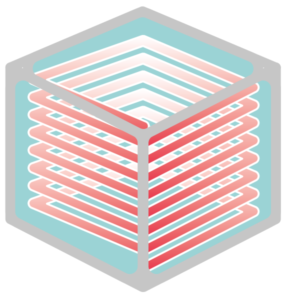


Figure 1.10
Heating element resistance

Source:
T. Hegbom. (1997). Integrating Electrical Heating Elements in Appliance Design, Marcel Dekker Inc., 270 Madison Avenue, New York, New York 10016

Figure 1.11
Pot on fireplace

Figure 1.12
Yayoi asukayama hanami. [Translated title Third Lunar Month, Blossom Viewing at Asuka Hill]. Woodcut print by Kitao Shigemasa, between 1772 and 1776. Library of Congress Prints & Photographs Division.

History of the electric kettle

The previous chapter was all about the general theories current physics interprets nature's rule and interpret them as formulas and schemes, but how is it done in practice in our current times, how do we heat water in our homes, appliances and devices? Which processes do they use, which materials are they made with? Which temperatures can they reach and how much energy do they need? Also What differentiate them from each other, and more importantly, how well do they perform? All these questions will be answered in this chapter whose aim is to provide a general understanding of the state of the art about electrical heating water appliances. **The kettle is quite a popular item in most kitchens around the world. It is used mainly to heat water for tea and it comes in many variety of shapes, sizes and colors. The history of the kettle as we mean it nowadays, started with tea.**

Tea has a rich and complex history, throughout which we find all sorts of political intrigue, social divisions, cultural traditions or mystery. Even the origin of tea is a little mystical, but it is an important starting point. China is the birthplace of the tea and it was used for a long time as a tool in trade relations and control. It was brought in Europe- its first official mentioning is in the document Chai Catai ("The Chinese Tea "), by Giovannita Ramusioin published in Venice in 1559.

The British make quite a fixation for tea and from there it gets in the United States around the 1700s, brought by the European immigrants. Around 1760, the tea was the 3rd most traded merchandise, being outranked by textiles and manufactured goods. The oldest known kettle was found in Mesopotamia and dates back to between 3500 and 2000 BC. It is made of bronze and has a decorated beak. However, apart from its comparable form, specialists do not believe it shares all similar functions with the kettle that has evolved over the last 200 years; that one found in Mesopotamia was probably used for filtering rather than for boiling water.

The history of the electric kettle is related to that of early iron and copper kettles, which were initially used for cooking. Kettles evolved and took different forms in different countries. The elegant Russian metal samovar is thought to have originated in Persia. In England, silver kettles are part of the tradition of English tea during the 1700s. Until now, kettles were always placed above a flame, and this practice continued until the late nineteenth century when the chore of boiling water began to change dramatically. Early kettles would have been made of iron and by the 19th century copper was a common material. Such kettles were heated directly over a fire or stove. The copper version required frequent cleaning as it tarnished each time it was used. **Carpenter Electric Company of Chicago introduced**

its first electric kettle in 1891. It took twelve minutes to heat the water because the element was in a separate compartment, and not immersed in the water as it is in modern kettles. The same year, a British inventor, R.E.B. Crompton of Crompton and Company in the United Kingdom, has developed a concept of heat radiator for the electric kettle. When the electric Carpenter company exposed its electric kettle at the Chicago World Fair in 1893, the company incorporated Crompton's thermal radiator concept. In 1922, the company Swan presented the first electric kettle with integrated heating element. The heating element was enclosed in a metal tube which was housed in the water chamber of the kettle. This design grew in popularity in the following years.
The credit for the creation of **the first electric kettle goes to Russell Hobbs**, a company established in the UK in the 1950s by William Russell (1920-2006) and Peter Hobbs (1916-2008). Kettles were mainly made from metal with bakelite handles and lids gaining popularity during the 1930s, during the second world war several ceramic designs that featured bakelite lids were

Figure 1.13
First electric kettle

produced due to the shortage of metal products. These stayed popular for many years and in 1956 Russell Hobbs produced the first fully automatic kettle bring the kettle into the modern age. Before this, electric kettles could evaporate completely if unattended or cause an electric shock. This automatic electric kettle, manufactured by Russell Hobbs in 1955, had a bimetallic strip that triggered off the kettle's tension.
Over the years, inventors have continued to create improvements in the kettle. In 1923, Arthur L. Large of the UK invented the first fully immersible heat resistance of the kettle. In the 1930s, a boilermaker named Walter H. Bullpitt invented the electric kettle safety valve. British inventor and entrepreneur John C. Taylor created and perfected the kettle thermostat, which ensures that the kettle stops after the water is boiling. In the modern era, in a world fascinated with automation, remote start-up programming and smart technologies, it is no wonder

Source:
http://www.russellhobbs.com/our-heritage.aspx

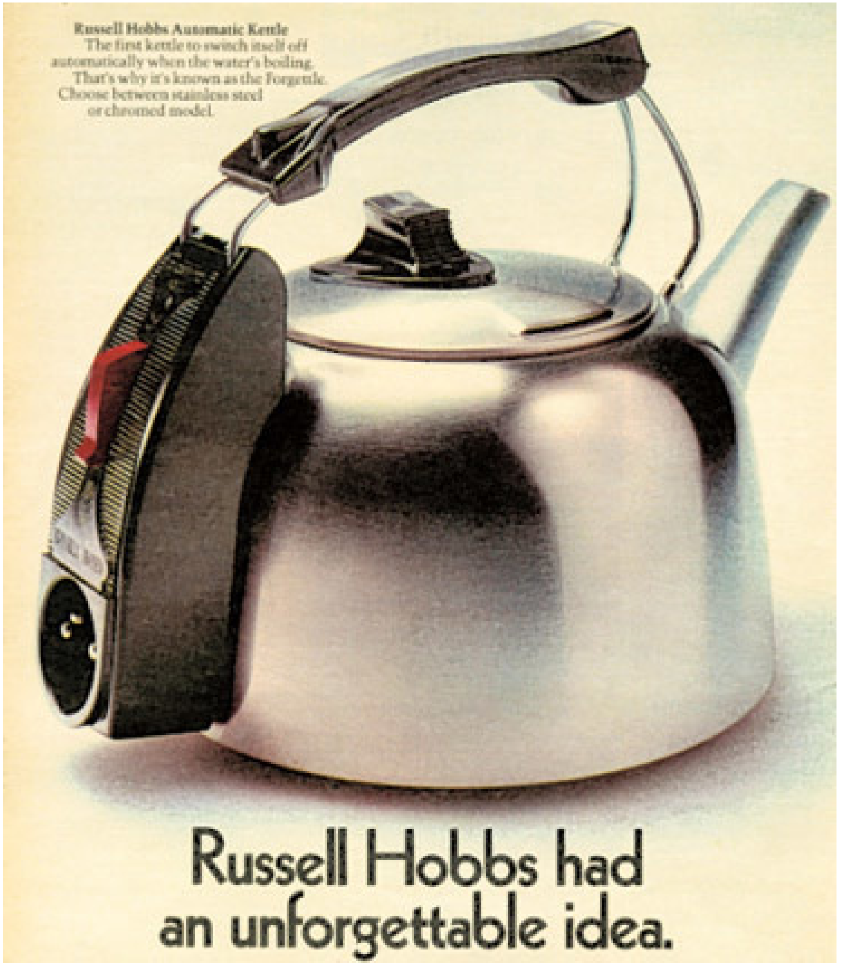


Figure 1.14
Russell Hobbs kettle

that even the good, old kettle has undergone some upgrades. Two examples to illustrate how technology transformed the kettle: the I-pot and the iKettle.
The I-pot is a Japanese invention made by the home appliance manufacturer Zojirushi, in partnership with Fujitsu and the NTT telephony operator, at the request of an association of aid to the elderly. The idea was to equip a daily object, in this case, the kettle, with a wireless communication system that records the movements of the object (displacements, uses) and sends this information to an outsider (family, life support): if the kettle is used at regular times, it is deduced that the person drinks tea or herbal tea normally; if the use of the kettle multiplies or stops abruptly, there is an alert. The I-pot allows non-intrusive surveillance of frail people.
The iKettle is connected via WiFi that you can program remotely with an iPhone. It is particularly handy in the morning or in the afternoon when you simply want to go to the kitchen and find hot water ready for you to enjoy with your favorite tea.

Figure 1.15
IKettle

Design history of the electric kettle and related objects

Figure 1.16
Arare Teapot

Arare Teapot (1700)

Unknown Designer
Various producers
from 1700 to nowadays
Iwachu, from 1914 to nowadays

It is not necessary to have visited Japan to recognize the Arare teapot: the ubiquitous teapot for daily use has raised its characteristic functional design to international standard. Made of cast iron, the Arare teapot - which in Japanese means "hail" - takes its name from the traditional rusticated decoration that covers the upper surface and the outer edge of the lid. The spread of Arare teapot dates back to the XVIII century Japan, when Japanese intellectuals adopted the Sencha method for the tea ceremony as a sign of symbolic revolt against the most sumptuous Chanoya ceremony favored by the ruling classes. When the Sencha method invited one to savor the pleasure of the tea ceremony to a greater extent, the market opened to a less expensive teapot. The Arare model - evolution of the previous Tetsubin, or "teapot" - appeared therefore in this period and finally established itself in 1914. The most famous reproduction plant of the Arare, the Iwachu of Morioka with over one hundred years of history, is today the largest and most important cast iron utensil factory for the kitchen. Still in production, the model is exported in significant quantities all over the world.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.17
Brown Betty Teapot

Brown Betty Teapot (1919)
Unknown Designer
Various producers
from 1919 to nowadays

The origins of the teapot par excellence date back to the 17th century, when British potters began to copy the spherical line of teapots imported from China. Dark brown, and glazed, the Brown Betty was an evolution, signed by the Dutch brothers Elers and Bradwell Wood, in Staffordshire, compared to the red clay teapots. From that moment on in Britain the Brown Betty embodied the passion for tea, even after the subsequent spread of more refined porcelain. The Acock, Lidley and Bloore company produced the model between 1919 and 1979. In 1974 the company was taken over by Royal Doulton. Since then, various manufacturers have reinterpreted this historic teapot, but not all of them refer to the original line. In a self-respecting Brown Betty, in the inside of the spout a series of holes filter the tea leaves; the lid remains in place even when the teapot is tilted, and the end of the spout is tapered to minimize dripping. Available in different sizes ranging from a capacity of two to eight cups, Brown Betty has conquered the mass market thanks to the perfect balance between functionality and elegance.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.18
Tea and Coffee service

Tea and Coffee Service
Marianne Brandt (1893-1983)
Bauhaus Metallwerkstatt, 1926
Alessi, from 1955 to nowadays

Distinguished lecturers and university professors have regularly paid tribute to Marianne Brandt's tea and coffee service, while collectors regret that it is her's only original full service. The set, including a kettle, teapot, coffee pot, sugar bowl, milk jug and tray, is in 925/1000 silver with ebony inserts. The clean profile and the geometric shapes of the circle and the square lend strength to the whole. The teapot is supported by a low support of two parts welded in a cross, with an elegantly polished hemisphere, the round lid and the high silver handle that incorporates a handle set in dark ebony. The only woman to work in the Bauhaus metal workshops, Marianne Brandt was a very versatile designer, known for her adjustable metal lamps, her paintings and her brilliant photomontages. The tea and coffee service reproduced here is a classic example of the Bauhaus progressive philosophy, which exalted manual work practices, and objects whose shape is determined by use.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.19
Tea infuser and strainer

Tea infuser and strainer
Marianne Brandt (1893-1983)
Bauhaus Metallwerkstatt, 1924

During its brief existence (1919-33) the Bauhaus produced a group of architects and designers whose work profoundly influenced the visual environment of the twentieth century. These men and women believed that everyday objects, stripped of ornament, could achieve beauty simply through form and color. Brandt's tea infuser is the quintessential Bauhaus object. Only three inches high, its diminutive size results from its function. Unlike conventional teapots, it is intended to distill a concentrated extract, which, when combined with hot water in the cup, can produce tea of any desired strength. While incorporating the usual elements of a teapot, the designer has reinvented them as abstract geometric forms. The body is a hemisphere cradled on crossbars. The thin circular lid, placed off center to avoid drips (a common fault of metal teapots with hinged lids), had a tall cylindrical knop. The handle, a D-shaped slice of ebony set high for ease of pouring, provides a strong vertical contrast to the object's predominant horizontality. Although the pot is carefully resolved functionally, its visual impact lies in the uncompromising sculptural statement it makes. It is definitely modern.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.20
Tea dispenser

Tea Dispenser
Hans Przyrembel (1900-1945)
Bauhaus
Metallwerkstatt, 1926
Alessi, from 1955 to nowadays

Simple in its form, this dispenser invites those who use it to the tea ritual. It is nothing but a small cylinder 20.5 cm high with a diameter of 6, and a mirror surface devoid of any decoration. By removing the cap, the arched spout protruding from the lower edge turns into a spoon to dose the right amount of tea. When the object is closed, the object is somewhat enigmatic, but opening it, it becomes useful and practical. Under the artistic direction of Làszlò Moholy-Nagy, the metal workshops of the Bauhaus developed a whole range of prototypes for industrial production. Then assistant master of the atelier, Willhelm Wagenfeld proved to be a decisive source of inspiration for this work: according to his words "each object must find its own formal solution in its formal use". Moved by this spirit, Hans Przyrembel designed the tea dispenser which, like eight other Bauhaus designs, was put into production only in 1995 by Alessi. The original Przyrembel prototype was in silver, while the version marketed by Alessi is in stainless steel.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.21
Chemex coffee brewer

Chemex coffee brewer (1941)
Peter J. Schlumbohm (1896-1962)
Chemex, from 1941 to nowadays

The Chemex coffee machine looks like both a laboratory tool and a kitchen utensil. Every detail, from the name to the design, is designed to offer a scientific approach to preparing coffee. Peter J. Schlumbohm, the chemist who created it, started from a simple chemist set: an Erlenmeyer flask and a laboratory glass funnel. That combination gave the final form of Chemex, made with a single piece of laboratory thermal borosilicate glass with the characteristic hourglass shape. Schlumbohm limited himself to making some practical changes, such as the addition of an air duct and a spout, a small notch on the side of the jug to indicate the level of the medium and a wooden and leather handle to be able to lift it when it was hot. The economy of materials used by Schlumbohm were justified in part from the restrictions imposed by the war, but also reflected the principles of simplicity and naturalness of the Bauhaus design that he brought with him from Germany. Ultimately, his coffee machine is the perfect fusion of science and art: it does what it seems to be made for and has an attractive look.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.22
Bombè tea and coffee service

Bombè tea and coffee service (1945)
Carlo Alessi (1916-2009)
Alessi, from 1945 to nowadays

In many respects the Bombè tea and coffee service can be considered the very symbol of the history of Alessi's production: it was created by Carlo, who joined the company after becoming an industrial designer in Novara. Alessi was appointed general manager of the company in the '30s and he was responsible for the creation of most of the objects produced between the middle of that decade and 1945, the year in which he presented his latest project, the Bombè tea and coffee service. This set, more than anything else, has helped to consolidate the reputation of the manufacturer of modern and innovative designs. Its durable design, made in four different sizes, is an openly an industrial product and the purity of its lines pays homage to the history of modern design. The Bombè tea and coffee service is clearly inspired by simple geometric shapes and a total absence of that decoration that characterizes works by previous designers. At the beginning of the era the set was supposed to be in chromed or silvered brass, and from 1956 it was manufactured in stainless steel. At the time it was openly modern and not even today is out of place among new designs. It remains one of Alessi's best selling tea and coffee sets.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.23
Table service TAC

Table service TAC (1969)
Walter Gropius (1883-1969)
Rosenthal, from 1969 to nowadays

Walter Gropius was one of the great exponents of architecture and industrial design of the twentieth century. Founding the Bauhaus in 1919, with his background as an architect he was able to translate a new training approach in which artisans, artists and entrepreneurs coexisted and collaborated. In 1937 he emigrated to the United States and in 1945 he founded "The Architects' Collaborative" (TAC), a studio that generated important projects, such as the Harvard Graduate Center between 1948 and 1950. In the 1950s the German porcelain firm Rosenthal, open to the international design, was commissioning the organic and sculptural ceramics of Beate Kuhn, and also the company was commissioning Raymond Loewy to design a coffee service in 1954. The TAC table service made for Rosenthal by Gropius managed to blend his penchant for curves with Kuhn styles and Loewy. The hemispherical height of the teapot evokes the basic forms of the Bauhaus, while the aerodynamics of the handle refers to the style of that period. The TAC tea and coffee service appeared in Rosenthal's Studio-Line collection in 1969 and has remained in production ever since.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.24
Kettle 9091

Kettle 9091 (1983)
Richard Sapper (1932)
Alessi, from 1983 to nowadays

The two-liter 9091 kettle from 1983 - shiny, elegant, massive - can be considered the first real kettle made by a designer. Richard Sapper was inspired for this design by barges and steamships that went up and down the Rhine and their sirens whose echos sounded in the fog. The considerable size of the kettle (19 cm in height for its 16, 5 in width), its refined and shimmering dome, it's rather high price, placed it in the center of the ideal house. There is almost a certain haughtiness in this dome facing upwards, a geometric purity that places it on a completely different plane than the traditional graceful forms of previous kitchen items of this type. The 9091 kettle has a copper base between two layers of steel which guarantees excellent heat transmission, the handle is made of polyamide and a spring mechanism operated by the handle opens the spout to fill it or to pour its content. To distinguish this kettle from any other it's his whistle: modulated in E and B, they are made expressly by some craftsmen of the Black Forest. Knowing the rest, he always said that it was important to "ensure some pleasure and fun to the people".

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.25
Kettle with whistle 9093

Kettle with whistle 9093 (1985)
MIchael Graves (1934-2015)
Alessi, from 1985 to nowadays

The kettle 9093 with whistle, designed by the american Michael Graves is one of the products of the most successful commercial series to be born from the post-modern design movement of the '80s. Received by Alessi the task of designing a kettle aimed particularly at the American mass market, Graves had started from Richard Supper's Kettle 9091 (1983) also produced by Alessi. With its simple clean shape, minimal decoration, a sober use of materials, the kettle with whistle 9093 is in essence a very simple modernist design, but a way to make it cross the borders of modernism are the details, such as the addition of the bird and the use of strong colors for the handle. From the red molded plastic bird comes out of the whistle of the kettle. When it was launched in 1985, this kettle became an instant hit, much appreciated by consumers for its extreme and witty design, and it earned the post-modernist design classic label. The kettle is still in production today, and is available in the satin as well as glossy version and with handles and birds in different colors.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.26
Hot Bertaa

Figure 1.27
Brunch set

Hot Bertaa (1989)
Philippe Starck
Alessi, from 1989 to 1996

This aluminum kettle is filled by pouring water in through the cylindrical handle. It's considered design allows the water to enter the kettle, heat and exit through an opening that appears to be an extension of the handle. Production of this kettle stopped in 1996, as a proof that not all of Philippe Starck's designs were so successful. This kettle, launched in 1990, is the favorite design fiasco of Alessi CEO Alberto Alessi. The cone-shaped shaft pierces the body of the kettle, serving as both its handle and spout. The complex mechanism needed to redirect the steam proved unreliable, leading Alessi to pull it from the market in 1997. Says Alessi, "You shouldn't need an instruction manual to operate a kettle." "The Hot Bertaa is one of my first pieces produced by Alessi. Alessi is a star, so it was a real highlight, a heart-stopping moment. Michael Graves had done it, as had Richard Sapper, so I had to be extraordinary, to show all my talent. But I became somewhat self-deluded and came up with the theory of immobile aerodynamics. With hindsight, I was just trying to get myself noticed, I wanted to make a masterly, sculptural object. In fact, this sculptural object is one of my worst pieces ever. It isn't very functional, it's dated, too fashion conscious. It's one of the things I'm most ashamed of."

Source:
http://www.designophy.com/designpedia/

Brunch Set (2003)
Jasper Morrison (1959)
Rowenta, from 2004 to nowadays

Kitchen appliances have long been advertised and purchased in the wake of new trends and innovations. The manufacturers have relied on marketing and design to distinguish their products and to guarantee them a dignified short life. Jasper Morrison's brunch set, produced by the manufacturer Rowenta, stands out immediately: with their delicate movements with inviting curves, surface and structure hold the key to communication. The automatic cordless kettle, with hidden polished stainless steel heating element, is noble in its use and appearance. the concept of concealment is also transposed into the "all in one" coffee maker, with a single integrated compartment for the coffee filters, the filter itself and the serving spoon. The toaster has instructions on the front, no longer as usual on one side. It would be a mistake to label this purity of lines with misleading interpretations, since the Set is neither minimalist, nor modernist, nor functionalist. But although valuable design objects, their success over time will always have to be a kettle, a toaster and a coffee machine.

Source:
Phaidon Press. (2013). The Design Book. London.

Figure 1.28
Plissè

Plissè
Michele De Lucchi (1951)
Alessi, from 2018 to nowadays

Echoes from the world of architecture, design and fashion are grafted into the details that give shape to Plissè, the project by Michele De Lucchi for Alessi. “With the wise and creative use of folding, stylists model the fabrics and create clothes like art sculptures,” says De Lucchi. “Plissé is shaped starting from a folded sheet of paper and created by Alessi as a beautiful tailoring object. The Plissé electric kettle is shaped by a pleat that enhances its timeless beauty, like that of a sculpture masterpiece or a sophisticated haute couture dress. “Plissé” seems to combine geometric solids: a cone for the body, a cylinder for the handle, a triangular prism for the spout. A domestic micro-architecture that represents a meeting point between functional and aesthetic aspects. With its shape “defined by the folds of an ancient but always current technique”, the “Plissé” electric kettle is a pure example of an advanced industrial culture, which synthesizes method of design, technology, experimentation and poetry, outlining a future as new icon. from the Alessi website: “The Plissé kettle combines functional aspects with a plastic and fascinating design that reveals the author’s training as an architect, as well as his passions for craftsmanship and sculpture. A kettle like a dress modeled by a stylist, a splendid object to be left visible on a kitchen surface”.

Source:
https://www.alessi.com/it_it/designers/dalla-c-alla-f/michele-de-lucchi.html

Figure 1.29
MIITO

MIITO
Nils Chudy
International Top 20, Dyson Award 2014

MIITO is an innovative product that heats liquids directly in the vessel to be used, hence eliminating the heating of excess water. Simply fill your cup with water, place it onto the induction base and immerse the rod in the liquid. The induction base heats the rod, which then heats the liquid surrounding it. MIITO works with non-ferrous vessels of any size, for example a pot of tea when inviting guests. MIITO can also heat your soup or milk for a coffee. The clean shape of the rod allows it to be cleaned easily. MIITO does not have an on/off button: simply lift the rod from the base and it shifts to “Standby” mode.

Source:
https://www.jamesdysonaward.org/en-GB/2014/project/miito-2/

Figure 1.30
Anna Czaniecka's Kettle

Anna Czaniecka's Kettle
Anna Czaniecka
Kingston University graduate show, 2014

This kettle by Kingston University graduate Anna Czaniecka is shaped like two mugs so the user can precisely measure how much water to boil for cups of tea. Anna Czaniecka's Kettle is designed to save energy, and therefore money, that is wasted from boiling too much water in traditional kettles. "I started this project by looking at kitchen appliances and I came across some data about the unusually high energy usage of a standard electric kettle," she told, stating that three quarters of British households overfill their kettles – wasting a total of £68 million per year. "Boiling more water than necessary has several implications - it takes longer time to boil which equals wasted electricity and higher energy bills," Czaniecka said. "I realised that it might be the shape of a standard kettle that causes a problem as it is so different from a cup shape it might be quite difficult to imagine the volume of how much water do we need," she said. The mug-shaped sections stack on top of each other, creating with a line between the two for measuring. "Its construction forces the user to look inside while filling it with water to have a better control over the amount of water needed," she said. "It is a perfect product for small households." "At the moment it is a speculative project which highlights the amount of water and electricity being wasted in the scale of the country and offers a simple, pragmatic solution,"

Source:
https://www.dezeen.com/2014/06/27/kttl-anna-czaniecka-kettle-kingston-university-graduate-show-2014/

Figure 1.31
Space kettle

Space kettle - Just kitchen, Macom
Spacesaver electric kettle

Foldable, space-saving silicon electric kettle. Convenient to use at home or on the go. Simple to use: it switches off automatically once the temperature is reached (it do not specify which is the reached temperature). Ideal for making tea, herbal teas, milk and coffee.
800 ml capacity. Heating element covered by stainless steel body. Practical and easy to handle with removable power cable, ergonomic handle and drip-catcher.
This appliance is designed for domestic use only.

Technical datas:
Voltaggio: 220-240 V - 50/60 Hz
Potenza: 900-1100 W
Capacità: 800 ml
Dimensioni aperto: L 16,0 x P 11,5 x H 17,8 cm
Dimensioni chiuso: L 16,0 x P 11,5 x H 11,5 cm
Peso: 0,600 kg

Test:
0,4 L - time to boil: 3 min 29 sec 96 centesimi
0,4 L - time to boil: 3 min 31 sec 29 centesimi
0,4 L - time to boil: 3 min 36 sec 26 centesimi
*initial and final temperatures measurements are not available.

Source:
https://www.macomsrl.it/prodotti/just-kitchen/space-kettle/

Heating water appliances and technologies

There are seemingly endless reasons to boil water, but how to most efficiently achieve the task has long been up for debate. Tom Murphy, a physicist at the University of California San Diego put the various theories to the test in 2012. Dr. Murphy focused on boiling water, but stove tops and appliances are used for heating up all sorts of things and they can use significant household energy, so his experiment helps underscore how small changes might boost efficiency.
Taking readings from his electric meter, and rigging a laser to monitor his gas usage, he calculated how much of the energy actually went to heating the water, versus dissipating along the way. As Dr. Murphy expected, the gas stovetop was not very efficient: with the largest burner on full-blast and no lid on the pot, he found that only about 15 percent of the natural gas being burned was converted to heat in the water. When the lid was added with the use of a small burner, which takes longer, it can potentially double that number but, he said, "the gas stove tops out at about 30 percent." While Dr. Murphy did not test an electric stovetop, other estimates tend to rate their efficiency considerably higher than gas ones. Geometry and cleanliness of the burner might also have conditional effects on the experiment results.
The microwave was a bit better; it clocked in at about 43 percent efficiency. The kettle came the closest to matching its pre-experiment hype. Most kettles, Dr. Murphy said, locate the heating coil directly in the water and have at least somewhat insulated sides, which both reduce energy loss. This enabled his

Figure 1.32
Heating water applian-ces and technologies

Source:
https://www.nytimes.com/2019/05/29/climate/nyt-climate-newsletter.html

setup to hit 70 percent efficiency. But those findings come with a few major caveats. Foremost is that efficiency largely depends on your energy source. By the time electricity from fossil-fuel-powered plants has reached your home, Dr. Murphy notes, it's already lost about 60 percent of its energy (some estimates have that number higher). That scenario, he said, could drastically hinder the performance electric stovetops and microwaves.
Kettles suffer from the same electricity issue, but also come with additional drawbacks that Dr. Murphy says can cause their efficiency to vary widely. The auto-stop function, for instance, often runs much longer than is necessary, which wastes energy. And people tend to overfill kettles. **"Habitually, you're just heating a lot more water than you need to be," he said. "In practice, you're not likely getting any better than a microwave."**
Dr. Murphy also looked into starting with hot water from your tap as a way to improve results. He found that it can probably help, because hot water systems are relatively efficient. But because a certain amount of the hot water will inevitably get left behind in your pipes, unused, the benefits of starting hot are greater when you're boiling large pots of water.
Further research conducted by the journalist Jordan Wirfs-Brock in 2016 have bought more datas to compare with the previous findings. The journalist spoke with Tom Williams, a researcher at the National Renewable Energy Lab, to break down the rough efficiencies on what is the most efficient heating water appliances:

Microwave: 50% efficient. A microwave is about 50 percent efficient. Most of the energy is lost in the process of converting electricity to microwaves (which are part of the electromagnetic spectrum).
Stovetop: 70% efficient. An electric stovetop is about 70 percent efficient, although that varies widely depending on the type of pot or kettle you use. Most of the energy is lost heating the air around the stove.
Electric Kettle: 80% efficient. An electric kettle is about 80 percent efficient, although again this varies from kettle to kettle. Electric kettles are generally very well insulated, and the heating coils sit directly in the water, so less heat is lost to the air.
Induction Stove: 85% efficient (when an Inox Steel pot is used). An induction stove or hot plate is about 85 percent efficient. It creates an electromagnetic current directly in a pot to generate heat, losing very little to the air.

Microwave

How does it work?
When microwave ovens become popular in the 1970s, they lifted household convenience to a new level. A conventional oven heats food very slowly from the outside in, but a microwave oven uses tiny, high-powered radio waves to cook food more evenly. Microwave ovens are so quick and efficient because they channel heat energy directly to the molecules inside food. Microwaves are very similar to the electromagnetic waves that zap through the air from TV and radio transmitters. It's an invisible up-and-down pattern of electricity and magnetism that races through the air at the speed of light (300,000 km or 186,000 miles per second). While radio waves can be very long indeed (some measure tens of kilometers or miles between one wave crest and the next), they can also be tiny: microwaves are effectively the shortest radio waves and the microwaves that cook food in your oven are just 12 cm long. Despite their small size, microwaves carry a huge amount of energy. One drawback of microwaves is that they can damage living cells and tissue. This is why microwaves can be harmful to people and why microwave ovens are surrounded by strong metal boxes that do not allow the waves to escape. In normal operation, microwave ovens are perfectly safe. But exactly how does a microwave turn electricity into heat?
Inside the metal box, there is a microwave generator called a magnetron. When the microwave is turn on, **the magnetron takes electricity from the power outlet and converts it into high-powered, 12 cm in length radio waves.**

Figure 1.33
Microwave

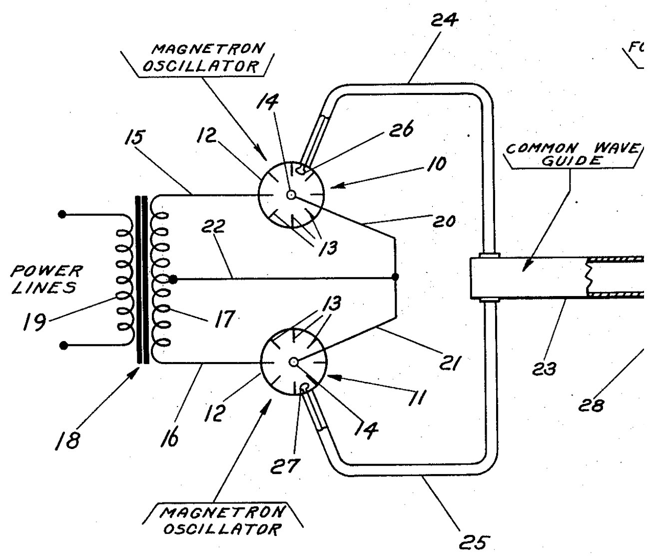
The magnetron blasts these waves into the food compartment through a channel called a wave guide.
The food sits on a turntable, spinning slowly round so the microwaves cook it evenly.
The microwaves bounce back and forth off the reflective metal walls of the food compartment, just like light bounces off a mirror. When the microwaves reach the food itself, they don't simply bounce off, instead microwaves penetrate inside the food and as they travel through it, they make the molecules inside it vibrate more quickly. Vibrating molecules have heat so, the faster the molecules vibrate, the hotter the food becomes. Thus the microwaves pass their energy onto the molecules in the food, rapidly heating it up.
In a conventional oven, heat has to pass from electric heating elements or gas burners positioned in the bottom and sides of the cooker into the food, which cooks mostly by conduction from the outside in. Exactly how the food cooks in a microwave depends mostly on what it's made from. Microwaves excite the liquids in foods more strongly, so something like a fruit pie, with a higher liquid content in the center, will indeed cook from the inside out, because the inside has the highest water content. Since they work by energizing water molecules, microwaves also tend to dry food out more than conventional ovens.
Another important factor is the size and shape of what you're cooking. Microwaves can't penetrate more than a centimeter or two into food, because the waves keep losing energy from the moment they enter the food, and after that first centimeter or so they don't have enough energy left to penetrate any deeper. Like every other cooking method, microwaving has its drawbacks.

Brief history
Like many other great inventions, microwave ovens were an accidental discovery. Back in the 1950s, American electrical engineer Percy Spencer (1894–1970) was carrying out some experiments with a magnetron at the Raytheon Manufacturing Company where he worked. At that time, the main use for magnetrons was in radar: a way of using radio waves to help airplanes and ships find their way around in poor weather or darkness.
One day, Percy Spencer had a chocolate bar in his pocket when he switched on the magnetron. To his surprise, the bar quickly melted because of the heat the magnetron generated. This gave him the idea that a magnetron might be used to cook food. After successfully cooking some popcorn, he realized he could develop a microwave oven for cooking all types of food. He was granted a series of patents for the idea in the early 1950s, including one for a microwave coffee brewer (US patent 2,601,067, granted June 17, 1952) and many others like the one for "treating foodstuffs" (US patent 2,495,429 "Method

of Treating Foodstuffs" on January 24, 1950), which shows the basic operation of a microwave oven. In this patent, readers can appreciate Spencer's own summary of how his invention works:

"...by employing wavelengths falling in the microwave region of the electromagnetic spectrum... By so doing, the wavelength of the energy becomes comparable to the average dimension of the foodstuff to be cooked, and as a result, the heat generated in the foodstuff becomes intense, the energy expended becomes a minimum, and the entire process becomes efficient and commercially feasible."

Spencer's early equipment was relatively crude compared to modern wipe-clean microwaves, his first oven was around 1.5 meters high. Since then, microwave ovens have become much more compact and millions of them have been sold throughout the world.



Source:
US Patent 2,495,429: Method of treating foodstuffs by Percy Spencer, granted January 24, 1950.

How efficient?

Readers might expect a microwave to be much more efficient than other forms of cooking: in other words, it is expected that more of the energy going in from the power cable to be converted into heat in the food and less to be wasted in other ways. Broadly speaking, that's correct: cooking in a microwave is cheaper and quicker than cooking with a conventional oven because the microwave do not have to heat up before cooking. But that's not the whole story. If you want to heat up only a small quantity of food or a cup of hot water, a microwave oven is not necessarily the best thing to use. When you microwave something, apart from putting energy into the food, you're also powering an electric motor that spins a relatively heavy glass turntable. Although you don't have to heat up the food compartment for the oven to cook, a microwave oven does, in fact, get fairly warm after it's been on for a while, so there are some heat losses. A magnetron is not perfectly efficient at converting electricity into microwaves: it will get hot. And you also have to power an electronic circuit, a timer display, and probably a cooling fan. Taken together, all these things make a microwave less efficient than it might seems to be. Exactly how much less efficient? Physicist Tom Murphy compared the energy efficiency of different methods of boiling water and found that it was only about 40 percent efficient, which is about half as efficient as using an electric kettle.

Are microwave safe?

The cooking cavities in microwave ovens are sealed metal containers. Looking closely at the inside of the glass door, you'll find it has a grid of metal stuck to the back; those holes are too small to let microwaves through. Another safety feature, called an interlock, keeps you safe: if you try to open the door, the magnetron stops buzzing immediately; most microwaves actually have two independent interlocks in case one fails. Even if your microwave is "leaking," it's unlikely to do you any harm. Although microwave ovens can produce very high power inside (up to 1000 watts in a typical large oven), the power drops off very quickly the further away you go. Outside the cooking cavity and some distance away, even a leaky microwave would produce only tiny amounts of electromagnetic radiation. According to the US Food and Drug Administration, at a distance of about 5 Cm, the amount of power a microwave can leak is about 5 milliwatts per square centimeter, which is "far below the level known to harm people," while at a distance of about 50 cm, it's about 1 percent as much again. The World Health Organization is reassuring on this point: "thermal damage would only occur from long exposures to very high power levels, well in excess of those measured around microwave ovens.", there's simply too little power to heat body tissue up enough to do damage.

Average tech datas
A microwave oven is a common kitchen appliance used for heating or cooking food by utilizing electromagnetic radiation. Compact microwaves use between 500 and 800 watts during heating, while a regular sized microwave will use 850 to 1800 watts depending on the model. An average modern microwave will use around 1200 watts.

Source:
Facts about microwave oven radiation. (1971). Washington, D.C.

Figure 1.34
RadioRange

Figure 1.35
Induction cooktops

Induction Cooktops

How does it work?
Induction cooking, uses electromagnetism to turn cooking pans into cookers, creating heat energy inside the pan itself, instead of firing it in from outside, which cooks food more quickly and safely with less energy.
An induction cooktop is simply an electromagnet you can cook with. Inside the glass cooktop, there's an electronically controlled coil of metal. When the power is turn on, current flows through the coil and produces a magnetic field all around it and directly above it. Now a simple direct electric current produces a constant magnetic field: one of the laws of electromagnetism is that fluctuating magnetism is produced only by a constantly changing electric current. So you have to use an alternating current, one that keeps reversing direction, to make a fluctuating magnetic field that will, indirectly, produce heat. And that's all that an induction hob does: it generates a constantly changing magnetic field. It does not generate heat directly.
When a suitable cooking pan stands on top of an induction cooktop that's powered up, the magnetic field produced by the cooktop penetrates the metal of the pan. The result is a fluctuating magnetic field moving around inside a piece of metal, for instance, the base and sides of the pan, and that makes an electric current flow through the pan too.
As the electric current swirls around inside the metal's crystalline structure, it dissipates its energy. So the metal pan gets hot and heats up whatever food is inside it, first by conduction as it passes its heat energy directly to the food, but also by convection,

since the liquid food rises and falls in the pan carrying heat with it. How induction cooking works:
An induction cooker looks much the same as any other ceramic cooktop, usually with distinct zones where you can place your pots and pans. The cooking surface is usually made from tough, heat-resistant glass-ceramic.
Inside each cooking zone, there's a tightly wound coil of metal. When you turn on the power, an alternating current flows through the coil and produces an invisible, high-frequency, alternating magnetic field all around it. Unless there's a pan on the cooking zone, no heat is produced: the cooking zone remains cold. Although normal home power supply alternates at about 50–60 Hz (50–60 times per second), an induction cooktop boosts this by about 500–1000 times, typically to 20–40 kHz.
When a pan is placed on the cooking zone, the magnetic field produced by the coil penetrates the iron inside it.
The magnetic field induces whirling electrical currents inside the pan, turning it into a heater.
Heat from the pan flows directly into the food or water inside it by conduction.

Brief history
The term "induction" is a shortened way of saying "electromagnetic induction." In a nutshell, **induction means generating electricity using magnetism. That's because electricity and magnetism aren't separate, unconnected things but two different aspects of the same underlying phenomenon: electromagnetism.**
In 1820, a Danish physicist named Hans Christian Oersted found that when a fluctuating electric current flows down a wire, it creates an invisible pattern of magnetism all around it; in other words, a magnetic field. The next year, French physicist Andre-Marie Ampère took this experiment a stage further: he found that two wires carrying fluctuating electric currents, placed near to one another, will either attract or repel one another, because the magnetic fields they produce cause a force between them. Things took a much more practical twist when the brilliant English physicist and chemist Michael Faraday figured out how he could use electricity and magnetism to develop a very primitive electric motor, in 1821. He placed a magnet near a piece of wire into which he fed an electric current. As the current flowed through the wire, it generated a magnetic field around it, pushing itself away from the magnetic field that the permanent magnet generated. Other inventors, notably Englishman William Sturgeon and American Joseph Henry, went on to develop practical electric motors, while Faraday continued to experiment with the science. In 1831, he pulled off the opposite trick: he showed how rotating a coil of wire through a magnetic field would make an electric current flow through it, inventing the electricity generator that would soon (in the hands of pioneers such as Thomas Edison) bring electric power to the world.
The science of electromagnetism was finally nailed down by Scottish physicist James Clerk Maxwell in the 1860s, who summarized everything that was then known about electricity and magnetism in four simple mathematical formulas. Maxwell's equations still form the foundations of electromagnetic science today.

How efficient
A traditional cooker generates heat energy at some distance from the cooking pot or pan and attempts to transport as much of that energy into the food as possible, with varying degrees of success. With induction cooking, the heat is produced in the pan, not the cooktop, and much more of the energy goes into the food. That's why we can say that induction cooking is more energy efficient than most other heating methods.
Induction cookers are usually built into ceramic or glass cooktops, which are very easy to keep clean with just a quick wipe. The magnetic fields they produce make heat appear in the

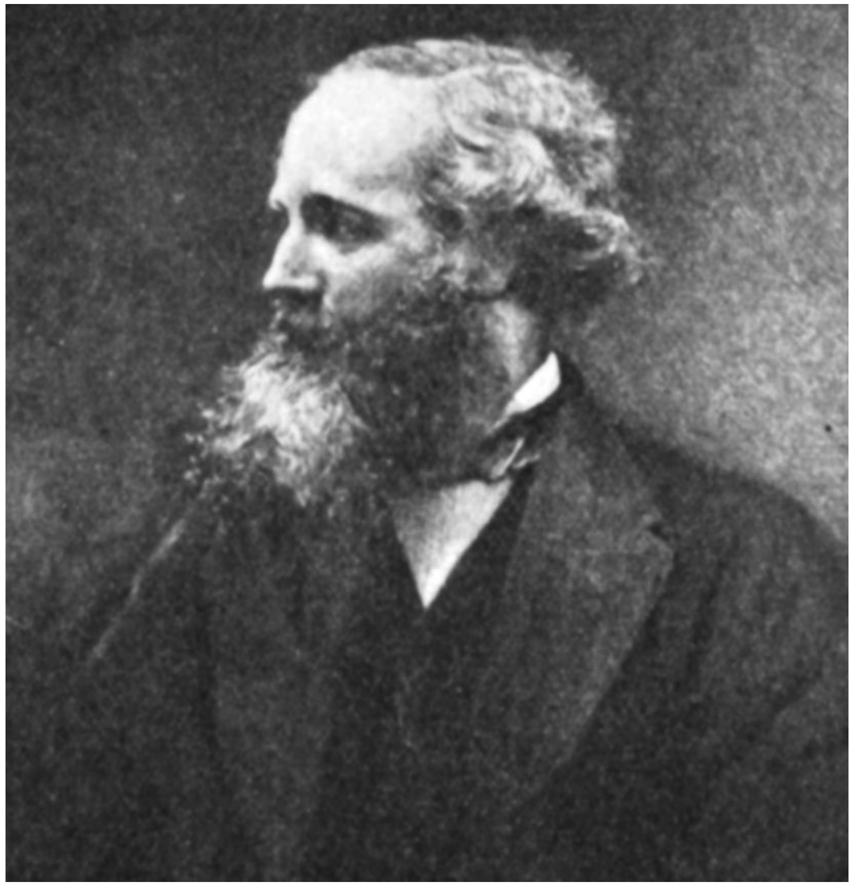


Figure 1.36
James Clerk Maxwell

pan almost instantly and they can make it disappear instantly too. Usually induction stovetops have the option to control the heat up or down with as much speed as a gas cooker. There's no open flame on an induction cooktop and no heat that can burn whoever is using the stovetop. Heat appears only when the cooking pan is in place and the cooktop itself can never get any hotter than the pan sitting on top of it. Electronically controlled cooktops can detect whether pans are standing on them and how much heat they're producing, and most will cut the power out automatically if they're left on by mistake or if a pan starts to boil dry. Induction cookers built into ceramic cooktops are only a couple of centimeters thick so they can be fitted at any height.

Drawbacks of induction cooktops
Until recently, cost was the biggest disadvantage: a typical induction cooktop could be two or three times more expensive than an ordinary electric or gas cooktop and, even though you'd save energy, the energy savings weren't usually significant enough to pay back the difference. The price of induction cooktops has now fallen significantly and there's much less difference in cost compared to ordinary ceramic cooktops. Another drawback is that induction cooking only works properly with cooking pans containing iron: the only metal that efficiently produces electrical currents and heat from magnetic fields. Copper and aluminum pans and glass cookware don't work. Two other minor issues worth noting are that induction cooktops can produce a small amount of noise from built-in cooling fans and radio-frequency interference that might pose a very small risk for people wearing heart pacemakers; that being said, the risk of that is not greater than the risk posed by other everyday electrical equipment.

Source:
Induction Cooktops:
Health and safety: Swiss Federal Office of Public Health, 8 November 2011.

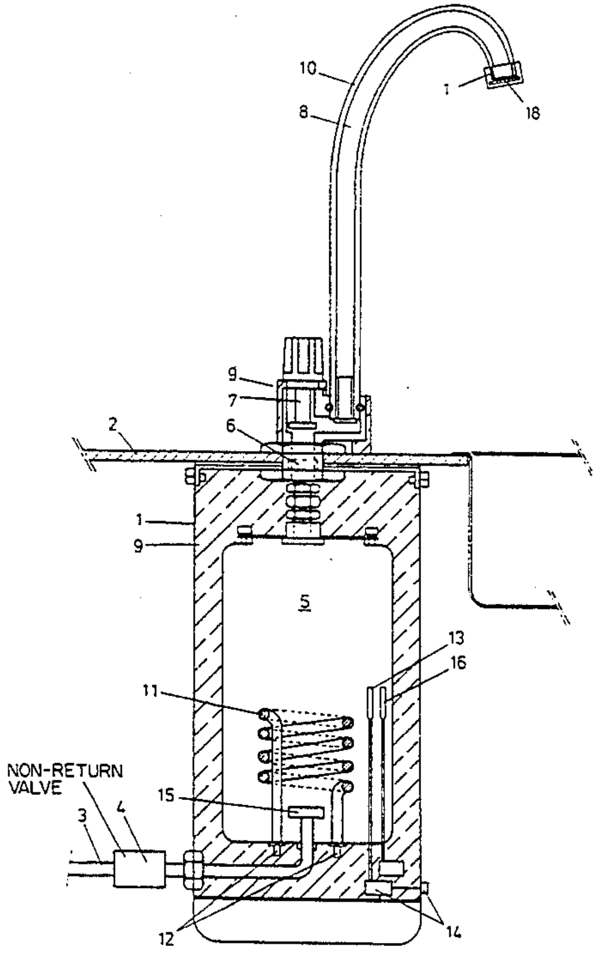
Figure 1.37
Kitchen boilers

Kitchen boilers

How does it work
As the name suggests, boiling-water taps provide instant hot water without the need to switch on the kettle or boil a pan on the hob. A boiling-water tap is a much more permanent addition to the kitchen than a conventional kettle or plug-in hot water dispenser, as it needs to be plumbed in alongside, or instead of, the standard kitchen-sink taps. Boiling water taps work with the help of a electric-powered hot water tank. These tanks plug directly into a power socket and are connected to your water supply. They heat the water and store it in the tank; when the tap is turn on to use the boiling water, it can deliver it instantaneously. Most boiling hot water taps dispense water at around 98°- 99°C. This accounts for the loss of heat in the time it takes to travel out of the tap and into a cup. Many of the best hot water taps also come with adjustable temperature options. Usually boiling-water taps come with different-sized tanks: the smallest can hold around two litres of water, while the largest can hold as much as 11 litres.

Brief history
The kitchen boiler is a relatively new appliance compared to electric kettles. They were first invented by the founder of the "Quooker" company, Henri Peter, in 1970. Rotterdam-born Henri Peteri worked for Unilever and was visiting the head office in London when he had the idea. It was during a presentation about instant soups. They showed how it was possible to dissolve soup in boiling water in just five seconds. 'And to do that, you have

to heat water for five minutes?' Peteri thought. "Why can't we get boiling water from the mixer tap in our homes?". When the first model was made, Peteri sold it to friends and acquaintances who were very enthusiastic. Once people had used a Quooker, they couldn't live without it.
When his son Niels finished his studies and joined his father, the idea became a product. In 1992, the first Quooker ('quick cooker') was introduced, the Quooker Basic. From the moment son Walter joined the company, Quooker gradually began to gain ground on the market, but it wasn't until the 2000, when things really started to take off. The boiling-water tap became a success in the Netherlands and from 2004, the first batch of Quookers was exported abroad.



Source:
US Patent 5,343,552: Device and method for boiling water by Henri B. Peteri, granted August 30, 1994.

How Efficient
Hot tap boilers aren't cheap. Usually, companies offers two different types of tanks. One, which dispenses only boiling water (100C), can be bought in different sizes, and costs between 850 and 1,120 Euros, while the other "combi" tank – which generates both hot (50-60C) and boiling water, which costs around 1,150 Euros.
The heavily insulated tanks, which range from three litres to 11 litres, sit under the kitchen sink and connect to the water supply, while being heated electrically. The water is purified when it passes through the filter, and is dispensed through the tap. Producers of tap water boilers claim that the cost of using its hot tap is one cent per litre delivered, or approximately three cents a day. The cost of boiling a full kettle, which typically holds 1.5 litres, is around 2.5 cents per boil, according to npower. This would suggest that a tap water boiler could save users a significant sum, particularly those who regularly boil their kettle. But Andy Smale, technical director at Expert Energy, a group of independent energy consultants, calculated that the difference in savings were in fact minimal. He said that the amount of energy it would take to make six 250ml cups of tea or coffee on six separate occasions with a kettle (typical minimum kettle fill of 500ml) would cost 5.46p per 24 hours, according to these calculations:

$$3 \text{ kW} \times 84 \text{ seconds} \times \text{six cups} = 0.42 \text{ kWh}$$
$$0.42 \text{ kWh} \times 13 \text{ cents/kWh} = 5.46 \text{ cents}$$

When using the boiler, the amount of energy it would take to heat 1.5 litres (six 250ml cups) from 15°C to 110°C would be:

$$4181 \times 95° \text{ C} \times 1.5 \text{ L} \times 2.777778e\text{-}7 = 0.1655 \text{ kWh}$$

To keep the water hot over 24 hours the amount of energy used would be:

$$0.01 \text{ kW} \times 24 \text{ h} = 0.24 \text{ kWh}$$

So, the total energy used would be:

$$0.1655 \text{ kWh} + 0.24 \text{ kWh} = 0.4055 \text{ kWh}$$

This is equal to 5.27cents per 24 hours (0.4055 kWh x 13 cents/kWh). Although using a boiler is slightly cheaper, with a basic hot tap costing 850 Euros it would take several years before any savings were actually made. Stephen Johnson, managing director at Quooker, one of the main tap water boilers company, said that the hot tap would also save users a significant amount of water because users only dispense as much water as they need, while many households waste water when using a kettle because they overfill it, reboil it, and because leftover water is often poured down the drain. “A hot tap can save around 100 litres of water a year,” he said. Anyway, **the initial cost of these appliances is still high and it makes it almost impossible to have a financial interest on the investment.** That being said, these smart solution for instant boiling water are very efficient in terms of energy consumption and water.

Pros and cons
Boiling water taps provide instant hot water on demand. The main advantage of these taps is that they provide hot water much more quickly and easily than a kettle. They also make it simpler to use just the amount of water you need, as they can be used to fill mugs or pans directly from the tap. Manufacturers reckon that this makes boiling-water taps more efficient than a kettle and therefore less expensive to run. Other advantages include: childproof handles and insulated sides should help to avoid singed fingers. People who have problems filling, lifting and pouring a conventional kettle may find a hot water tap easier to use. Most models will also remove harsh-tasting chemicals and in some cases soften and aerate the water, too. What are the downsides of installing a boiling-water tap? The most obvious one is cost. The cheapest boiling water taps cost more than £500, and those that can dispense water at variable temperatures usually costs even more, with some costing well over £1,000. Not all boiling water taps come with installation included in the price. Although installation can be done by the users himself, it’s not necessarily straightforward, so the cost of a plumber might be also included and should be considered when purchasing one of these boilers. Maintenance of these devices must be also considered since these boilers needs some cleansing from time to time of the tap and the tank to free them of limescale, and also, most models require regular replacement of filters which can significantly add to the ongoing cost. Is a boiling-water tap cheaper to run than a kettle? You’d expect anything that can keep water at boiling point would be expensive to run, but if leading brands, such as “Quooker”, “Grohe” and “Franke”, are to be believed then hot water taps can be more economical than your average kettle. The company “Quooker” says that its taps cost 3p per day if left on standby. The cost of boiling a litre of water in a kettle is just over 2p. So, it is possible to have a return of investment if the kettle is often used more than two or three times a day. A boiling-water tap doesn’t have to mean adding a second or third tap around the sink. There are different combination available:

- Two-in-one taps - dispense boiling and cold water; three-in-one taps that dispense hot and cold water, as well as boiling water;

- Four-in-one taps which dispense on-demand cold filtered water in addition to mains hot and cold water, and boiling water.
- Some even dispense fizzy water, for the ultimate in on-demand water.

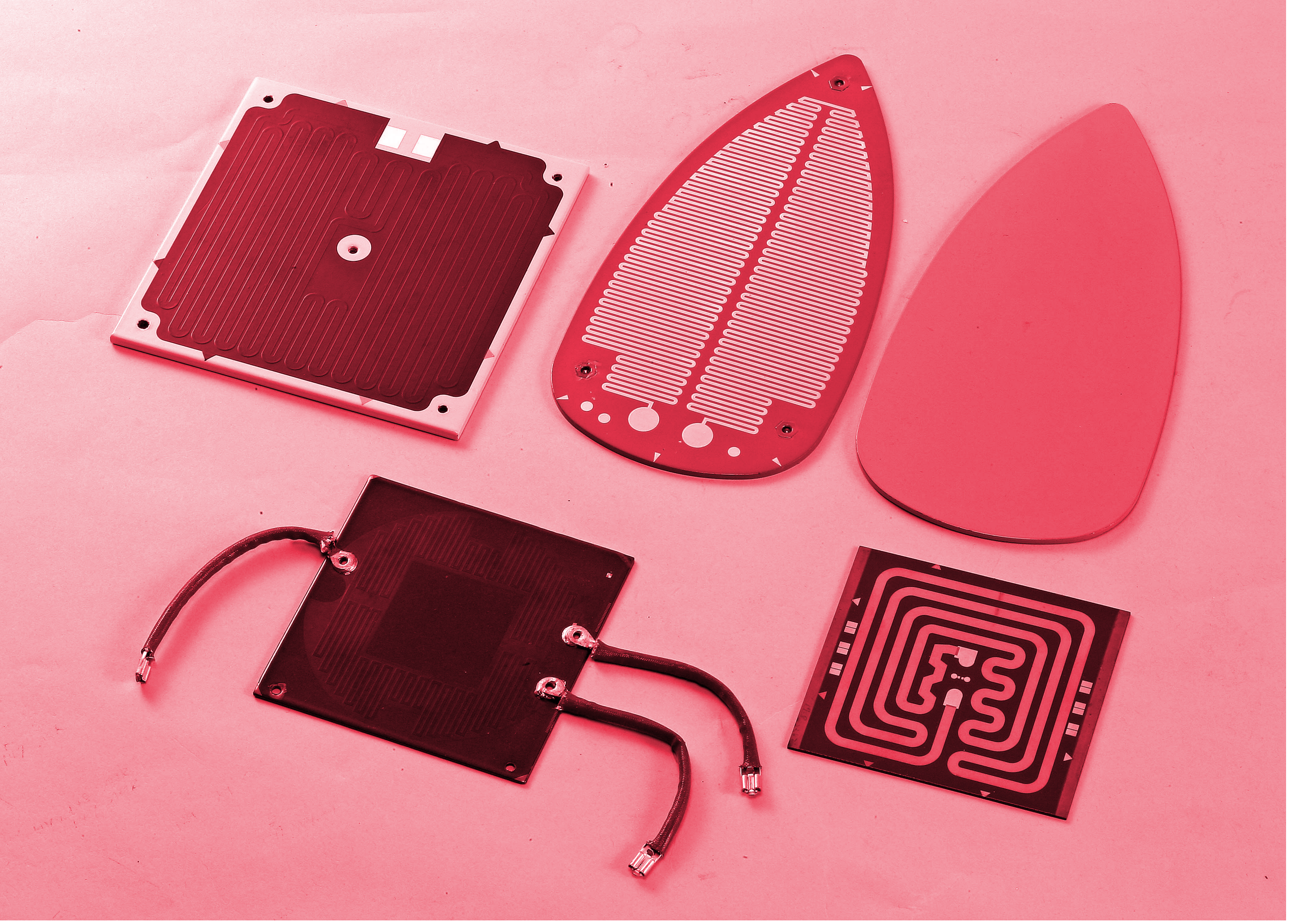
Red-hot water in an instant could be dangerous, especially if it is used by the children who are used to getting cold water when they use the tap, but childproof handles should prevent this issue.

Sources:
https://www.quooker.co.uk/history

https://www.grohe.it/it_it/cucina/gamma-rubinetteria/grohe-red.html

https://www.telegraph.co.uk/money/ask-a-money-expert/i-want-an-instant-boiling-water-tap--will-it-cost-more-than-usin/

Figure 1.38
Kitchen boiler tap



Thick and thin film

How does it work
Thin and thick film resistors are the most common types in the market. They are characterized by a resistive layer on a ceramic base. Although their appearance might be very similar, their properties and manufacturing process are very different. The naming originates from the different layer thicknesses. Thin film has a thickness in the order of 0.1 micrometer or smaller, while thick film is around thousands time thicker. However, the main difference is method the resistive film is applied onto the substrate. Thin film resistors have a metallic film that is vacuum deposited on an insulating substrate. Thick film resistors are produced by firing a special paste onto the substrate. The paste is a mixture of glass and metal oxides. Thin film is more accurate, has a better temperature coefficient and is more stable. It therefore competes with other technologies that feature high precision, such as wirewound or bulk metal foil. On the other hand, thick film is preferred for applications where these high requirements are not critical since prices are much lower.

Thin film technology: The resistive layer is sputtered (vacuum deposition) onto a ceramic base. This creates a uniform metallic film of around 0.1 micrometer thick. Often an alloy of Nickel and Chromium is used (Nichrome). They are produced with different layer thicknesses to accommodate a range of resistance values. The layer is dense and uniform, which makes is suitable to trim the resistance value by a subtractive process. With photo etching or by laser trimming patterns are created to increase the resistive path and to calibrate the resistance value. The base is often alumina ceramic, silicon or glass. Usually thin film is produced as a chip or smd resistor, but the film can also be applied onto a cylindrical base with axial leads. In this case, more often the term metal film resistor is used.
Thin film is usually used for precision applications. They feature relatively high tolerances, low temperature coefficients and low noise. Also for high frequency applications thin film performs better than thick film. Inductance and capacitance are generally lower. The parasitic inductance of thin film can be higher if it is executed as a cylindrical helix (metal film resistor). This higher performance comes with a cost, which can be factors higher than the price of thick film resistors. Typical examples where thin film is used are medical equipment, audio installations, precision controls and measurement devices.

Figure 1.39
Thick and thin film

Thick film technology: Thick film heaters are a type of resistive heater that can be printed on a thin substrate. Thick film heaters exhibit various advantages over the conventional metal-sheathed resistance elements. In general, thick film elements are characterized by their low profile form factor, improved temperature uniformity, quick thermal response due to low thermal mass, low energy consumption, high watt density and wide range of voltage compatibility. Typically, thick film heaters are printed on flat substrates, as well as on tubes in different heater patterns. These heaters can attain watt densities of as high as 100 W/cm2 depending on the heat transfer conditions. The thick film heater patterns are highly customizable based on the sheet resistance of the printed resistor paste.
These heaters can be printed on a variety of substrates including metal, ceramic, glass, polymer using metal/alloy-loaded thick film pastes. The most common substrates used to print thick film heaters are aluminum 6061-T6, stainless steel and muscovite or phlogopite mica sheets. The applications and operational characteristics of these heaters vary widely based on the chosen substrate materials. This is primarily attributed to the thermal characteristics of the heater substrate. Thick film heating elements are intended for contact heating of flat surfaces and for heating of liquids through a flat wall. Compared with an ordinary tubular heating element, a heating element on a sheet metal provides substantially better heat transfer into a flat wall. Their high efficiency of 70 – 95% depends on the mode of operation (direct or indirect heating). Usually, for thick film heating elements substrates made of stainless steel according to standards AISI 430, DIN 1.4016 are used. The substrate (printing area) must be flat, but can be of various shapes and can contain openings manufactured in advance, before the printing process. The elements operate at standard line voltage (up to 400 V). Thick film heating elements feature very high surface power

density (up to tens W/cm2). Nevertheless, their operation conditions should be adjusted according to the particular application: adequate heat transfer should be provided so that the surface temperature does not exceed 300 °C. There are several conventional applications of thick film heaters. They can be used in griddles, waffle irons, stove-top electric heating, humidifiers, tea kettles, heat sealing devices, water heaters, iron and cloth steamers, hair straighteners, boilers, 3D printer heated beds, thermal print heads, glue guns, laboratory heating equipment, clothes dryers, baseboard heaters, deicing, or defogging devices, warming trays, car side mirrors, fridge defrosting, heat exchangers, etc. Therefore, these resistors can be found in almost any device with an AC plug or a battery. Advantages of thick over thin technology are not only lower cost, but also the ability to handle more power, provide a wider range of resistance values and withstand high surge conditions. For most applications, the thermal performance and temperature distribution are the two key design parameters. In order to avoid any hotspots and to maintain a uniform temperature distribution across a substrate, the circuit design can be optimized by changing the localized power density of the resistor circuit. An optimized heater design helps to control the heater output and modulate the local temperatures across the heater substrate. In cases where there is a requirement of 2 or more heating zones with different output power over a relatively small area, a thick film heater can be designed to achieve a zonal heating pattern on a single substrate.

Figure 1.40
Thick film section

How efficient

The prospect of application in the field of thick film heater is very wide because of its advantages such as high speedy heating. These products not only economize on much energy, but also use unpolluted energy. It doesn't pollute the environment, and the used products can be recycled, so thick film heater has become a heater that can protect the environment, and save the energy. The followings are the advantages of thick film heater:

- **High power density:** the power density of thick elements is generally 40-60 W/cm2, and if it is forced to cool, the power density even runs up to 200 W/cm2; this value is closely 10 times of the value of domestic heater which made of alloy. The great of power density also means that it has smaller size than other heaters that provide the same power, and it can switch on in low voltage.
- **Fast temperature response:** thick Film Heating Elements start very fast, and the heating rate on the surface of resistance coating can reach 200 to 300° C/s, which is electro thermal alloy components can not achieve.
- **The high mechanical strength, anti-vibration, and the resistance of thermal shock:** thick Film Heating Elements will not have brittle substance when they are in high temperature, but alloy electric material does. Besides, the coating of thick film heating elements combine with stainless steel substrate, and the power of bond is strong, so that they can resist mechanical and thermal shock.
- **Compact contour and structure, controllable heating temperature:** electric components are flat and the shape of size is thin, and also installed easily. It works with thermostat and the situation of components is stabile. The lifetime can be used at 100,000 times and above. They can direct wilding on stainless steel plate, and is easy to install. Furthermore, they provide laser-welding technology, and it is safe and stable to connecting devices. It is possible to design any resistance, and the temperature control is made possible according to heating.
- **Long lifetime:** traditional electric components of alloy often oxidize and its life is generally not more than 3000 hours; the life of Thick Film Heating Elements are up to 10,000 hours above.
- Energy-saving: thermal efficiency runs up to 70-95% base on different modes (direct or indirect heating).
- **Environmental protection:** there are not toxic components and heavy metal ions in the material of thick film heating elements.

Pros and cons

The cost advantage of using thick film heaters in preference to traditional heaters has been investigated by Dr. J. Lorenz of E.G.O. and is found to be dependent on the application and the number of heaters to be manufactured. In small domestic appliance heaters, for example, a tubular heating element may cost as little as $ 1. However, the viability of the thick film heater becomes apparent when all components and connectors necessary to form a complete heating system are considered: the heating element, the thermostat, for the control of operation and safety, the connectors for power supply and control functions, the indicators, such as light emitting diodes or buzzers, the wiring of the components and lastly, fixing the heating element to the body to be heated illustrates a complete thick film heating system, with the heater and the “wiring” of the components being an integral part of the printed substrate. The conductor material not only provides the connections between the heater and the components but also provides a solderable termination for power input and surface mounted components. The heating system is attached to the aluminium plate with a thermally stable adhesive or held in contact with the plate by pressure of a spring on a central bolt. The thick film heating system uses far fewer parts than the tubular heater assembly, and can be seen to offer significant reduction in both size and weight. This, in turn, enables a more compact and lower cost appliance casing to be used. The cost of this complete thick film heating system is around $2, compared to $2.50 for the tubular heater assembly, provided the production volume is tens of thousands. For some applications it is extremely difficult, even impossible, to use a wire heater element. Applications requiring low power dissipation at line voltages result in fine, fragile wires being used. These are difficult to handle in mass production and the heaters are easily damaged. Using the thick film approach a resistor paste with higher resistivity is selected and the cost advantage becomes related to ease of manufacture and high yield.

Source:
Tait, R., Humphries, R., & Lorenz, J. (1994). Thick film heater elements and temperature sensors in modern domestic appliances. IEEE Transactions on Industry Applications, 30(3), 573–577. doi: 10.1109/28.293701

U.S. Patent Apr. 4, 2000 Sheet 3 of 3 **6,046,438**

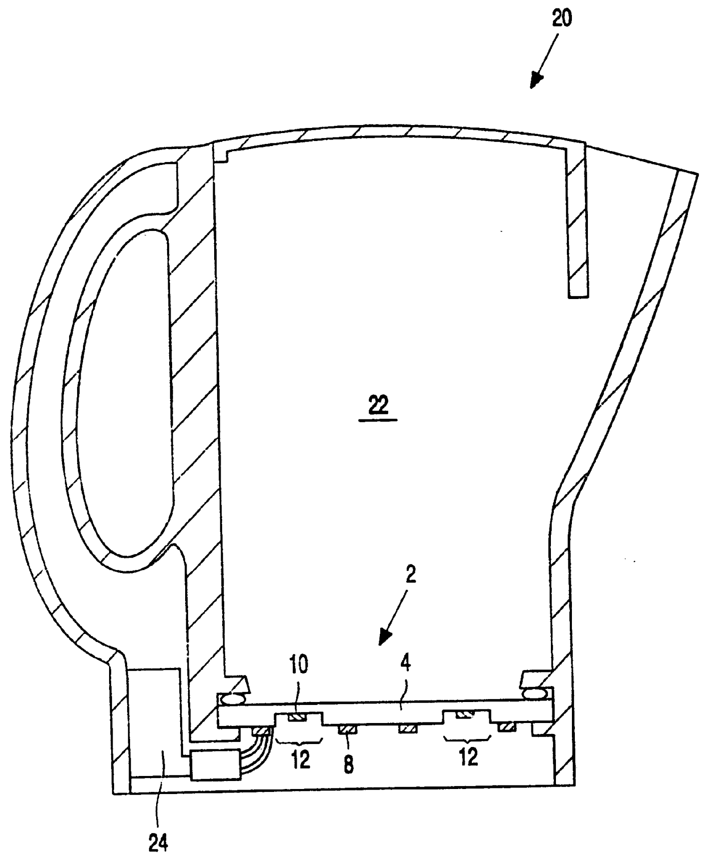


FIG. 5

Source:
US Patent 6,046,438: Thick film heating element with thermal sensor disposed in thinner part substrate by Sander Slegt, granted April 4th, 2000.

Espresso machine heating systems

Today there are four primary technologies that heat water for espresso: thermoblocks, boilers and double boilers, heat exchangers, and thermo-coils. Each technology comes with its own benefits and drawbacks.

Thermoblocks
A thermoblock is metal block **with embedded heating elements and a pipe for water.** As the water travels along the length of the pipe it picks up heat from the block, exiting at the desired temperature. The water is in contact with the thermoblock for a short time, but in that time it can flash heat to temperatures high enough to generate dry steam.
The simplest thermoblocks are fabricated out of two plates of metal with a spiral route cut into it for the water to travel through. A gasket is compressed between the two pieces, preventing the system from leaking. Other thermoblocks are simply a length of pipe with a heater attached along its length. Common materials for thermoblocks include aluminum, brass, and stainless steel. Some thermoblocks use a composite design with stainless steel pipes encased within an aluminum body.
Thermoblocks are inexpensive to produce and also are energy efficient as they only heat water immediately prior to it being used. Many superautomatic espresso machines feature a thermoblock system that makes heating water quick. While thermoblocks are able to generate hot water extremely rapidly, their temperature control is less perfect than some other heating technologies. It is common for espresso machines to use thermoblocks on the steam side and a boiler for the brew side. This allows the thermoblock to do what it does best, heat water quickly, while avoiding the pitfalls of its inconsistency. The thermoblock is often put near the group head, providing indirect heating of the brew chamber in addition to heating the water.

Figure 1.41
Espresso machine

Boiler
The original espresso makers used stainless steel boilers heated by open flame, but as time went on they progressed to electric heat. In the 1920s Achille Gaggia invented the lever-operated espresso maker, and he used in his machines, but instead of steam pressure used a lever-operated, spring-powered piston to drive the water through the grounds. While lever operated systems have mostly been replaced by pump driven systems, the single boiler heating unit has persisted. Some single boiler systems require to flip a switch when switching between brewing and steaming. Forgetting to do so can run overly hot water through the grounds or result in water too cool to generate steam effectively. Switching modes is relatively quick and easy, usually only taking 25-50 seconds.

Double boilers
Double boiler espresso makers employ two separate heating units: one for steam, and one for coffee. With one boiler dedicated to steam and another to espresso. Many commercial espresso machines use double boilers as they churn out consistent espresso shots and steam all day long. While double boiler systems are great coffee makers, they have several disadvantages. They are bulkier than other heating systems, involve considerable complexity and corresponding cost, have long preheating times, and are not energy efficient as the water is held at temperature constantly.

Heat exchangers
Heat exchanger systems were developed as a way to overcome the inherent limitations of single boilers. Heat exchanger systems get their name from the fact that the boiler in these systems only directly heats water for the steam side. The coffee brew water runs through a copper line that is coiled through the heated water. As the water travels along the line it picks up heat from the steam reservoir and comes up to a temperature sufficient for espresso brewing. Ernesto Valente's Faema E61 was the first pump driven espresso machine and utilized a heat exchange heating system. It was released in 1961.

Thermo-coils
As a close relative to thermoblocks, thermo-coils work on the same principle: a heating element embedded in metal runs alongside a water pipe flash heating the water. While the body

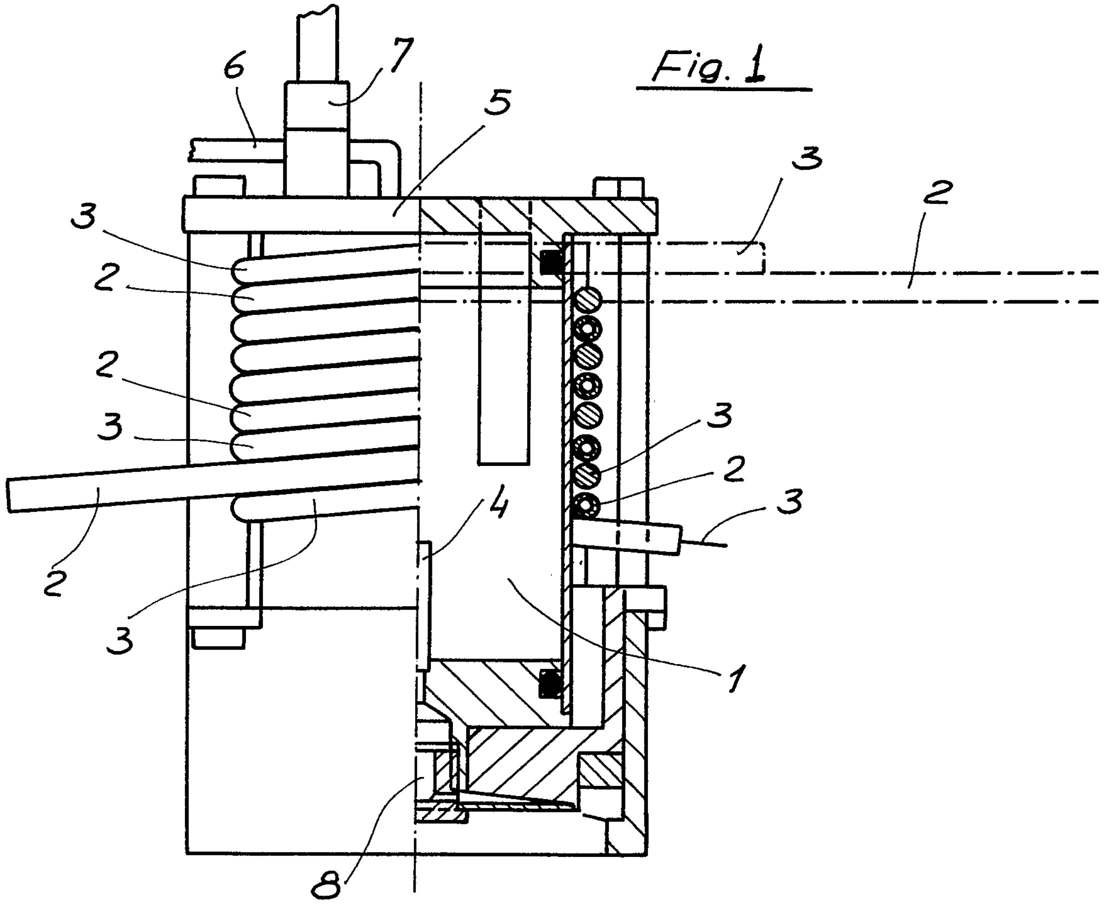
of the thermocoil is usually aluminum, the embedded pipe may be a different material such as copper or stainless steel. The main difference between the two technologies is that thermocoils are one piece units, and thus don't suffer from the leakage problems of thermoblocks. Some thermo-coils are built into the exterior of boilers. These units serve double duty, heating the water in the brew chamber and then directing water from the tank through the serpentine passages in order to create steam. The primary disadvantage of thermo-coils is their cost compared to other thermo heating units.

Comparisons:
Thermoblock Vs Boiler
Thermoblocks:
- Require less preheating time
- Can generate constant hot water
- Are more energy efficient
- Have better temperature control compared to single boiler systems
- Have worse temperature control compared to double boiler systems
- Are more susceptible to leaking
- Are more heavily impacted by scale
- Have shorter lifespans before needing repair or replacement

Thermoblock Vs Thermocoil
Thermoblocks:
- Cost less
- Are equally energy efficient
- Are more susceptible to leaking

Taking care of thermoblock systems:
The single biggest danger to thermoblocks is the accumulation of calcium deposits, also known as scale. Some materials such as stainless steel and bronze are less likely to accumulate scale, but no material is immune to the problem. If the water used is hard the risk is greater, but even relatively soft water can cause scale accumulation over time. To avoid this a water filter can be used, but also those can lose efficacy over time, and the only option is to change them at manufacturer's recommended intervals. The heating unit will eventually need to have its gaskets replaced.

Source:
https://www.home-grounds.co/thermo-block-vs-thermo-coil-boiler/



Source:
Fascicolo del brevetto 632402: Caldaietta per macchina da caffè espresso, ad uso familiare e professionale, provvista di un circuito separato per la produzione di vapore by Pietro Nascardi, granted October 10, 1982.

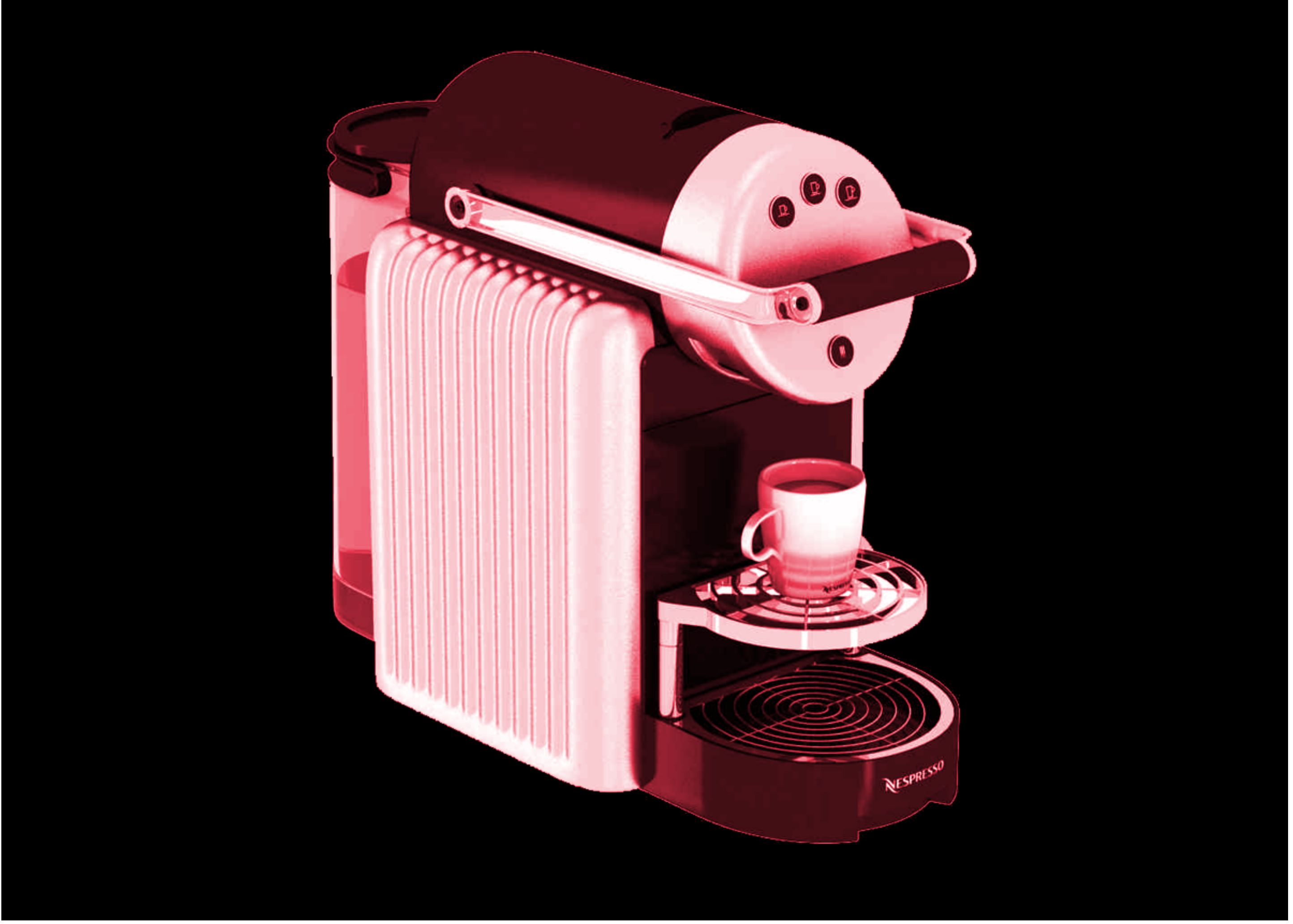


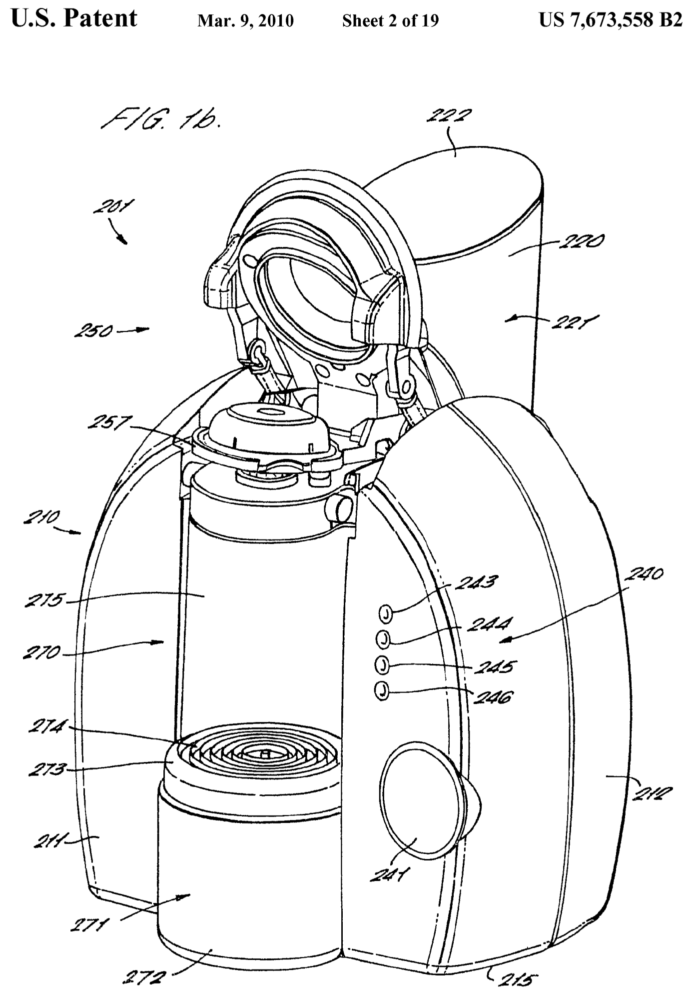
Figure 1.42
Single serve coffee pod machine

Single serve coffee pod makers

How does it work
The starting point is the pod, which has ground coffee inside a plastic container lined with filter paper and it is sealed with foil. When the pod is placed inside the machine, the foil breaks through automatically. The machine heats the water to almost boiling (around 90°C), then forces it at high pressure through the coffee in the pod into the cup, in a similar way to a traditional espresso machine. How coffee pod machine work step by step:
Water is loaded into the tank at the back of the machine.
A pump at the bottom sucks the water in and pumps it through the machine.
The water heats up to the perfect temperature as it flows up past the heating element.
The water is pumped through a narrow needle to increase its pressure.
The hot, high-pressure water pumps through the ground coffee in the pod, releasing the flavor.
Coffee drips through into your cup.

Main components of the single service pod coffee makers:

- **Outer case:** This is made from tough ABS plastic and designed as a two-part clam-shell.
- **Water tank:** This holds roughly 1.5 liters of water. It sits on the back of the machine and has a spring-loaded valve at the bottom, where it clips onto the water pump.
- **Water heater:** In the original design, this is a 1550-watt heater (compared to the 2000–3000 watt heating elements in typical electric kettles). It can heat enough water to make a coffee from about 20°C to about 85°C in under a minute.
- **Water pump:** This powerful pump can move almost a liter of water in a minute; its job is to move the water from the tank at the back into the water heater and then through the coffee pod. It works at a pressure of 1–2 bars (roughly 1–2 times normal atmospheric pressure). That might sound a lot, but it's considerably lower pressure than in a typical espresso machine, which works at more like 8–15 times atmospheric pressure.
- **Air compressor:** After the coffee is dispensed, this blows pressurized air through the machine to ensure that all the pipes are clear, ready for brewing the next cup.



Source:
US Patent: 7,673,558 B2: Insert, a machine and a system for the preparation of beverages by Satwinder Singh Panesar, Steve Carter, granted March 9th, 2010.

Brief history

Single-serve coffee makers might seem a recent development, but they were originally pioneered about 40 years ago by Eric Favre, who invented Nespresso for Nestlé in 1976 before founding Monodor, another pioneer of capsule-based coffee, in 1991. The individual pods machines are initially intended for a specialized and selected public (bars, hotels, offices). Two models are tested in Switzerland, Italy and Japan. However, the new system is struggling to mesh. In 1989 Nespresso therefore relocated to the "demanding clientele" segment. After the development of the pod with a polypropylene case and the rising popularity of the machines. The segment's explosion has wide-ranging implications for consumers, the environment and the coffee business, from farmers to corporate giants.
The convenience does come at a price. At about 65 cents per cup, that Nespresso coffee costs about $59 per pound.
The technology the single service coffee machines use to heat the water is called thermal blocks, also known as thermo blocks, and they are essentially a block of metal with a small passage or torrent that allows water to pass through. This block is heated using an embedded heating element, which heats the block to a suitable coffee temperature as the water is passing through. The water should have reached the desired temperature by the time it exits the thermal block. If steam is required, it will heat to the desired temperature to turn the water to vapour.

pros and cons

Benefits thermal block coffee machines include:

- Quality consistent dry steam
- Consistent water temperature
- Energy Saving
- Fast heat up
- Can be cheaper due to their inexpensive and compact nature

Drawbacks of thermal blocks:

Due to narrow paths, these can quickly get blocked with scale or other foreign matter, so staying on top of cleaning is important. Some models can cool off and lose quality when producing large quantities of milk or multiple cups. This can produce wet steam, which is undesirable, and it will then need time to recover. Potentially shorter life span than traditional boilers if not cared for properly

Source:
https://houseofswitzerland.org/it/swissstories/economia/eric-favre-linventore-svizzero-del-caffe-capsule

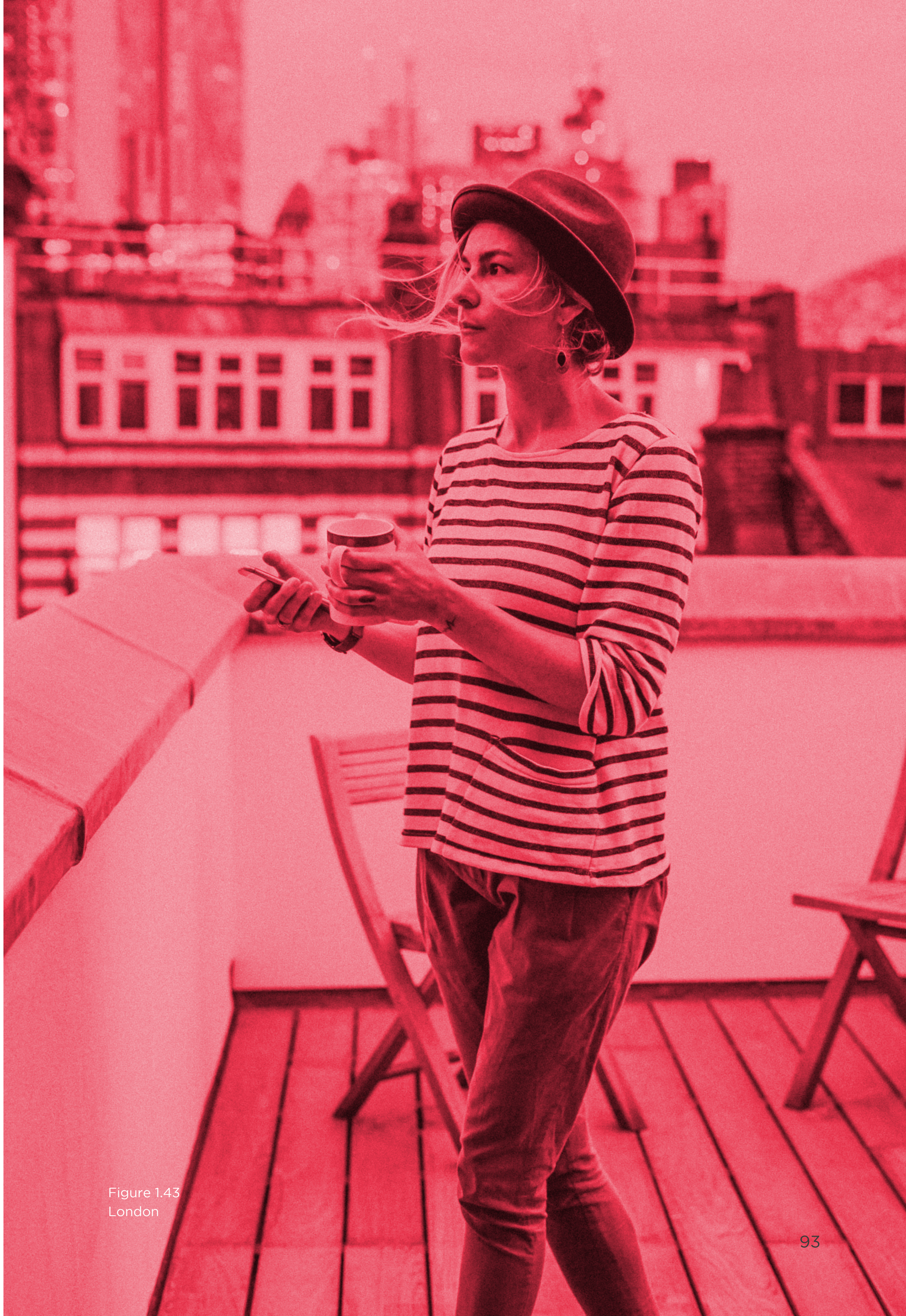


Figure 1.43
London

Figure 1.44
Kettle on fireplace

The electric kettle

The kettle, an energy-intensive consuming device

The previous chapters wanted to establish the fact that in modern society, as never in human history, hot water had become a basic and given for granted human need, simply because it became incredibly easy to provide in any circumstances a cup of hot boiling water. But that doesn't mean that an high quantity of energy is not needed in the current age in order to make the water raise its temperature. To heat water, is necessary a demanding amount of energy, whatever the form of that energy is: it might be the combustion of natural gas such as the one provided by our stovetop while we heat the water in a pot, or could be electrical, the one that we use when we turn on our electric kettle.
The main role played in our household when we talk about heating water for alimentary use is the kettle. The analysis of datas that have been collected among the years on national energy grids have shown how the electric kettle have a huge impact on our electricity consumption, and the problems that it raises when all the appliances in a concentrated area are switched on simultaneously. In fact, **some years ago a new problem raised the attention of the english national grid company: the so called TV pickup effect.** The electric kettle is one of the most used appliances in the United Kingdom (UK) as well as the appliance with the highest rates of ownership; according to UKs Department for Environment, Food and Rural Affairs 2006 report, **97% of UK households own a kettle.** Kettle ownership, and consequently kettle load demand, is also growing worldwide, according to the "Flexible demand in the GB domestic electricity sector in 2030" forecast study conducted by the Cardiff School of Engineering. **In the UK, more than nine in ten people (90%) use the kettle every day, with 40% doing this five times a day or more. Thus, the kettle has become a key domestic consumer.** The 2012 annual electricity consumption of the kettle in the UK was 4489 GW/h, which is roughly 34% of the total consumption attributed to cooking. Moreover, the electricity demand from the kettle is increasing (at the expense of electric ovens and hobs due to changes in cooking practices and increased oven efficiency) and according to the study, will surpass, in the UK, the annual consumption of 5000 GW h by 2030, contributing close to 40% of the overall cooking electricity demand. Though, overall, a lower consumer when compared to the electric heater or washing machine, **the electric kettle is one of the appliances that has the highest wattage and requires the highest current when switched on.** This is evidenced by high

spikes, caused by kettle usage, in the otherwise low to medium demand profile of a typical household. Due to the spiky nature of its demand, **the kettle can significantly influence electricity generation and the power distribution network, mainly due to the so-called "TV pick-up effect" that manifests itself through significant and synchronised usage of appliances,** such as kettles and microwaves, during TV programme breaks. The TV pickup is a phenomenon that affects electricity generation and transmission networks. It often occurs when a large number of people watch the same TV programmes while taking advantage of breaks in programming to operate electrical appliances, thus causing large synchronised surges in national electricity consumption. A typical TV pickup imposes an extra demand of 200–400 megawatts, with larger soap storylines bringing around 700–800 MW. T**he world record TV pickup electric demand ever recorded in the United Kingdom was in 1990, during the England - West Germany FIFA World Cup semi-final match.** The match was watched by an estimated 26 million people in the UK, and when full time was called they caused a 2,800MW surge in electricity demand, equivalent to 1,120,000 kettles (based on 1 MW = 400 kettles). The kettle is also one of the most inefficiently used appliances. **In a survey of 86,000 homes in the UK, by the Energy Saving Trust, it was found that three-quarters of British households admit to overfilling their kettle when boiling water and are subsequently wasting GBP 68 million each year.** These statistics are based on interviews, instead of measurements. While kettle usage is generally assumed to be very regular and non-random, to the best of our knowledge, there has been no in-depth study which analyses patterns of kettle consumption. This is probably because of the assumption that kettle usage is highly routinized. A clear trend in increased kettle usage evidenced by these studies,a lack of any efficiency labelling guidelines, slow technological progress in improving efficiency (relative to other cooking appliances), and current consumers attitudes (86% of people do not choose kettles based on their features, but on looks to match a kitchen design/ already owned products), all call for urgent investigation into consumer behaviour patterns with respect to kettle usage and energy conservation measures and possibly an innovative solution.

Another important factor to consider of electric kettles available on the market is that most of them require a minimum level of water of 400 ml. This implies that even when the heated water need is less than 400 ml, let's say a single cup of tea, 250 ml, the appliance waste 150 ml, just to operate normally.

Another problem that the electric kettle raise, are the bad habits people have taken in their routines. These bad habits, that we blame most entirely on the design of the device, have produced countless water wastes, material wear and with it energy wastes.

Source:
D.M. Murray, J. Liao, L. Stankovic, V. Stankovic, 2016, Understanding usage patterns of electric kettle and energy saving potential, Applied Energy, Volume 171.

Usage Patterns and the TV Pickup

With growing electric kettle ownership and usage, lack of any efficiency labelling guidelines for the electric kettle, slow technological progress in improving kettle efficiency relative to other domestic appliances, and current consumer attitudes, urgent investigation into consumer kettle usage patterns is warranted. From an efficiency point of view, little can be done about the kettle, which is more efficient than other methods of heating water such as the stove top kettle, but with today's technology, the availability of smart metering and smart appliances enables detecting and characterising appliance use in a household, quantifying energy savings through efficient appliance use and predicting appliance-specific demand from load measurements is possible and a study conducted by the Department of electronic and electrical engineering from the University of Strathclyde, shows interesting results concerning electric kettle usage patterns, and way to reduce the energy and water wastes.

However, **since a majority households use the kettle inefficiently by overfilling, in order to meet energy targets, it is imperative to quantify inefficient usage and predict demand.** Also, the data gathered in these studies suggest that the misinformation and the non-careness for the topic is widely spread among consumers, therefore an informative campaign should be held or at least the manufacturers should take action and design a new heating appliance that allows consumers to be aware of the topic and then guide them towards a more sustainable choice. The main challenge in assessing energy waste due to overfilling the kettle is measuring fill water volumes in a non-intrusive way, since it is impractical to measure and record water volume for every kettle use. The analysed study, overcomes the above problem by measuring the individual kettle consumption (kW/h) and estimating the water volume from this measurement using mathematical modelling. Since consumers directly interact with appliances, appliance-level load forecasting is particularly challenging as it depends on human behaviour, which is often stochastic and unpredictable. Despite the fact that the kettle has a non-negligible influence on electricity demand, modelling and forecasting methods to understand and predict demand, as well as calculating energy-wasteful usage, have not been analysed in detail so far for this appliance. Improving usage efficiency and designing eco-feedback to reduce energy wastage when using the kettle is considered by the HCI community in many studies. In the research presented in this study, the effects of using adaptive aversive and appetitive stimuli to change consumer behaviour is discussed. Specifically, when the consumers use the correct amount of water, they are rewarded with a virtual gold star. On the other hand, when they draw too much water,

they receive a negative reinforcement message. The method has not been tested in the field.
In this paper, a kettle prototype is designed, dubbed stroppy kettle, with a goal of changing bad habits of overfilling the kettle. The main idea is to impose on the user a punishment task if he/she is overfilling the kettle. Similarly, recognising that synchronous use of kettle can have significant negative impact on the grid, in this study, a new kettle design is proposed with a goal of achieving load management and providing users with immediate feedback. None of these designs have been tested in a longitudinal study.

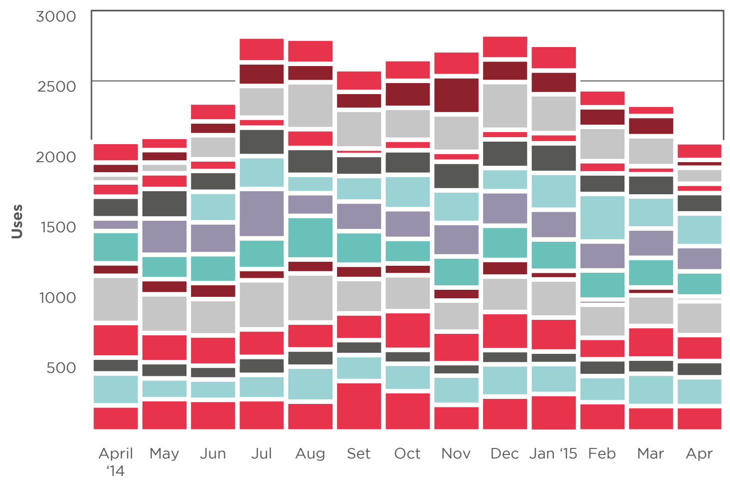
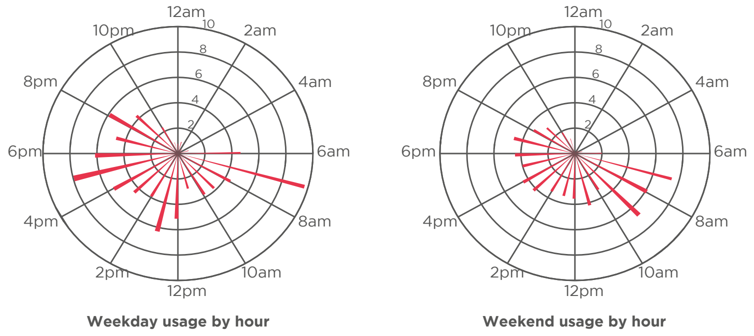


Chart 1.24
Seasonal kettle usage for all 14 houses from April 2014 to April 2015. Each house is represented with a different colour.

Chart 1.24 shows that across the year the seasonal effect on kettle usage is minimal, with a general pattern showing slightly increased usage during winter which agrees with work done in a previous study. **We observe, however, that increase in usage occurs during UK holiday periods July, August, December, and January, when occupants are at home for longer periods of time.**



Charts 1.25 and 1.26
Average daily usage of the kettle in october 2014 across all 14 houses, by hour.

Chart 1.25 shows the total usage for all 14 houses during October 2014, which is not a holiday period. Chart 1.19 shows the trend across all households of significantly higher usage at 7am, 1pm and 5pm (lunch is generally taken at 1–2pm and 5pm signifies the end of the working day). Chart 1.26 shows the general shift that can be seen during the weekend: uses are more prominent later in the morning.
While the number of uses explains patterns of use, it does not quantify how much energy each household consumes when using the kettle, nor identify variations in occupancy and energy waste due to overfilling the kettle. We confirm that **while individual households have predictable patterns of use, there are weekday/weekend variations as well as seasonal variations, which we attribute primarily to holidays rather than weather changes.**
Due to the simplicity of a kettle driven by a heating element, and our observation that the boil time is nearly linear with respect to the volume of water, we can reasonably assume a linear relationship between water volume and consumed power, taking starting temperature into account.

“Intuitively, lower volumes of water require less power to heat up than larger volumes.”

Obviously, different households have different preferred levels of water per boil, and consequently, consume differently per single kettle use. The data that has been gathered and analysed by the authors of the study reports many differences among the two years of collection, and their conclusions is that the wide range of consumption per usage suggests that the kettle is filled with little thought as to the purpose. While the consumption difference may be insignificant to an individual household, it is significant for the whole housing stock, with clear impact on electrical demand and regional carbon footprint. Indeed

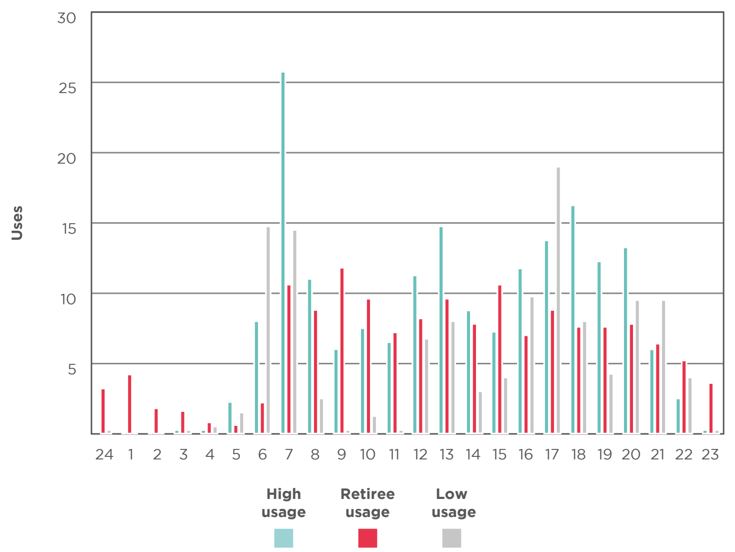


Chart 1.27
Usage for all 14 houses grouped by occupancy type. The numbers present the average usage for October 2014 per house in the group.

House	Occupancy	Total kWh	Kettle kWh	Total monthly cost (GBP)	kWh per single kettle use	% of total energy consumption
2	4(2)	621.45	14.83	1.96	0.062	2
3	2SR	471.17	18.28	2.41	0.072	4
4	2R	270.59	6.87	0.90	0.068	3
5	4(2)	676.58	19.41	2.56	0.073	3
6	2SR	324.74	15.04	1.98	0.060	5
7	4(2)	514.88	8.69	1.14	0.075	2
8	2R	571.73	16.09	2.12	0.067	3
9	2	537.10	23.24	3.07	0.098	4
11	1R	152.51	12.02	1.58	0.072	8
12	3	305.78	19.07	2.52	0.097	6
13	4	317.26	6.09	0.80	0.088	2
17	3	324.57	21.01	2.77	0.062	6
19	4(2)	216.38	9.00	1.19	0.057	4
20	3	291.55	11.65	1.54	0.067	4

Chart 1.28
The number of occupants, total electrical consumption, and kettle electrical consumption for all 14 monitored houses. The data are given for December 2014.

the total consumption of the housing stock taken from the analysed samples of dwellings adds up to 2181 kW h, which is not insignificant. **Kettle usage patterns are part of established domestic daily routines** (e.g., a high likeliness of usage early in the morning), and hence it is natural to assume that they can be accurately analytically predicted. **By predicting kettle demand, one can quantify the amount of energy that could be saved** (annually or monthly) if usage patterns change, for example, if the kettle is not overfilled. Moreover, appliance demand prediction is useful in time-use studies to understand routines and practices in the home.

Time of use analysis confirms well-defined patterns of use with respect to weekdays during standard "office hours", pattern variation depending on type of occupancy and general daily schedule, holiday periods and minor seasonal variation. Specifically, the analysis shows that kettle usage patterns are regular at peak times (morning, evening around dinner) and mainly sporadic otherwise during the day. Additionally, the study shows quantitatively, in-line with previous studies, that a significant percentage of households do overfill their kettle. Another factor is reheating water soon after it has boiled. In these cases households that appear not to overfill, based on the number of occupants, waste energy on reheating or reboiling.

In conclusion, the article demonstrates that due to well-defined patterns of use, it is possible to accurately predict kettle usage at a large scale using only smart metre readings, which could be of interest to network operators since synchronous kettle usage can have negative effects on the grid. An additional application of the proposed tools is to predict energy savings if water filling patterns change through, for example, more efficient behaviour of filling to ideal levels.

House	Occupancy	Kettle consumption (kWh)	Household reduced fill volume (ml)	Consumption above volume (kWh)	Savings per year (kWh)	Savings per year (GBP)
2	4(2)	210.10	825	115.07	21.66	2.98
3	2SR	170.07	550	126.31	41.22	5.67
4	2R	95.88	550	59.55	10.97	1.51
5	4(2)	199.21	825	100.45	19.85	2.73
6	2SR	207.27	550	110.51	24.86	3.42
7	4(2)	72.84	825	31.65	6.56	0.90
8	2R	184.99	550	145.44	36.67	5.04
9	2	248.42	550	215.81	92.22	12.68
11	1R	157.58	500	98.44	30.83	4.24
12	3	162.60	825	93.63	21.33	2.93
13	4	90.73	825	61.71	10.19	1.40
17	3	166.49	550	107.97	26.00	3.58
19	4(2)	95.07	825	29.68	4.57	0.63
20	3	120.19	825	19.06	2.38	0.33

Chart 1.29
potential energy savings if households did not overfill their kettle.

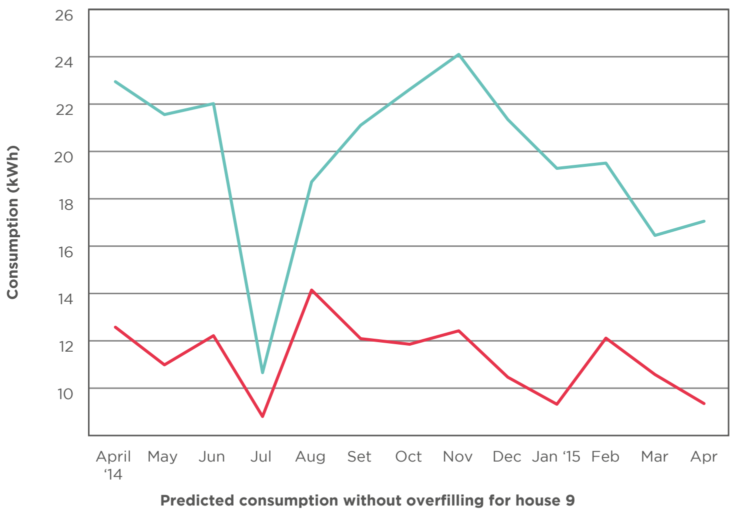


Chart 1.30
Predicted consumption without overfilling for house N°9.

Source:
D.M. Murray, J. Liao, L. Stankovic, V. Stankovic, 2016, Understanding usage patterns of electric kettle and energy saving potential, Applied Energy, Volume 171.

Environmental performance of the kettle / LCA

Economic development results in increased human impact on the environment, as the production scale is larger. Production companies are forced to face more and more strict requirements (legal, economic, social, environmental, etc.), which should be taken under consideration for planning and running production processes.
After the years of continual improvement, running environmental programmes and achieving objectives and targets, a very high level of environmental performance can be achieved.
A profound analysis of a given product may reveal that **the most important environmental impacts result not from industrial activities of the producer but from the other stage of the product life cycle.** The analysis like this needs “from cradle to grave” approach and usually is performed according to life cycle assessment (LCA) methodology. LCA provides a very wide perspective that includes various life cycle phases, like:

- Acquisition of resources (metal ores, crude oil, coal extraction processes, etc.)
- Raw materials production, from which the final product is being made (production processes of metals, alloys, plastic, ceramic, etc.)
- Raw materials, materials and semi-products transport (influence of transport means on the environment)
- final product manufacturing processes (direct environmental impact of the product manufacturer)
- Packaging production
- Product distribution (supplying the product to wholesalers, chain stores and customers – environmental impact of transport)
- Phase of product usage (materials needed, energy consumption)
- Waste disposal – getting rid of the product, packaging and materials after being used (environment impact of disposal methods such as re-use recycling, landfill processes, waste incineration, etc.)

The environmental impact of the above-mentioned stages of the product life cycle usually depends mostly on the designer, who by his decisions determines: raw materials usage, energy consumption, etc. Design phase role grows to the most important from the environmental impact’s point of view. In the era of maximizing efficiency and awareness of limited availability of raw materials, we are obligated to examine products in terms of eco-design. Testing alternatives, reducing the natural resources usage and analyzing possible scenarios should precede each product market entry. Market of household appliances is

Figure 1.45
Kettle on fireplace

expected to reach a value of 343.98 Billion USD by 2020. The size of home appliances market clearly reflects the demand for research and potential for reducing the environmental pressure by introducing more eco-friendly solutions. There are numerous papers that include research results concerning environmental impact assessment of various households appliances. Most of them show that the most significant environmental impact results from usage stage of product and is connected with energy consumption. Reduction of energy consumption is a very effective way to achieve better environmental efficiency of products. Murray et al. (2016) underlines the worrying level of energy efficiency improvement in electric kettles compared to other electric home appliances. Authors also point out that the market of electric kettles lacks proper efficiency labeling. Moreover, over-filling the kettles to the unnecessary level is rather common which contributes to the excessive energy consumption.

It has been stated that the usage phase of the life cycle is the most harmful for the environment. The results are clearly unilateral – **the environmental impact of electric kettle outweighs the stovetop one in every category.** Products' life cycles were assumed to consist of three stages: assembly (including environmental impact of resources extraction, raw material processing and kettle production – from cradle to gate approach), usage stage (predominated by electricity consumption), waste scenario (environmental impact of waste product disposal).

The average boiling frequency was assumed in accordance with previous researches – 3 times a day, the lifespan included 350 days a year (vacation days deducted) during 4 years of usage (4-5 years according to literature), therefore the mean data was obtained using the formula 0.8 l x 3 x 350 x 4 = 3360 l, specific heat for water 4.19 kJ/(kg·K), temperature difference (100°C - 20°C) and boiling efficiency (0.83 and 0.45 for electric and traditional kettles respectively). As far as the environmental impact of transport is concerned, it is assumed here that both kettles are manufactured in the same place in Europe.

Thus, the amount of transport needed is proportional to mass of kettles only. As expected, even a small amount of nickel causes quite a big threat for environment (29%) so replacing it with a substitute is worth considering. The majority of environmental impact is related to the electricity consumption during usage stage (over 92%). The production phase contributes in only 7% of entire environmental load. Waste scenario and transport processes seem to be negligible (0.17% and 0.09% respectively). An analysis of normalization indicators shows that most environmental impact (88%) concerns fossil fuels depletion category, that results from natural gas consumption.

In case of electric kettle, majority of the life cycle impact is

associated with pollution emitted from coal burning power plants that are represented by human health and ecosystem quality indicators. In case of stovetop kettle, the environmental impact associated with pollution is relatively low as emission from natural gas burning is not so harmful. The life cycle impact is predominated by resources depletion that results from natural gas consumption.
It is clear that the stovetop kettle is more environmentally friendly than the electric one. The total environmental impact of the latter is higher by 39%.
Basing on LCA results, some improvements of products can be suggested. In case of analyzed kettles, the most significant life cycle stage concerns energy consumption needed for water boiling. What can be said is that the kettle manufacturer does not have a direct influence on this stage, but it can redesign its product to obtain higher efficiency of energy use. In case of electric kettle efficiency could be increased by boiling time optimization.
In case of stovetop kettle the efficiency could be increased by application of a proper whistle, starting to indicate boiling earlier. However, it is quite difficult to estimate energy saving, as the gas stove does not turn off automatically.
Production of kettles in the form of thermos can be seen as an another way to increase energy efficiency. As the kettles are assumed to be used for three times a day, water remaining after boiling could keep temperature significantly above ambient temperature. The next boiling would start from higher initial temperature and it would use less energy. The change like this would entail higher environmental impact in assembly stage, but energy saving would outweigh this effect. Electricity generation pattern in a given state or region has the most significant impact on comparison research results. However, also in this case, kettle manufacturers have no possibility to control this factor.

Raw material	Mass
Stainless steel	546.246 g
Steel	1.572 g
Copper	17.046 g
Brass	10.303 g
Nickel	70.938 g
Chromium	17.734 g
Polypropylene	758.319 g
Polyethylene	1.360 g
Polyvinyl chloride	80.047 g
Silicone	26.629 g
Textiles	0.503 g
Overall weight	1530.697 g

Raw materials used for electric kettle production

Raw material	Mass
Aluminium	231.446 g
Steel	17.292 g
Polypropylene	78.745
Overall weight	327.483 g

Raw materials used for stovetop kettle production

Chart 1.31
Kettles raw materials

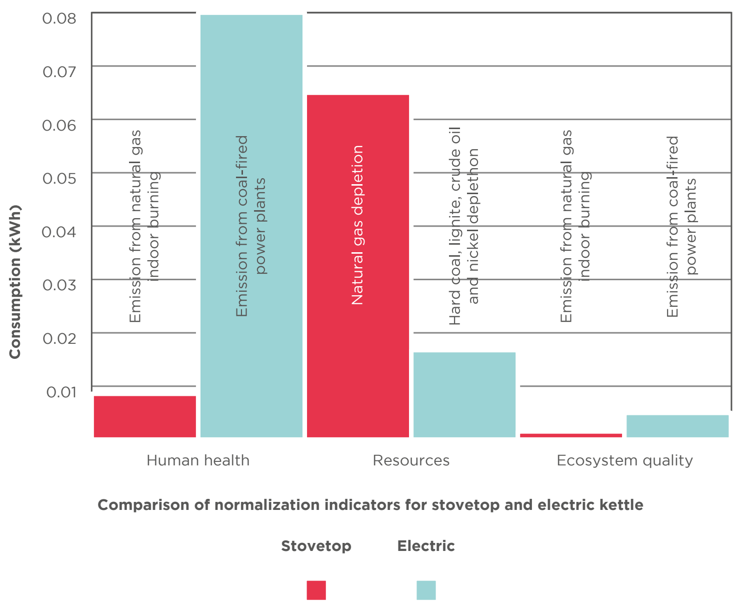


Chart 1.32
Comparison of normalization indicators for stovetop and electric kettle

Source:
Andrzej Marcikowski, Krzysztof Zych, Lodz University of Technology, 2017, Environmental performance of kettle production: product life cycle assesment, Volume 25, Issue 4, pp 255-261

Figure 2.1
The opportunity

Brief

The opportunity

The collected material needs to be re-elaborated in order to map the problems related to heating water systems for beverages consumption in a clear and explicit way. This phase will direct the path to take for the design phase, managing to bring out the ideas, insights.

- **Water requires a lot of energy (electrical power) in order to be heated.** That is because water has an high specific heat value: the amount of energy (joules) required to heat a single gram of liquid of 1 degree celsius.
- The most widespread device used in our homes to heat water is the electric kettle, but **people often overfill** it with water. That is because most people do not pay attention to their routine habits, and also the electric kettle design impedes the users to see how much water is in fact into the device.
- **Most home kitchen electric kettles operates only when filled at least with 400 ml of water**. That is because most kettles are dimentioned and powered to heat up to 1 and a half liters of water. This brings wastes both in water and energy everytime a kettle is filled with water to prepare just a single cup of a beverage, that usually can hold 250 ml of liquid.
- Electric kettle are usually switched on at regular monitored times of the day. That is because most people uses their kettle in the morning as they prepeare their tea for breakfast. This create an high demand in power supply on national electrical grid.
- The trend forecasted by specialized agencies is that people will prefer natural and home-processed beverages in the near future. This bring us the opportunity to re-design the way people prepare their beverages.
- There is raising awareness of young people of the resources limits of earth, in particular clean drinkable water. This bring us the opportunity to design a device that allow users to prepare their beverages with as little wastes as possible.

The last point to be made is the key insight of this master thesis:

- **Energy used to heat water can be reduced to the essential if we heat only the water that the user will actually consume.**

The most useful technolgy that allow us to heat only the water that is being used come from the coffee machines world, in particular coffee pod machines, that uses an heating element that heat streaming water in rapid times and without water wastes.

From concept to project

After all the research done on the hot beverages market and after all the aknowledgements about heating water systems and technologies we can now start talking about the main focus of this master thesis, the project.
At the beginning the project started just as a simple concept, and it was developed over months of research and design.
The initial concept started with the question “how can we reduce the energy used for heating water?”; this question bought me on different research fields, from the physical theories of heating water to the technologies applied by todays home appliances. This research on heating water technologies further developed new concepts and ideas but in the end I narrowed it down to streaming water heating systems.
The most useful and inspiring technology I found that is widely available on the market right now is the pod coffee machie system and I decided to use it to further develop my concept. With this heating system it is possible to heat streaming water quickly and safely, it is an energy efficient technology and it can be costumized in shape and size. That made it perfect to adapt to my concept and it soon became integral part of the project. In order to better understand the heating system I provided myself with a model of pod coffee machine to disassemble and study. The project now had a technology and some geometrical and physical constraint to start with. The next step to develop the project was to think about a shape and with that the use of the appliance, the interaction and all the parts I needed to make it work. After a lot of drawings and possible ways to adapt the technology to the use of the appliance I figured out the most simple and intuitive one.

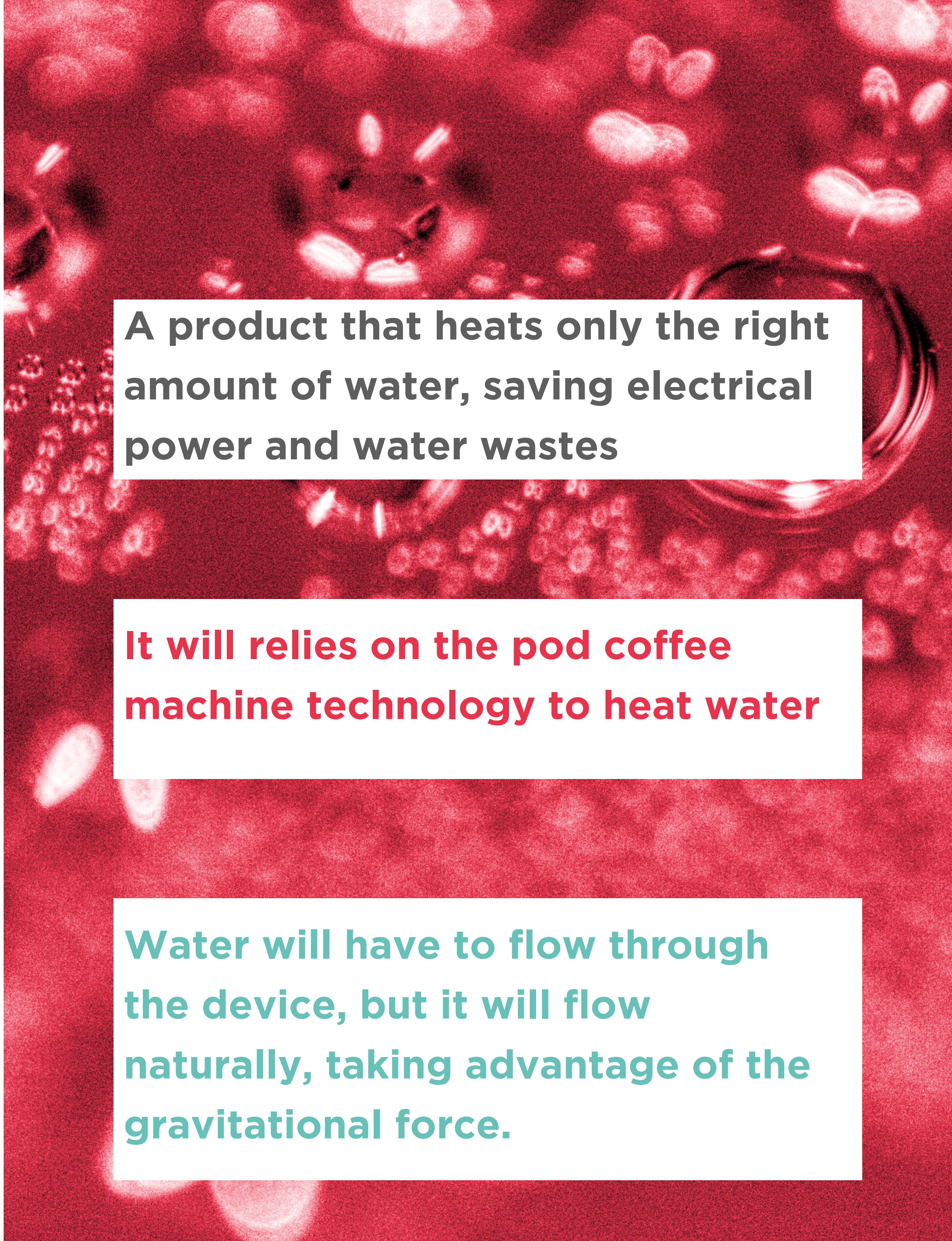


Figure 2.2
From concept to project

Reverse engineering

In order to better understand streaming water heating systems for this master thesis a pod coffee machine has been disassembled. The machine chosen for the disassembly was the “Nespresso Inissia” machine. The model “Inissia” was chosen for this experiment because of its popularity and cheap cost. **The machine operate at 1260 W, it takes 30 seconds start and it can hold 0,7 liters of water in it’s tank.**

Nespresso coffee pod machine, Inissia

L=120 mm
H=230 mm
D=321 mm

220-240 V
50-60 Hz
1150-1260W0

Max. 19 Bar

2,4 Kg
0,7 L

Figure 2.3
Nespresso Inissia

Figures from 2.4 to 2.21
Nespresso Inissia disas-sembled

Heating element study

IRCA R
230 V
1150 W

Water pipe diameter	= 5 mm
Time water takes to flow trough it	= 10 seconds
Water capacity	= 16 ml
Water pipe lenght	= 845 mm

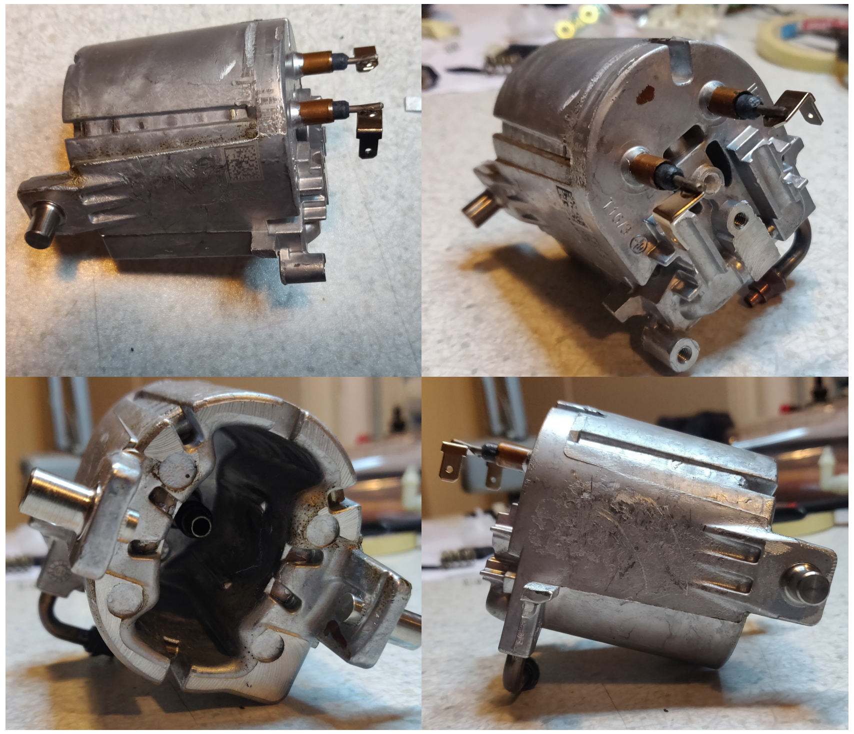


Figure 2.22
Nespresso Inissia heating element

The lenght of the pipe (Lp) was obtained with calculations, the volume of water it can contain was poured into a cylindrical glass.
Since the cylinder height and radius were known values we can put these datas in an equation:

$$A_{cylinder} * H_{cylinder} = A_{pipe} * L_{pipe}$$

With the lenght of the pipe figured out the next step was to plot all the other datas with the streaming water heating formulas, showed in the previous chapter.

r pipe (m)	0,0025	
A pipe (m^2)	0,00001963495408	r^2 * phi
l pipe (m)	0,845	
P (KW)	1,15	Electric power
Velocity (m/s)	0,0845	lenght divided by time (10s)
Water flow (m^3)	0,0000055	110 ml in 20 seconds with pressure

Chart 2.1
Inissia pod coffee machine datas.

The results of our calculations are suggesting that the temperature delta of the machine is around 50 degrees celsius. This is a reasonable result since coffee temperature from these machine is never too high. Another important factor to consider is that these machine operates with a pump, and that the water flowing into the heating element is under a strong pressure. This allows water to flow very quickly into the heated pipe, and the heating element is dimentioned and powered consequentialy.
The heating element is an aluminium pressure die casted part. We can also notice that the component has a metal pipe and the nichrome resistance drowned in it. Those elements, pipe and resistance are placed inside the die before the molten metal is injected and they remain unremovable once the metal has taken it's final form. The threads are done later on in the production process, with the use of a CNC machine.
Another lesson we can learn from the Nespresso Inissia machine is a **material study of the components, especially those parts in direct contact with the heating element**. These plastic parts are made of a particular material, the PA66 GF. The PA66 GF30 is a PA 66 loaded with 30% glass fibers. It exhibits exceptional mechanical properties such as superior strength, stiffness and creep resistance, as well as excellent dimensional stability. If compared to the unfilled PA 66, the properties of this modified material GF30 make it suitable for use in the production of parts that will remain exposed for a long time to high static loads and high temperatures.

Concept heating element study

Since the Nespresso Inissia pod coffee machine datas are now known values, and we know it's functioning and the physics rules behind it, it is time to plot these datas in order to create our own heating element.
First of all, we decide that our heating element will have similar parts and geometry, since it rely on a well known and widespread technology and manufacturing process. The water pipe we are going to use will have the same diameter value but with a slightly shorter lenght:

Pipe diamerer: 5 mm
Pipe lenght: 700 mm

During the test we conducted on the Nespresso Inissia machine heating element, we noticed that the water takes around 10 seconds to flow from the entry to the exit of the pipe when we let it fall without any pressure. Therefore we can plot these datas like this: if water takes 10 seconds to make 845 mm of pipe inside the Inissia heating element, how many seconds will water take to run 700 mm in our concept heating element?

10 seconds : 845 mm = x seconds : 700 mm

The result of this equation is 8,2 seconds. Since we now know the time taken by water to run through a certain distance we can calculate it's velocity:

Velocity = Distance / Time
= 0,7 m / 8,2 seconds
= 0,0854 m/s

Now that we know the water velocity we can calculate it's flow rate through a certain section of the pipe:

Water flow = Pipe Area * Velocity
*= 0,000019 m² * 0,0845 m/s*
= 0,0000016 m³/s

Now that we know the water flow rate into the pipe we need to dimentionate the electrical power and use the inverted formula of streaming water heat to get a similar result.

Water flow = Power / (water density * water specific heat * delta temperature)

Using the Excel software we can now easily find a balanced value of power in order to get a certain delta temperature.

r pipe (m)	0,0025
A pipe (m^2)	0,00001963495408
l pipe (m)	0,7
Time (s)	8,284023669
P (KW)	0,55
Velocity	0,0845
Water flow (m^3)	0,00000165915362
Delta t (°C)	79,30486109

Chart 2.2
Concept plotted datas.

Using the Excel softare we have putted the value 550 watts as electrical power value. This gave us a satisfing result: almost 80 degree difference can be reached with these geometry and power values. Another confirm that what we did was correct is the fact that if the Inissia machine would operate with this power it would be insufficient to heat enoght the water while is straming through the pipe since it is flowing under a very strong pressure. Our heating element instead, will operate using gravitation force only, therefore it's flow will be much slower and the heating element will need much less energy to heat water sufficiently.
Another proof that our calculations are correct is the comparison of results of different water flow formulas using the now known values. If the results are the same (or very close to each other) we can say that we did everything correctly:

Water flow formula with cross section and velocity:

Water flow = Pipe Area * Velocity
*= 0,000019 m² * 0,0845 m/s*
= 0,0000016 m³/s

Water flow formula with delta temperature and power:

Water flow =
Power / (water density * water specific heat * ∆ temperature)
*= 0,55 kW / (4,18 J/g·k * 1000 kg/m³ ** 80°C)
= 0,0000016 m³/s

All the calculations have been simplified using the specific heat and density of water in normal atmosferic conditions:

c = 4.18 J/g · K (Specific heat)
y = 1000 kg/m3 (density)

Summary of results

Once we established the values of our heating element characteristics, we can start the design process. T**he geometry of the pipe, and with it of the heating element are now the free variables**, but still have to keep in mind that we have the Nespresso Inissia heating element as a reference during our design process.

Pipe Lenght	700 mm
Pipe Diameter	5 mm
Water Flow Rate	1,6 ml/s
Electrical Power	550 W
Delta Temperature	80 °C

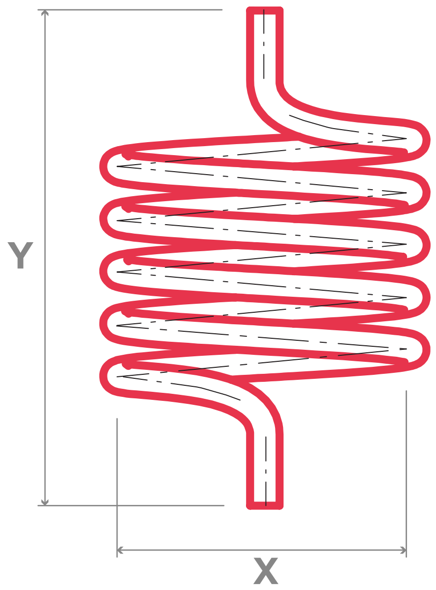
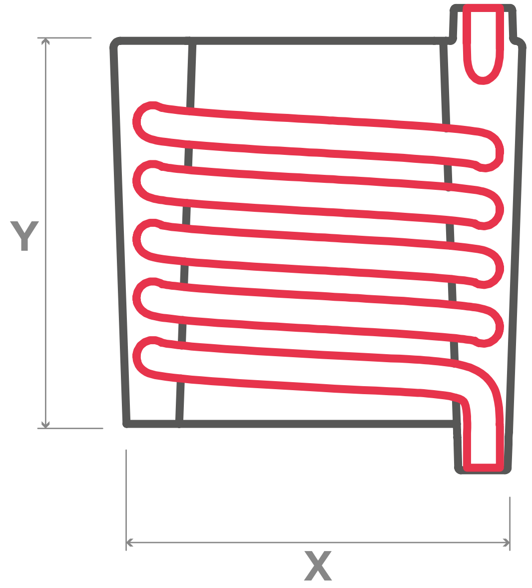


Chart 2.3
Summary of results

Figure 2.23
Summary of results

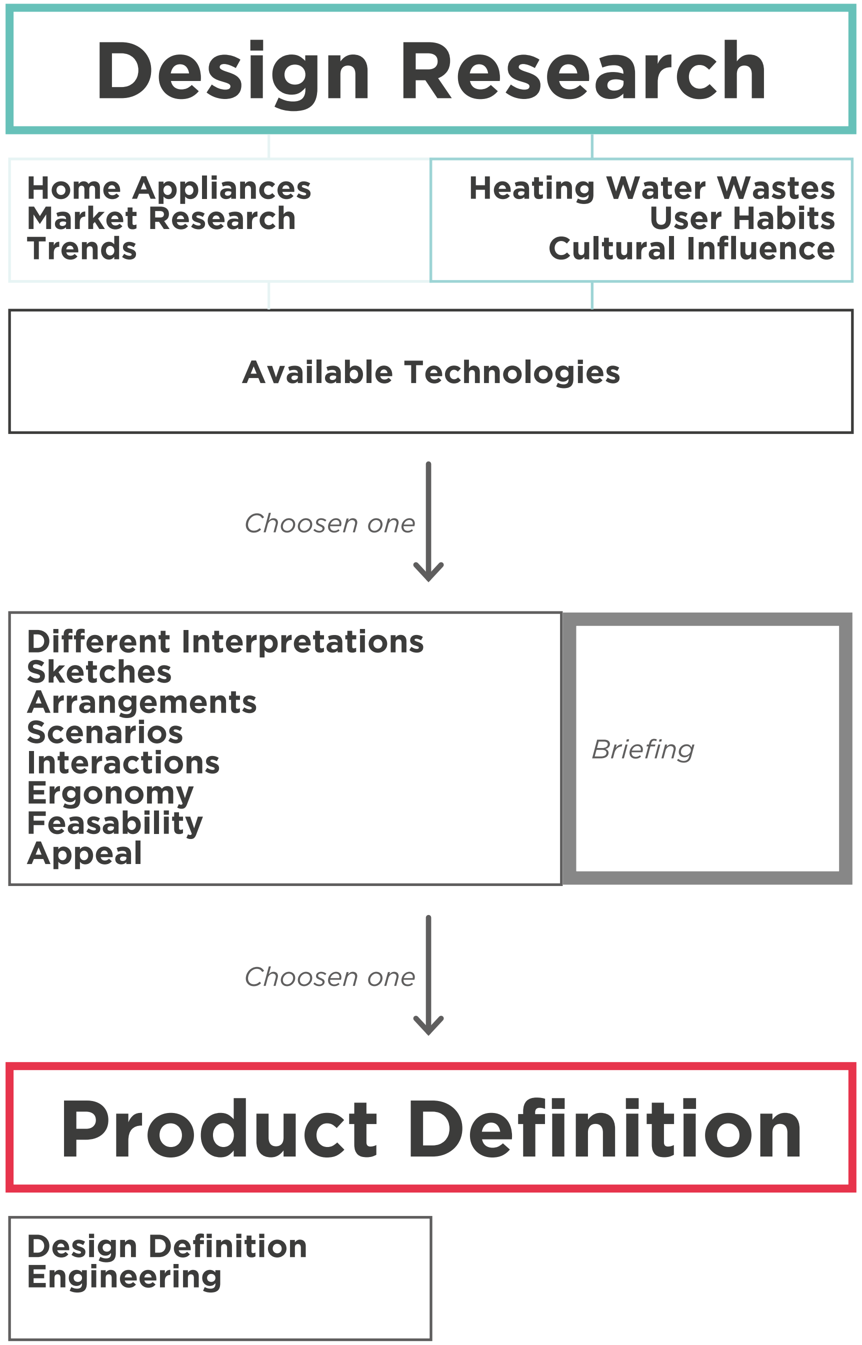
In order to achive a result similar to the Nespresso Inissia heating element, I decided to design an helicoid pipe, with the already known lenght and diameter (700 mm and 5 mm).
With small changes in the coil terminal directions, it is possible to have a water pipe that has the two terminals aligned along the vertical axis. This will allow the heating element to work by gravity only, without the use of a water pump.



Once we have selected a rational part arrangement, a shape of the device, the overall functioning and all the different components, **we can define the water pipe coil dimentions.** The next part to be design will be the heating element that will follow the coil shape.

Figure 2.24
Summary of results

Design process



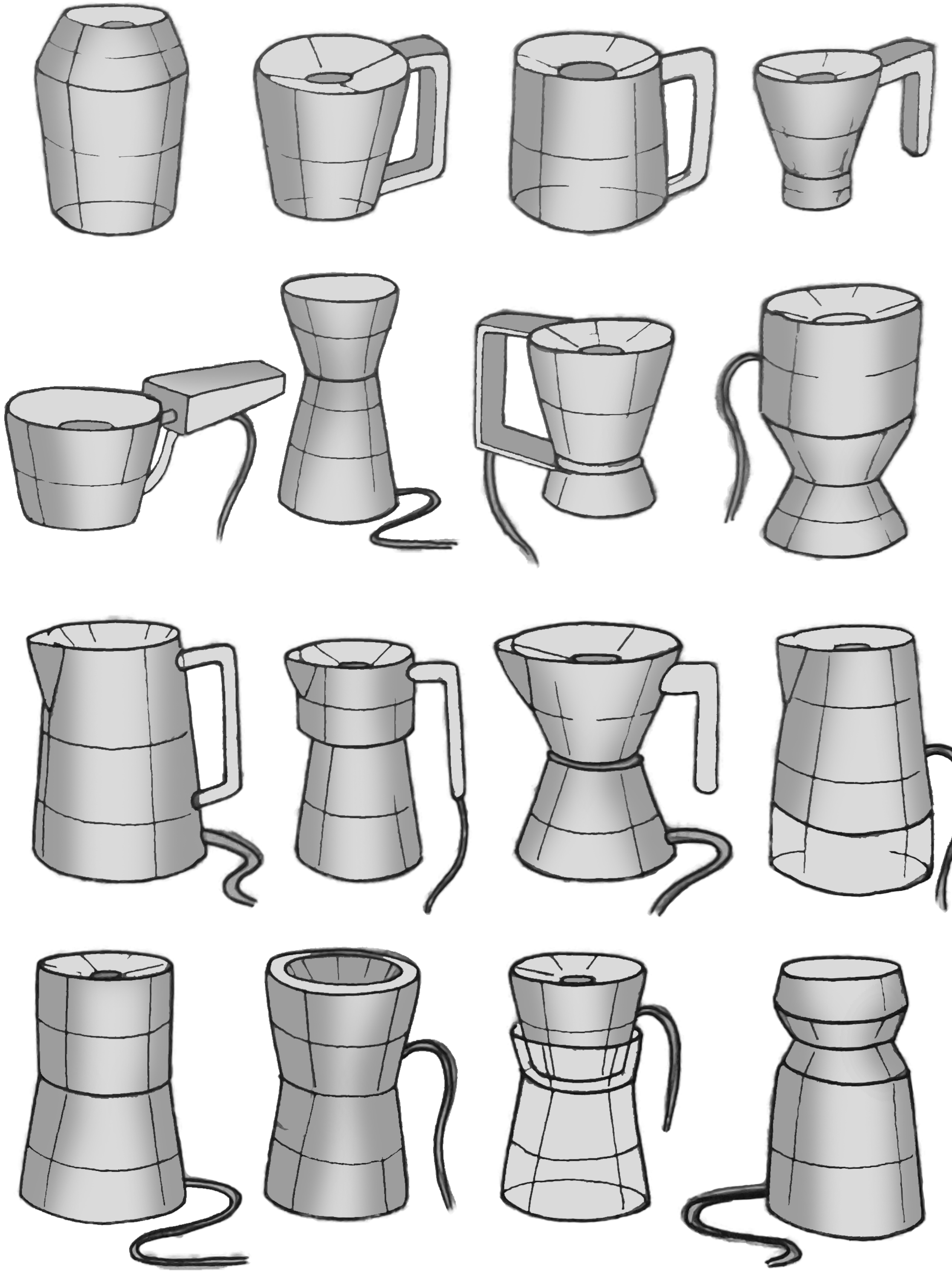


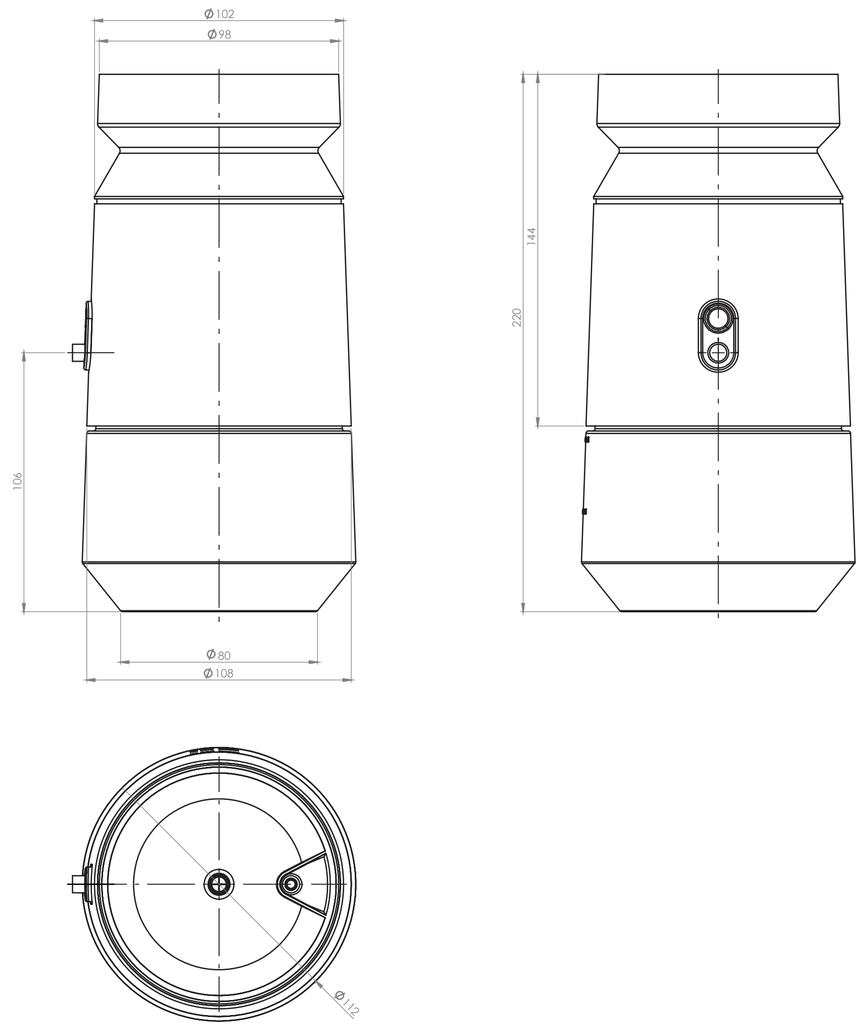
Figure 2.25
Early sketches

Figure 3.1
0W electric kettle 1

03. Project

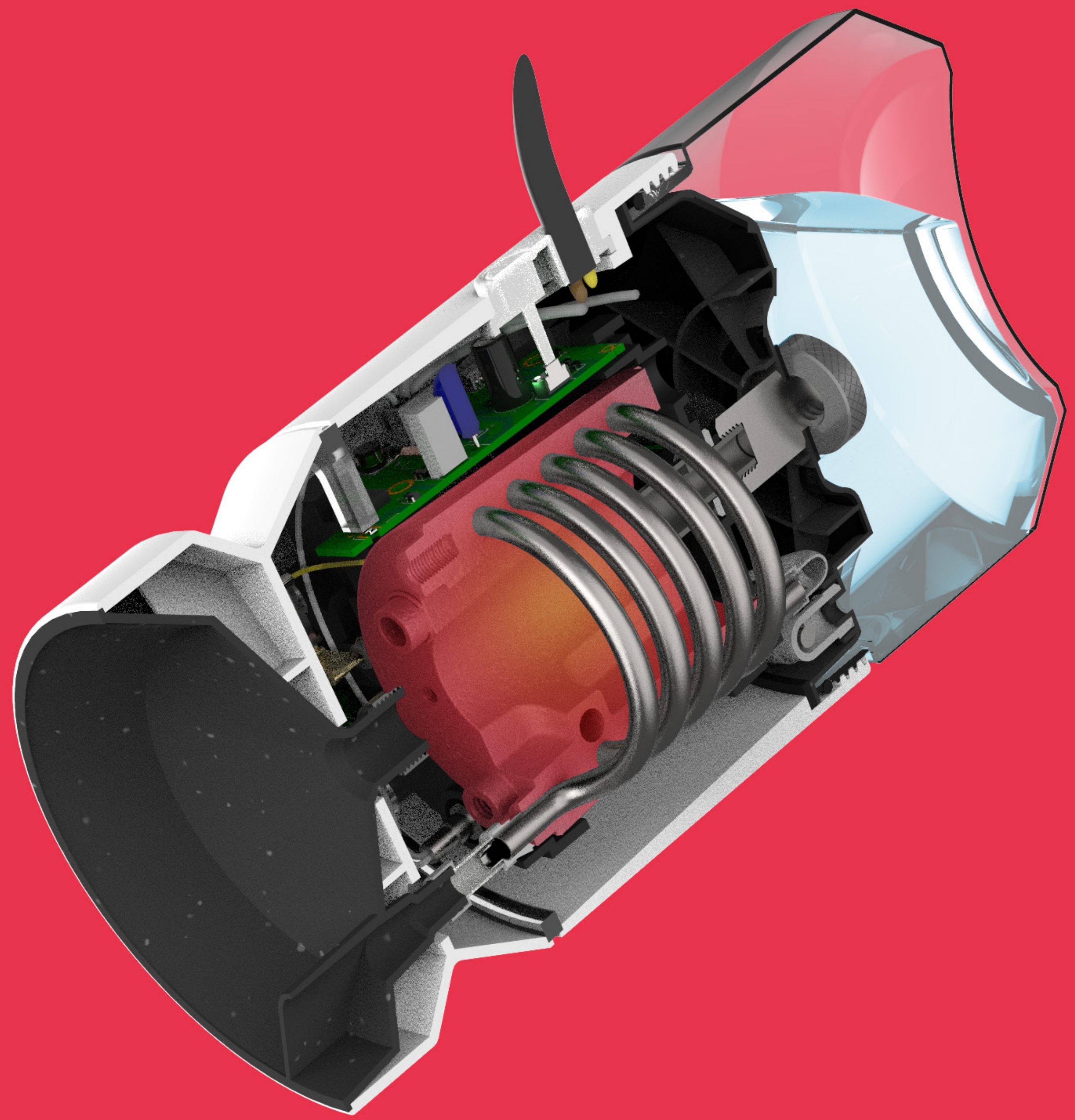
0W electric kettle

0W electric kettle is a water heating device that **heats only the water needed for a couple of tea cups.** The device can be holded like a water bottle and the user can pour steaming hot water direcly into his/her cup. The advantage that 0W electric kettle bring is that it consumes only the electric power needed to heat a certain amount of water, reducing wastes both in terms of electrical energy and water used when preparing hot beverages.



0W
Electric Kettle

Figures 3.2 and 3.3
0W electric kettle



Figures 3.4
0W electric kettle

Technical datas

0W operates like a pod coffee machine, but since it do not need a water pump to make the water flow through it's heating element it requires a very low electrical power compared to similar kitchen appliances.

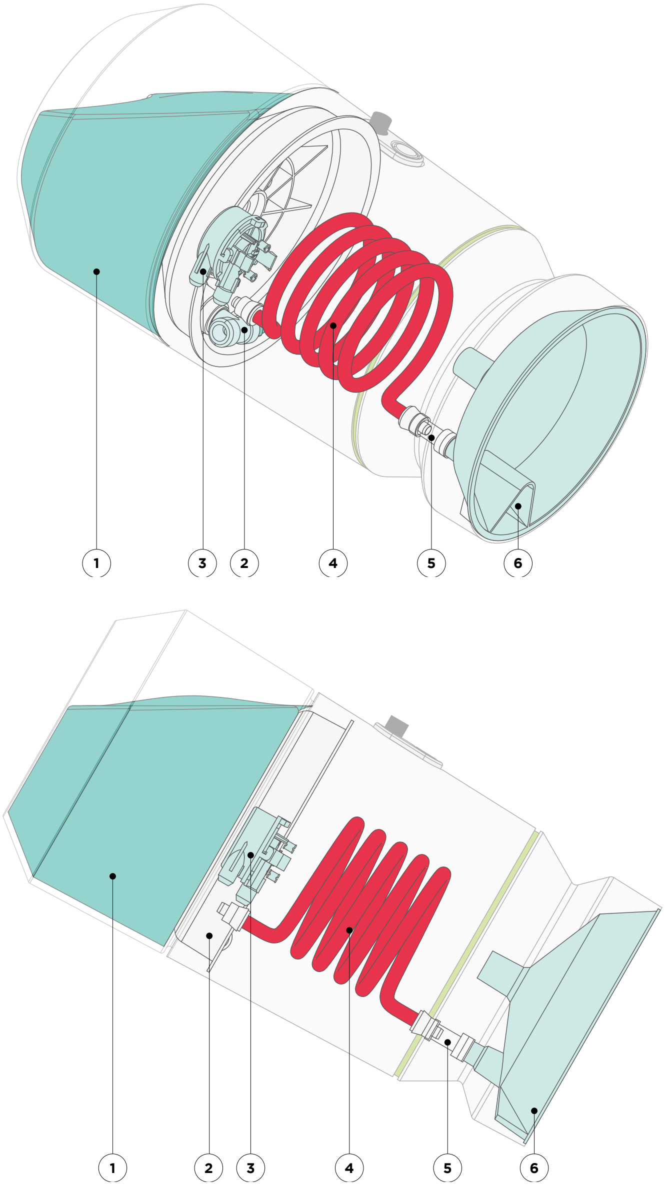
Capacity	500 ml
Power consumption	550 W
∆ temperature*	80°C
Flow rate	1,6 ml/s
Time delay**	8 s
Time to fill a cup *(250 ml)*	150 s

∆ temperature*
This means that at maximum power the device can heat up water of 80°C. For instance, if the water in the tank is at 10°C, the device will heat it until 90°C. If the water will have an higher initial temperature, the device will not bring it to the boiling point for safety issues. For instance, if the water flowing in the device is registered to be at 25°C, the device will not apply full power but it will heat it until 95°C, therefore the ∆ temperature reached will be 70°C

Time Delay**
Time it takes for water to flow from the tank to the funnel spout. In this moments the user will not see anything coming from the device because the water is still travelling through the pipes.

How does it work (pouring)

Water flow through the device
Pouring water from 0W electric kettle is easy and intuitive, as it works just like a regular water bottle. Tilting the device will make the water stored inside the tank to flow through the pipes. The flow meter and thermocouples will make sure that the water is heated to the right temperature safely.



Figures 3.5 and 3.6
Water flow through the device

1. Water tank
The water is contained at the bottom of the device in a transparent plastic tank, with a maximum capacity of 500 ml, enought to prepare a couple of tea cups.

2. T connection
The T connection is firmly attached to the bottom lid, and it's the first component in which water flows trhough as it is poured down. It's right arm is connected with a pipe to the next step, the Flow meter component, while on the other arm there's the thermocouple that monitors the initial water temperature. This data will be transmitted to the brain of the product, the PCB that will regulate the heating element temperature consequently.

3. Flow meter
The flow meter check water passage velocity and it provides this data to the main PCB, that regulates heating temperature conquently. As soon as the flow meter will detect a change in direction the heating element will shut down completely to avoid the dangerous flash boiling effect.

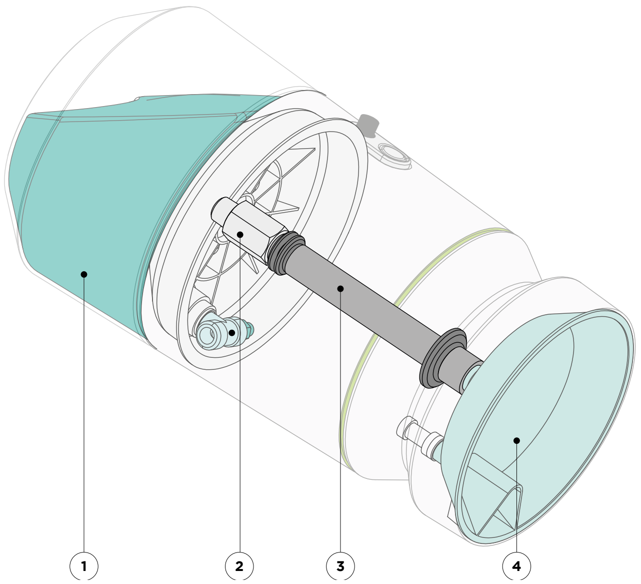
4. Heating pipe
The heating water pipe is drowned in the aluminium heating element, and it's helicoid shape provides a large surface area to exchange heat with water in a small contained space.

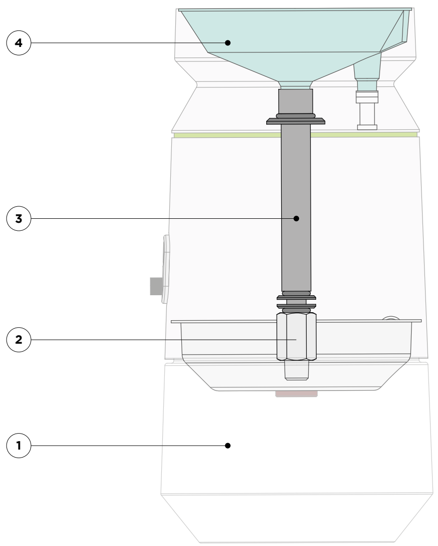
5. Connecting pipe
The connecting pipe provides a junction to the heating element pipe to the funnel, it's the last step of water flow inside the device.

6. Spout
The spout on the funnel provides an direction to the user to pour water directly into his/her cup.

How does it work (refilling)

Water flow through the device
When the user wants to fill the water tank he/she can easily pour it from the top. The central pipe will allow water to flow through the device, to the check valve. The check valve will let the water flow to the water tank. When the device is tilded by the user, in order to pour hot water, the check valve prevent the water to flow back to the funnel in the wrong pipe.





Figures 3.7 and 3.8
Water flow through the device

1. Water tank
The water is contained at the bottom of the device in a transparent plastic tank, with a maximum capacity of 500 ml, enought to prepare a couple of tea cups.

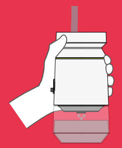
2. Check valve
The check valve will prevent water to flow in the wrong direction. When water comes from the top (funnel) the check valve will allow it to flow down to the water tank. When the device is tilted, in order to pour hot water, the check valve will prevent water to flow back to the funnel in the wrong pipe.

3. Central pipe
It connects the funnel with the check valve and it’s hollow shape allows water to flow trhough it.

4. Funnel
The user can use the funnel to fill the water tank easily. The water will flow from the funnel to the central pipe, and from it to the check valve and at last into the water tank.

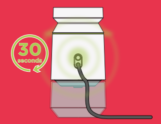
Interaction (story board)

This chapter wants to explain the functioning of the whole system that has been designed in eight steps, highlighting those that are aspects of usability of the project. In particular, a storyboard will be developed to visualize the main steps of using the device focusing on the interaction with the user.



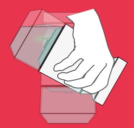
1. Refill

2. Switch on

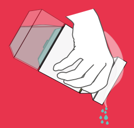


3. Loading

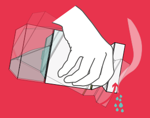
4. Ready to use



5. Tilting



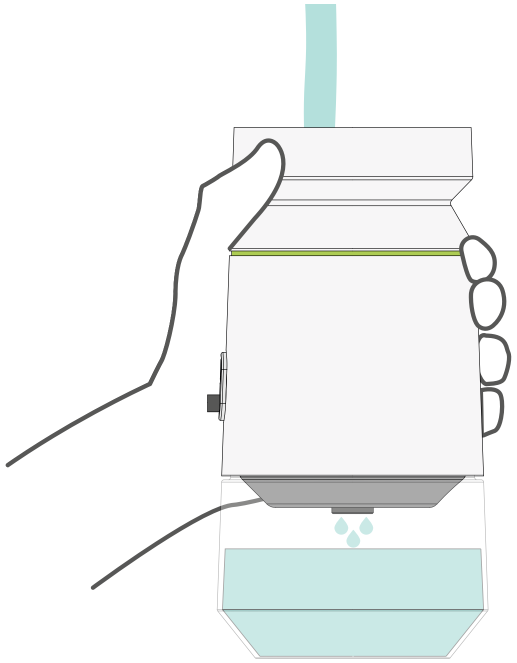
6. Pouring



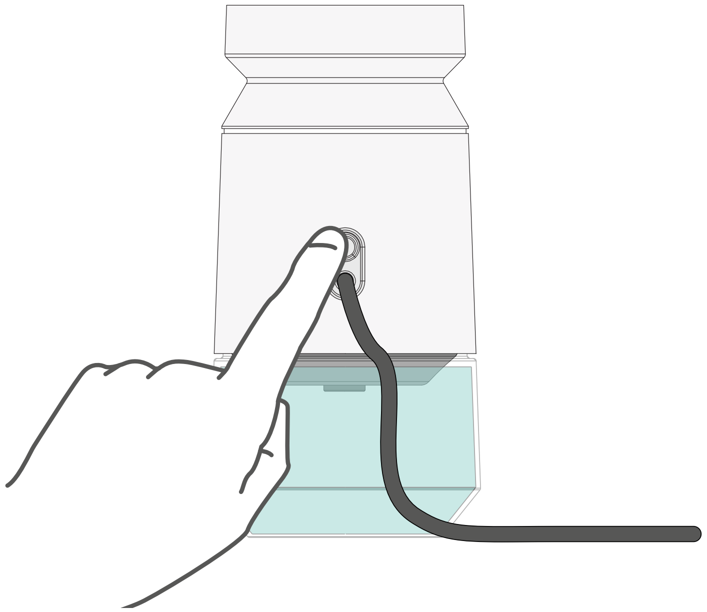
7. Tilting back

8. Switch off

Figures 3.9
OW electric kettle



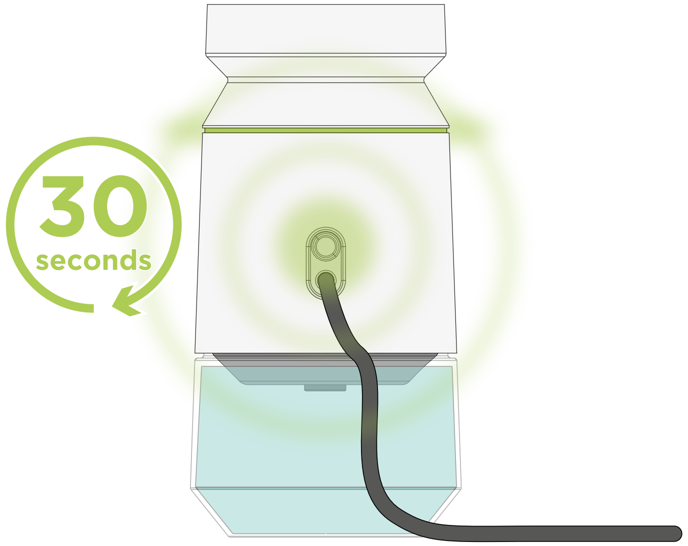
1. Refill
The user will have to fill the water tank from the top, pouring water into the funnel. The water will drop through the device into the water tank.



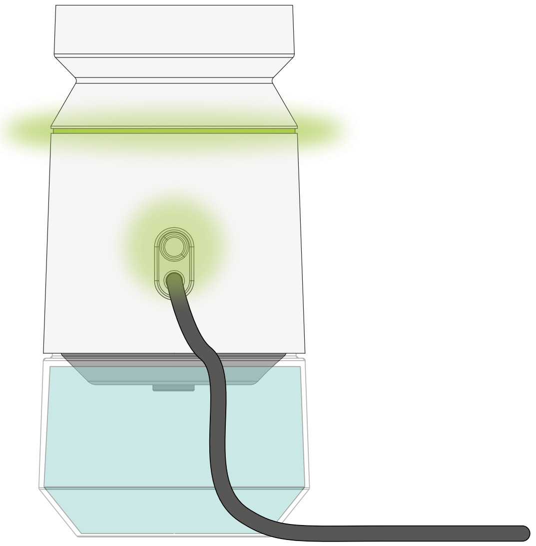
2. Switch on
To turn on the device, the user will push the button placed above the cable.

Figures 3.10 and 3.11
Interaction , steps 1 and 2

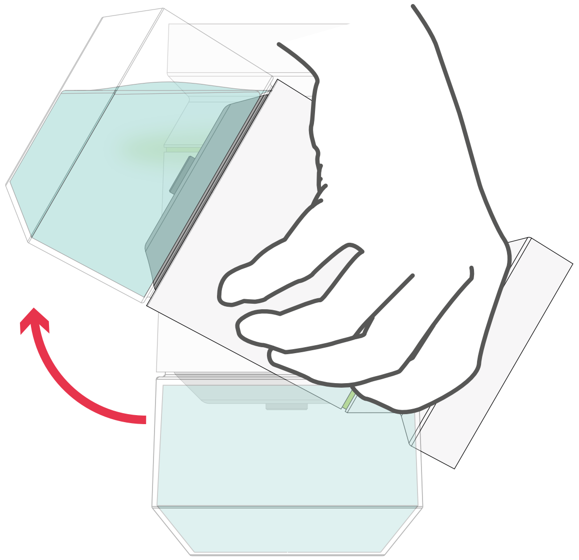
3. Loading
The green light of the button and on the LED ring will start blinking immidiatly after being turned on. The device will need around 30 seconds to heat up the resistance and pipe, exactly like a pod coffee machine.

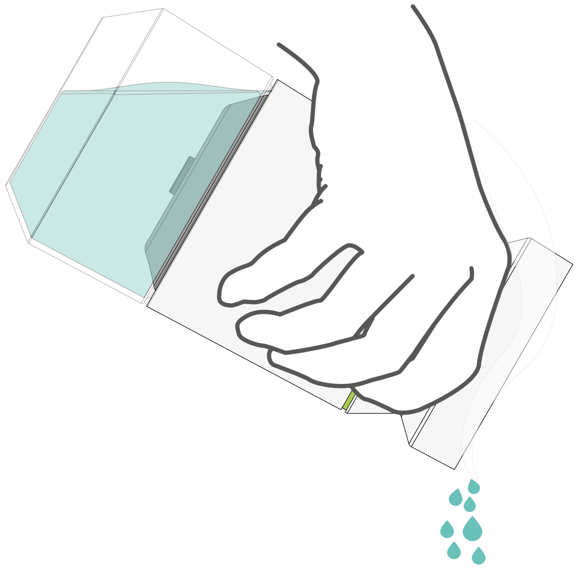


4. Ready to use
After heating up the device will signal the user that it is ready to be used with a steady green light.



Figures 3.12 and 3.13
Interaction, steps 3 and 4





5. Tilting
The user can now tilt the device. The water will start flow through the pipes, and the flow meter and thermocouple will comunicate the PCB how much power is needed to heat up the water.

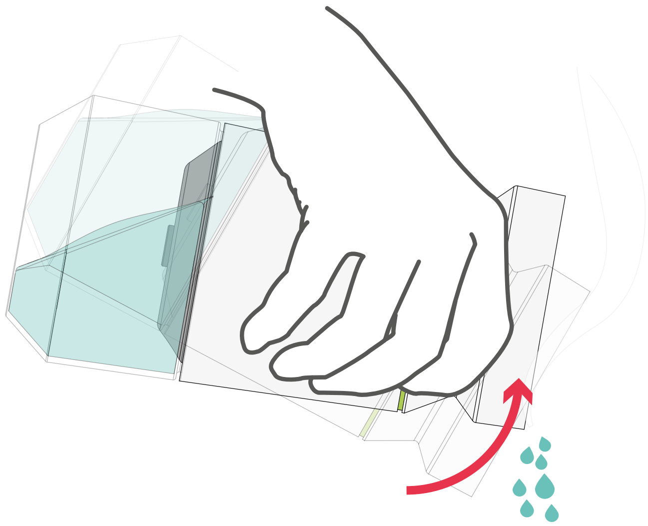
6. Pouring
Water will start to drop from the funnel spout.

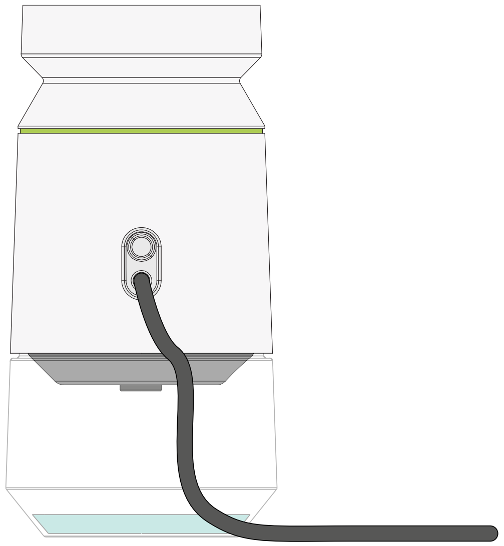
Figures 3.14 and 3.15
Interaction, steps 5 and 6

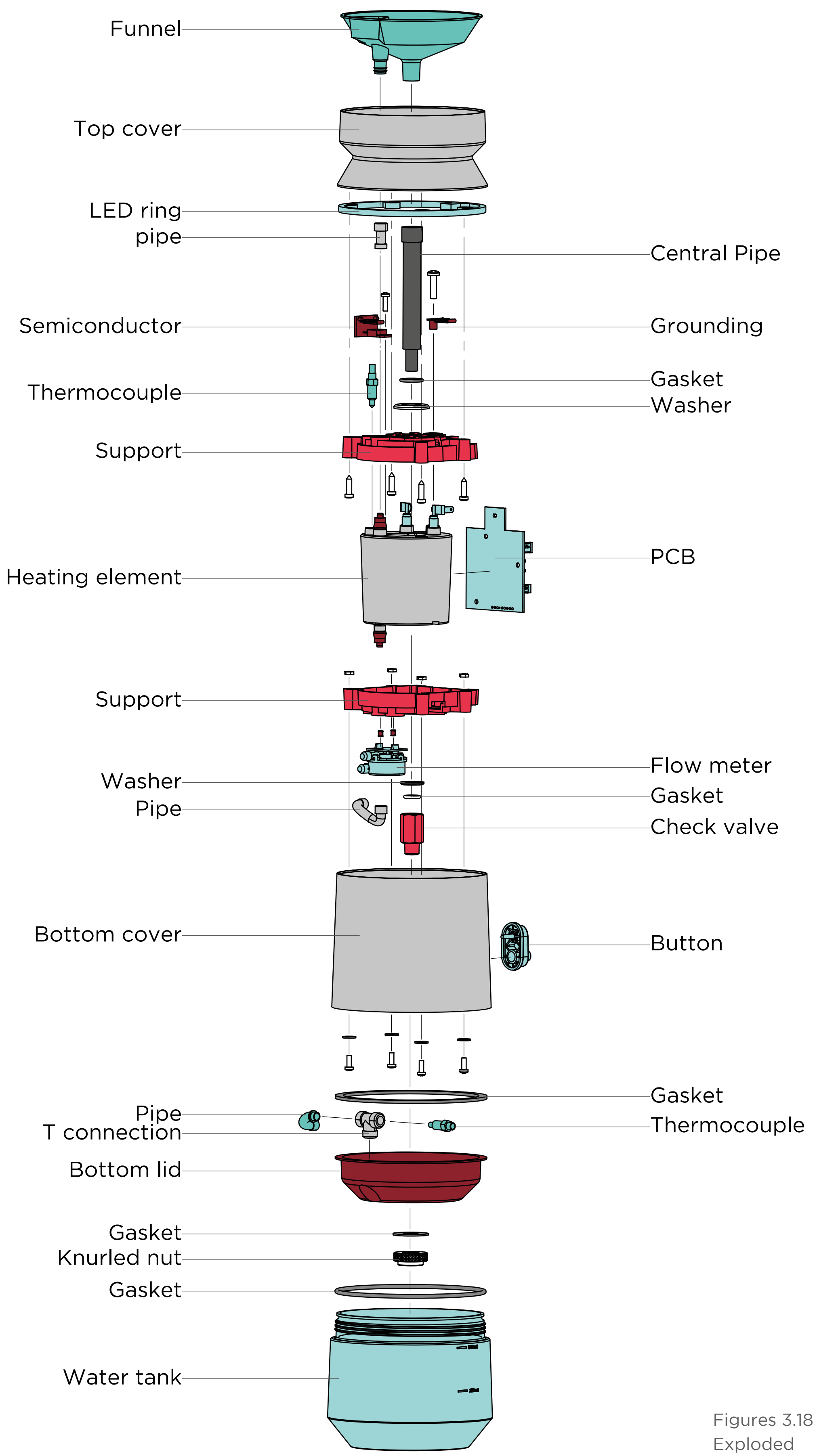
7. Tilting back
As the user will tilt back the device, the flow meter will signal the PCB to turn off the heating system.

8. Switch off
The device will automatically switch off after 2 minutes of non-use.

Figures 3.16 and 3.17
Interaction, steps 7 and 8







Figures 3.18
Exploded

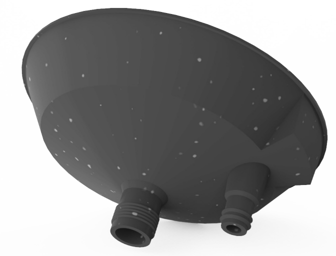
Components description

Made-components
The main parts that have to be made are the product covers, the supports and the heart of the product, the heating element. These parts have been designed with an **high production rate in mind, therefore these componets take advantage of industrial processes** that otherwise would be too expensive to apply, such as plastic injection molding and pressure die casting. In this chapter all the manufacturing characteristics and details will be described in detail.
Made components:
- Funnel
- Top Cover
- Bottom Lid
- Bottom Cover
- LED Ring
- Water Tank
- Heating Element
- Core Support

Buy-components
The research and the evaluation of these components involved most of the design process, and was the starting point to reach the goals set during the briefing phase. In accordance with this, these components were selected, not based on cost limits, but according to performance criteria that guaranteed the product a long useful life and the minimum need for maintenance.
The choice of the buy parts was influenced by three fundamental factors:
- Dimensions: the dimensions of the sensor are critical especially when designing covers and connections between the parts.
- Measurement range: the sensors chosen must be able to provide accurate measurements on temperature and flow rate.
- Already used: since this product is born with in mind the idea to make a kettle similar in the process of a pod coffee machine some components have been “recycled” from the Nespresso coffee machine disassembly.

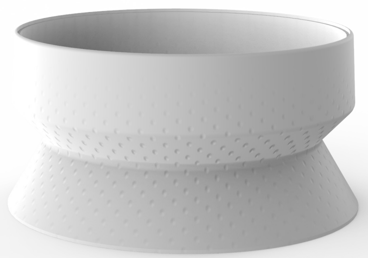
Buy components:
- Flow Meter
- Thermocouple
- PCB
- Check Valve
- Semiconductor
- Grounding
- T Connection
- Knurled Nut

Funnel
The main purpose of this part is to pour the steaming hot water from the spout, but also to direction the water that is being poured from the top into the central pipe when the tank is being refilled. Another important function of this part that is not visible from the outside is to screw the central pipe to it when assembled, and this will keep all the upper assembly of the device in place.



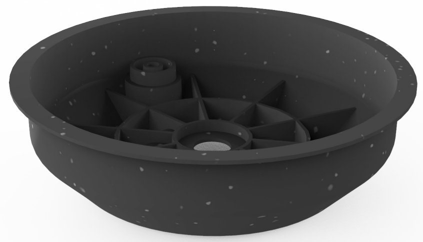
Figures 3.19
Funnel

Top cover
The main purpose of this part is to ensure a good hold from the user to the product. Other important function this component have it to keep the funnel in place, and with that also the LED ring and the screws attached to it.



Figures 3.20
Top Cover

Bottom lid
The bottom lid is attached to the bottom lid thanks to the central pipe and it is keeped steady with gaskets and the knurled nut. The main function of this component is to collect water inside the tank and direction it’s flow through the T connection. Even dough this part is merely visible it is very important for it to keeps liquids sealed inside the tank.



Figures 3.21
Bottom Lid

Bottom cover
The main function of this part is to hold the heart of the product, the heating element assembly. This component also connects with the water tank and the button. The major function of this part is to keep everything inside it in place.

Figures 3.22
Bottom Cover

LED ring
This LED ring allows light coming from a single point to spread all along it’s outer surface. This allows to save money on the production of the device, since only one light source is needed to achive the desired effect: the light feedback signals that the device have to give to the user when operated.

Figures 3.22
LED Ring

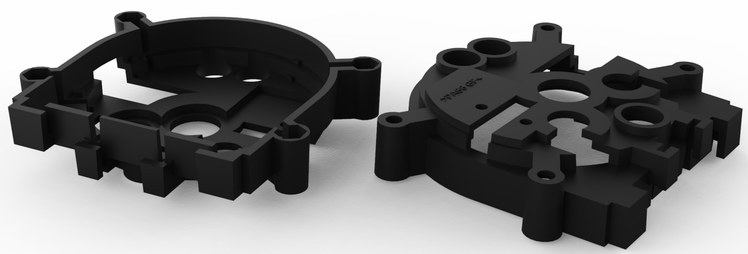
Water tank
The main function of this part is to store the water when the prodcut is refilled. This part must be transparent to let the user see how much water is left inside it.

Figures 3.23
Water Tank

Heating element
The heating element is the heart of the product and it’s function is to convert electrical power to heat. The resistance and the pipe are drowned in this element during the metal casting, therefore these element are not disassemblable.

Figures 3.24
Heating Element

Support
This component main function is to hold all the internal components in place, such as the heating element, the PCB, the flow meter, the central pipe and all the electronincs parts. It is designed to have a minimum surface contact with the heating element.



Figures 3.25
Core Support

Flow meter
The main function of the flow meter is to ensure that the water is flowing in the heating element direction, otherwise it will signal the PCB to shut down the electrical power. This will prevent the flash boiling effect that would have dangerous outcomes.

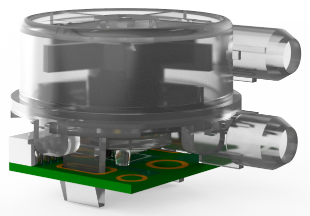


Figure 3.26
Flow Meter

Thermocouple
Thermocouple function is to monitor the heating element and the water temperatures. This allows the PCB to regulate the heat inside the heating element and also they provide a safety measure.

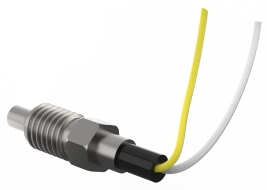


Figure 3.27
Thermocouple

PCB
It is a resin board on which the elements are placed to detect, receive, process and send all the information. The PCB is the central "brain" of the device, and it coordinates all the components to do their function properly. Attached to it there is also the hood pin switch that turns on the device and also the LED light that give the user visual feedback of the state of the device during it's different stages.

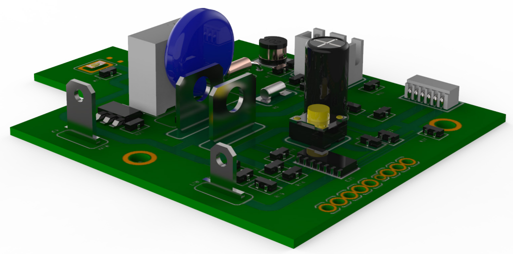


Figure 3.28
PCB

Check valve
The check valve allows water to flow downwards into the water tank and it prevents it to flow upwards even when the device is tilted upside down.

Figure 3.29
Check Valve

Semiconductor
The semiconductor is a safety device, attached directly to the heating element and it can take hige loads of electrical current without compromising the heating element function even when power is shutted down without any warning.

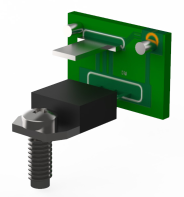


Figure 3.30
Semiconductor

Grounding
The grounding function is another safety measure attached to the heating element.

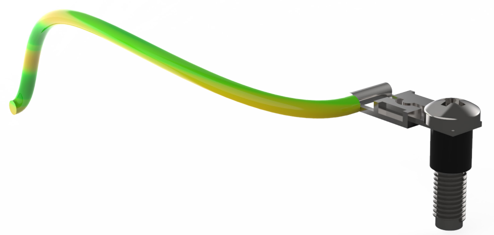


Figure 3.31
Grounding

T connection
This part main purpose is to direct the water flow towards the flow meter from the bottom lid hole. Inside the other arm there will be attached a thermocouple, that will measure water temperature.

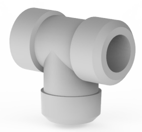


Figure 3.32
T Connection

Knurled nut
The knurled nut is the final nut that closes the bottom lid to the upper assembly of the product.

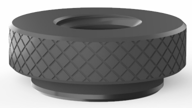


Figure 3.33
Knurled Nut

Figure 3.34
Material Selection

Material selection

After a careful research on the materials that are currently used in this family of products I have identified, for the main components produced, the material class of belonging. A first phase was formed to identify the constraints in the selection of materials, they were transformed into design requirements and, through the use of CES Ashby software, it was possible to obtain a first Material selection. The Next step was the one to deepen the research and taking into consideration such Processability, Costs, and Design Requirements, in order to identify the appropriate material.

General requirements
The main aim is that the product covers will have an excellent surface finish. The construction material must satisfy the following principles:
- High level of cleanability and surface finish
- Good Resistance
- Resistant to abrasion
- High surface finish
- Easy to clean

Other important requirements have to explained for the heating element supports that will directly connect with the heating element. The construction material of this support must have an high temperature resistance and a proper mechanical strenght.

Funnel and covers
The injection moulding allows obtaining shapes and finishes that meet our requirements. Generally, plastic polymer family is well suited to these requirements. For some plastics, contact with water does not affect mechanical and long-lasting capacity. They are easily producible and have a relatively low material cost.

Function constraint: Resistance to water and acids and hot temperatures
Aesthetic constraint: High level of surface finishing
Structural constraint: Threads, Stifness
Free variable: material

Limits introduced into the CES Ashby software:

Maximum service temperature= (minimum) 100°C
Durability: water and acqueous solutions= Acceptable;Excellent

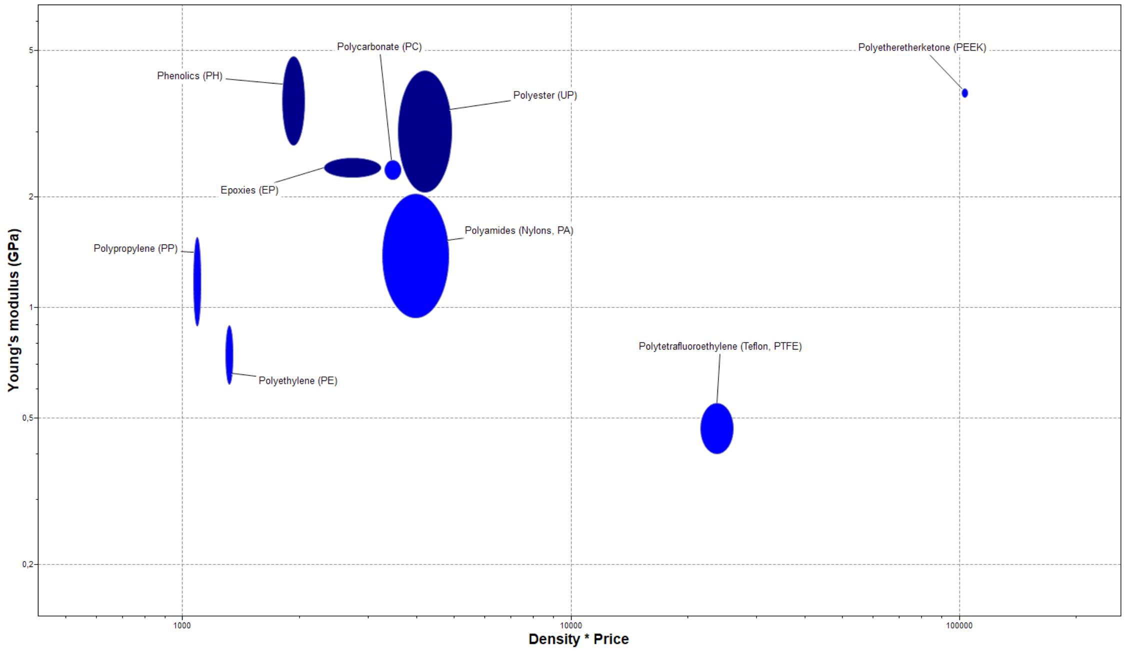


Figure 3.35
Material chart

After the result it's needed a material comparison to choose the lightest and cheapest material. From the chart we can see that among all the thermoplastic material that are suitable for the job, the cheapest and strongest materials are PP, PE, PA and PC. If we look at the specifics of each of these materials we can see that the most suitable one is the Polycarbonate for it's high maximum service and it's strenght. PC is also the best material for our components that present large thickness variations during the injection molding process.

Material	Polycarbonate
Price	2,76 - 3,03 EUR/kg
Density	1,19e3 - 1,21e3 kg/m³
Young's Modulus	2,24 - 2,52 GPa
Yield Strenght	55,9 - 68,9 MPa
Maximum Service Temperature	96,6 - 120 °C

Design guidelines
The optical transparency and high impact resistance of PC make it suitable for bullet-resistant or shatter-resistant glass applications. It is readily colored. PC is usually processed by extrusion or thermoforming (techniques that impose constraints on design), although injection molding is possible. When designing for extrusion with thermoplastics, the wall thickness should be as uniform as possible to prevent warping, and projections and sharp corners avoided- features like hollows and lone unsupported die sections greatly increase the mold cost. The stiffness of the final part can be improved by the incorporation of corrugations or embossed ribs. PC can be reinforced using glass fibers to reduce shrinkage problems on cooling and to improve the mechanical performance at high temperatures.
Typical uses
Safety shields and goggles, lenses, glazing panels, business machine housing, instrument casings, lighting fittings, safety helmets, electrical switchgear, laminated sheet for bullet-proof glazing, twin-walled sheets for glazing, kitchenware and tableware, microwave cookware, medical (sterilizable) components.

Water tank
The injection moulding allows obtaining shapes and finishes that meet our requirements. Generally, plastic polymer family is well suited to these requirements. For some plastics, contact with water does not affect mechanical and long-lasting capacity. They are easily producible and have a relatively low material cost.

Function constraint: Resistance to water and acids and hot temperatures
Aesthetic constraint: High level of surface finishing
Structural constraint: Threads, Stifness
Free variable: material

Limits introduced into the CES Ashby software:

Optical properties, Transparency= Transparent; Optical Quality
Durability: water and acqueous solutions= Acceptable;Excellent

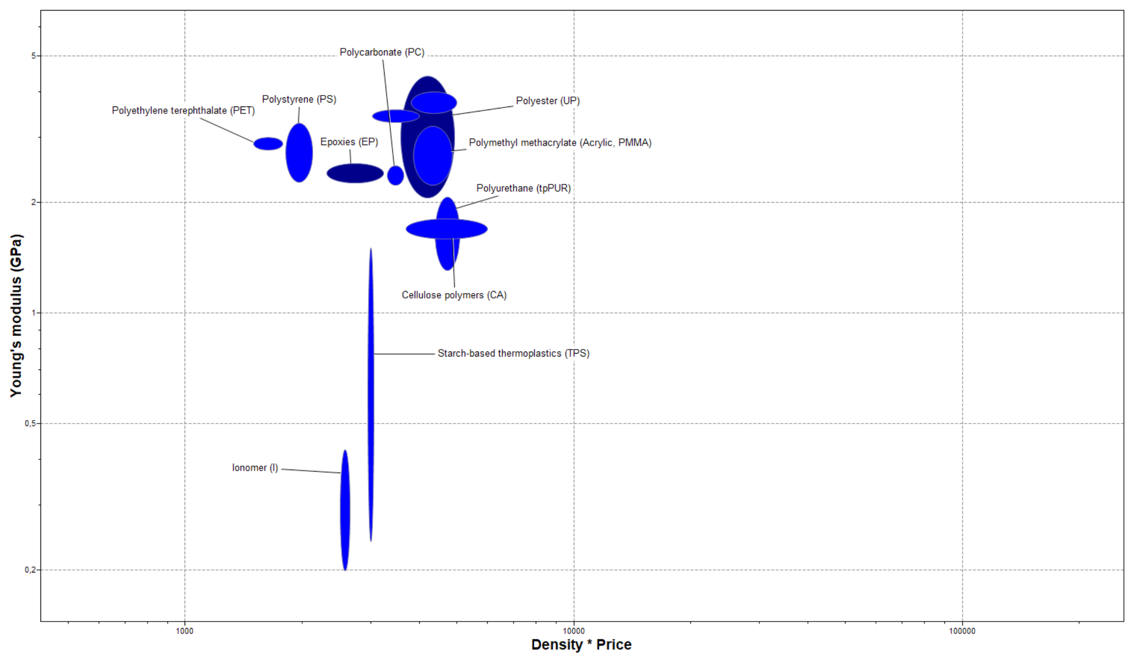


Figure 3.36
Material chart

After the result it's needed a material comparison to choose the lightest and cheapest material. From the chart we can see that among all the thermoplastic material that are suitable for the job, the cheapest and strongest material is *Polyethylene terephthalate (PET)*

Material	Polyethylene terephthalate
Price	1,22 EUR/kg
Density	1,29e3 - 1,39e3 kg/m³
Young's Modulus	2,79 - 3,01 GPa
Yield Strenght	47,2 - 58,2 MPa

Design guidelines
There are four grades of thermoplastic polyesters: unmodified, flame retardant, glass-fiber reinforced and mineral-filled. Unmodified grades have high elongation; flame retardant grades are self -extinguishing; glass-fiber reinforced grades (like Rynite) are some of the toughest polymers but there are problems with dimensional stability; and mineral-filled grades are used to counter warping and shrinkage although some strength is lost. The PET used in carbonated drink containers is able to withstand pressure from within, it is recyclable and lighter than glass. The limits of the material's permeability to oxygen is overcome by sandwiching a layer of polyethylvinylidene-alcohol between two layers of PET giving a multi-layer material that can still be blow molded. Polyester can be optically transparent, clear, translucent, white or opaque; the resin is easily colored.
Typical uses
Electrical fittings and connectors, blow molded bottles, packaging film, photographic and X-ray film, audio/visual tapes, industrial strapping, capacitor film, drawing office transparencies, fibers. Decorative film, metallized balloons, carbonated drink containers, ovenproof cookware, windsurfing sails, credit cards.

Core support

In the case of the core support components, the chosen material is the same used in the Nespresso Inssia pod coffee machine heating element covers, the PA66 PG. This material offers an high resistance to heat and also a great mechanical strenght. The technical datasheet of this material will be attached at end of this document.

Material	Polyammide 6.6
Density	1,34 g/cm³
Young's Modulus	5,5 GPa
Yield Strenght	91 Mpa
Maximum Service Temperature	180 °C

PA66 GF material datasheet in the references chapter

Heating Element

The heating element used in the OW electric kettle is manufactured and processes exactly like the heating element of the Nespresso Inissia pod coffee machine. The heating element is a pressure die casted component, where a stainless steel pipe and the nichrome resistance are embedded into the alumium body.

Material	Cast Al-alloys
Price	2,03 - 2,19 EUR/kg
Density	2,65e3 - 2,77e3 kg/m³
Young's Modulus	69 - 76 GPa
Yield Strenght	118 - 263`MPa
Maximum Service Temperature	138 - 200 °C

Manufacturing

In design phase it is essential to suggest process and assembly steps for this proposal. Considering BOM, geometrical & material constraints reasonable methods suggested below. For each critical make-part applied design rules listed. The electric kettle is a widespread home appliance, and the avarage prices of these products makes us think that manufacturers ofter mass-produce these eletrical appliances. For reasonable and justified selection, It has been assumed that %1 of the market can be good starting point for the sector.
The geometrical constraints, material and the annual batch sizes investigated together to make reasonable and strong hypothesis. Considering the market need and industries, annual batch size assigned to 100.000 which refers to **"medium to high"** production as seen from the PRIMA table.
This product will compose of two main material families. These are Aluminium family for the heating element and Thermoplastic family for parts for functional and aesthetic elements.
As shown in PRIMA table with the determined annual batch size of 100.000, selected manufacturing operations and applied design rules will be explained.

MATERIAL / QUANTITY	IRONS	STEEL (carbon)	STEEL (tool, alloy)	STAINLESS STEEL	COPPER & ALLOYS	ALUMINIUM & ALLOYS	MAGNESIUM & ALLOYS
VERY LOW 1 TO 100	[1.5] [1.6] [1.7] [4.M]	[1.5] [1.7] [3.10] [4.M] [5.1] [5.5] [5.6]	[1.1][1.5][1.7] [3.10] [4.M] [5.1] [5.5] [5.6] [5.7]	[1.5] [1.7] [3.7] [3.10] [4.M] [5.1] [5.5] [5.6]	[1.5] [1.7] [3.10] [4.M] [5.1]	[1.5] [1.7] [3.7] [3.10] [4.M] [5.5]	[1.6] [1.7] [3.10] [4.M] [5.1] [5.5]
LOW 100 TO 1,000	[1.2] [1.5] [1.6] [1.7] [4.M] [5.3] [5.4]	[1.2] [1.5] [1.7] [3.10] [4.M] [5.1] [5.3][5.4][5.5]	[1.1][1.2][1.7] [4.M] [5.1] [5.3] [5.4] [5.5][5.6][5.7]	[1.2] [1.7] [3.7] [3.10] [4.M] [5.1] [5.3][5.4][5.5]	[1.2] [1.5] [1.7][1.8][3.5] [3.10][4.M][5.1 [5.3] [5.4]	[1.2][1.5][1.7] [1.8][3.7][3.10] [4.M] [5.3] [5.4] [5.5]	[1.6] [1.7] [1.8] [3.10] [4.M] [5.5]
LOW TO MEDIUM 1,000 TO 10,000	[1.2] [1.3] [1.5] [1.6] [1.7] [3.11] [4.A] [5.2]	[1.2][1.3][1.5] [1.7][3.1][3.3] [3.10] [3.11] [4.A][5.2][5.3] [5.4] [5.5]	[1.2][1.5][1.7] [3.1][3.4][3.11] [4.A][5.2][5.3] [5.4] [5.5]	[1.2][1.5][1.7] [3.1][3.3][3.7] [3.10] [3.11] [4.A][5.2][5.3] [5.4] [5.5]	[1.2][1.3][1.5] [1.8][3.1][3.3] [3.10][3.11][4.A] [5.2][5.3][5.4]	[1.2][1.3][1.5] [1.8][3.1][3.3] [3.7][3.10][3.11] [4.A][5.3][5.4][5.5]	[1.3] [1.6] [1.8] [3.1] [3.3][3.4][3.10] [4.A] [5.5]
MEDIUM TO HIGH 10,000 TO 100,000	[1.2] [1.3] [3.11] [4.A]	[1.9][3.1][3.3] [3.4] [3.5] [3.11] [3.12] [4.A][5.2][5.5]	[3.1][3.4][3.5] [3.11][3.12] [4.A] [5.2]	[1.9] [3.1] [3.3] [3.4] [3.5] [3.11] [3.12] [4.A]	[1.2][1.4][1.9] [3.1][3.3] [3.4][3.5][3.11 [3.12] [4.A]	[1.2][1.3][1.4] [1.9][3.1][3.3] [3.4][3.5][3.11] [3.12][4.A][5.5]	[1.3] [1.4] [3.1] [3.3] [3.4] [3.5] [3.12] [4.A]
HIGH 100,000+	[1.2] [1.3] [3.11] [4.A]	[1.9] [3.1] [3.2] [3.3] [3.4] [3.5] [3.12] [4.A]	[4.A]	[1.9] [3.2] [3.3] [4.A]	[1.2][1.9][3.1] [3.2][3.3][3.4] [3.5][3.7][3.8] [3.11][3.12][4.A]	[1.2][1.3][1.4] [1.9][3.1][3.2] [3.3][3.4][3.5] [3.8][3.12][4.A]	[1.3] [1.4] [3.1][3.3][3.4] [3.8][3.12][4.A]
ALL QUANTITIES	[1.1]	[1.1] [1.6] [3.6] [3.8] [3.9]	[1.6] [3.6]	[1.1] [1.6] [3.6][3.8][3.9]	[1.1] [1.6] [3.6] [3.8] [3.9] [5.5]	[1.1] [1.6] [3.6] [3.8] [3.9]	[1.1] [3.6] [3.8] [3.9]

MATERIAL / QUANTITY	ZINC & ALLOYS	TIN & ALLOYS	LEAD & ALLOYS	NICKEL & ALLOYS	TITANIUM & ALLOYS	THERMOPLASTICS	THERMOSETS	FR COMPOSITES	CERAMICS	REFRACTORY METALS	PRECIOUS METALS
VERY LOW 1 TO 100	[1.1] [1.7] [3.10] [4.M] [5.5]	[1.1] [1.7] [3.10] [4.M] [5.5]	[1.1] [3.10] [4.M] [5.5]	[1.5] [1.7] [3.10] [4.M] [5.1][5.5][5.6]	[1.1] [1.6] [3.7] [3.10] [4.M] [5.1] [5.5][5.6][5.7]	[2.5] [2.7]	[2.5] [5.7]	[2.2] [2.8] [5.7]	[1.5] [5.1] [5.5] [5.6] [5.7]	[1.1] [5.7]	[5.5]
LOW 100 TO 1,000	[1.1] [1.7] [1.8] [3.10] [4.M] [5.5]	[1.1] [1.7] [1.8] [3.10] [4.M] [5.5]	[1.1] [1.8] [3.10] [4.M] [5.5]	[1.2][1.5][1.7] [3.10] [4.M] [5.1] [5.3] [5.4] [5.5]	[1.1][1.6][3.7] [3.10][4.M][5.1 [5.3][5.4][5.5] [5.6] [5.7]	[2.3] [2.5] [2.7]	[2.2] [2.3]	[2.2] [2.3] [2.8] [5.7]	[5.1] [5.3] [5.5] [5.6] [5.7]	[5.7]	[5.5]
LOW TO MEDIUM 1,000 TO 10,000	[1.3] [1.8] [3.3] [3.10] [4.A] [5.5]	[1.3] [1.8] [3.3] [3.10]	[1.3] [1.8] [3.3] [3.10]	[1.2][1.3][1.5] [1.7][3.1][3.3] [3.11][4.A][5.2] [5.3][5.4][5.5] [3.10]	[3.1] [3.7] [3.10] [3.11] [4.A] [5.2] [5.3][5.4][5.5]	[2.3] [2.5] [2.6] [2.7]	[2.2] [2.3] [2.4]	[2.1] [2.2] [2.3]	[5.2] [5.3] [5.4] [5.5]		[5.5]
MEDIUM TO HIGH 10,000 TO 100,000	[1.3] [1.4] [3.3] [3.4] [3.5] [3.12] [4.A]	[1.3] [1.4] [3.3] [3.4] [3.12]	[1.3] [1.4] [3.3] [3.4] [3.5] [3.12] [4.A]	[3.1][3.3][3.5] [3.4] [3.11] [3.12] [4.A] [5.2] [5.5]	[3.1][3.4] [3.11] [3.12] [4.A][5.2][5.5]	[2.1] [2.3] [2.5] [2.6] [2.9]	[2.1] [2.3] [2.9]	[2.1] [2.3]	[3.11]	[3.12]	[3.5]
HIGH 100,000+	[1.4] [3.2] [3.3] [3.4] [3.5] [4.A]	[1.4] [3.3] [3.4] [4.A]	[1.4] [3.2] [3.3] [3.4] [4.A]	[3.2] [3.3] [4.A]	[4.A]	[2.1] [2.6] [2.9]	[2.1] [2.3] [2.4] [2.9]		[3.7] [3.11]		[3.5]
ALL QUANTITIES	[3.6] [3.8] [3.9]		[3.6]	[1.1] [1.6] [3.6] [3.8] [3.9]	[3.8] [3.9]				[5.5]	[1.6]	[1.6]

KEY TO MANUFACTURING PROCESS PRIMA SELECTION MATRIX:

CASTING PROCESSES
[1.1] SAND CASTING
[1.2] SHELL MOULDING
[1.3] GRAVITY DIE CASTING
[1.4] PRESSURE DIE CASTING
[1.5] CENTRIFUGAL CASTING
[1.6] INVESTMENT CASTING
[1.7] CERAMIC MOULD CASTING
[1.8] PLASTER MOULD CASTING
[1.9] SQUEEZE CASTING

PLASTIC & COMPOSITE PROCESSING
[2.1] INJECTION MOULDING
[2.2] REACTION INJECTION MOULDING
[2.3] COMPRESSION MOULDING
[2.4] TRANSFER MOULDING
[2.5] VACUUM FORMING
[2.6] BLOW MOULDING
[2.7] ROTATIONAL MOULDING
[2.8] CONTACT MOULDING
[2.9] CONTINUOUS EXTRUSION (PLASTICS)

FORMING PROCESSES
[3.1] CLOSED DIE FORGING
[3.2] ROLLING
[3.3] DRAWING
[3.4] COLD FORMING
[3.5] COLD HEADING
[3.6] SWAGING
[3.7] SUPERPLASTIC FORMING
[3.8] SHEET-METAL SHEARING
[3.9] SHEET-METAL FORMING
[3.10] SPINNING
[3.11] POWDER METALLURGY
[3.12] CONTINUOUS EXTRUSION (METALS)

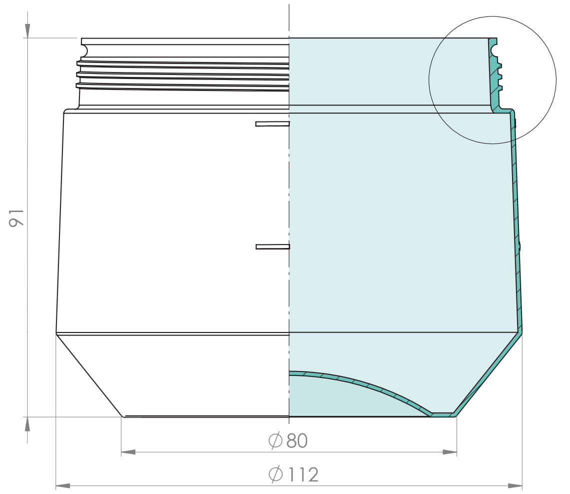
MACHINING PROCESSES
[4.A] AUTOMATIC MACHINING
[4.M] MANUAL MACHINING

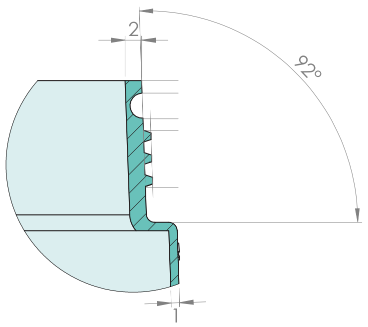
(THE ABOVE HEADINGS COVER A BROAD RANGE OF MACHINING PROCESSES AND LEVELS OF CONTROL TECHNOLOGY. FOR MORE DETAIL, THE READER IS REFERRED TO THE INDIVIDUAL PROCESSES.)

NTM PROCESSES
[5.1] ELECTRICAL DISCHARGE MACHINING (EDM)
[5.2] ELECTROCHEMICAL MACHINING (ECM)
[5.3] ELECTRON BEAM MACHINING (EBM)
[5.4] LASER BEAM MACHINING (LBM)
[5.5] CHEMICAL MACHINING (CM)
[5.6] ULTRASONIC MACHINING (USM)
[5.7] ABRASIVE JET MACHINING (AJM)

Figure 3.37
PRIMA table

Water Tank
The water tank manufacturing process is blow molding.



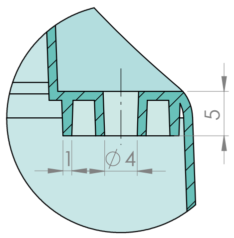


Applied design rules:

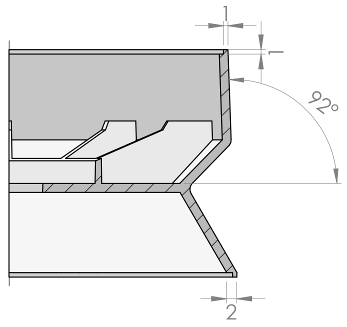
- The wall thickness should be as nearly uniform as possible to ensure more rapid molding cycles, conserve material, and avoid distortion due to uneven cooling. (Thinner sections cool more quickly.)
- The neck portion must have a thicker wall than the body to provide a rigid sealing structure, the ratio of wall thickness between the neck and body should not exceed 2:1.
- The part design should permit portions of the blow mold that are perpendicular to the parting plane to have a draft. This is preferred to a square configuration in ensuring that the molded part can be removed from the mold.
- Regular, well-rounded shapes are more easily molded, are more economical, and should be specified when there is a choice.
- The use of standard container-closure designs helps promote manufacturin economy.

Source:
James Bralla - Design for Manufacturability Handbook - McGraw-Hill Professional (1998)

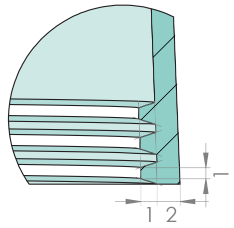
Covers, Funnel and Lid
These components are manufactured with the injection molding process.



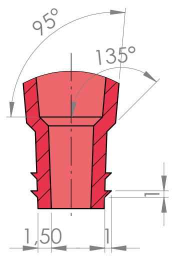
Bottom Lid detail



Top Cover detail



Bottom Cover detail



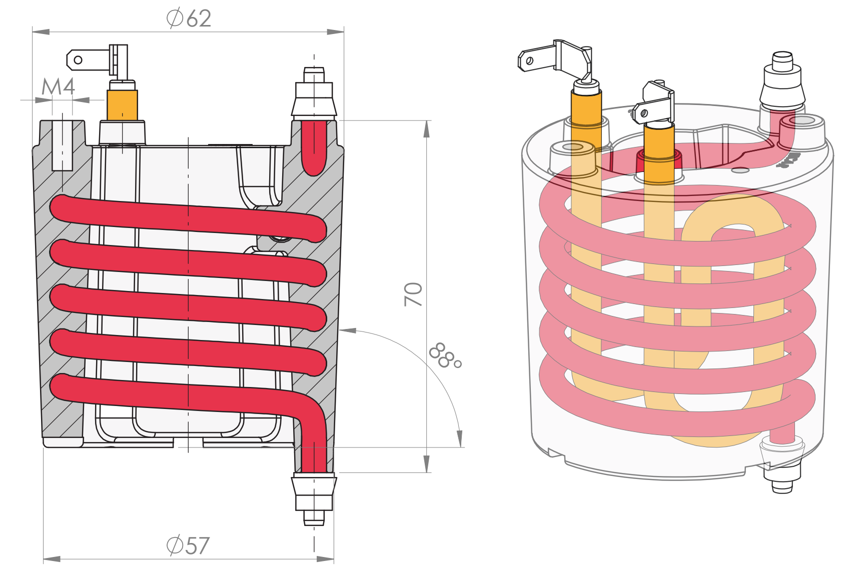
Funnel detail

Source:
James Bralla - Design for Manufacturability Handbook - McGraw-Hill Professional (1998)

Applied design rules:

- Uniform wall sections will help to produce warp-free and strain-free molded parts.
- If external undercuts are essential, sideactivated split molds or removable mold sections are required. This results in increased mold and piece-part cost.
- The spacing between holes and next to sidewalls should be as large as possible.
- Molded ribs may be incorporated to increase strength or decrease warpage of thermoset parts. The width of the base of the rib should be less than the thickness of the wall to which it is attached.
- Taper, or draft, should be provided both inside and outside the thermoset part.
- Both internal and external threads may be molded in most thermosets, but increased part and mold costs may be expected. Articles with molded male or external threads may be removed from the mold by unscrewing the part from the mold, or the threaded section may be in a removable unscrewable section of the mold.

Heating element
The heating element manufacturing process is the pressure die casting.



Applied design rules:
- The easiest die casting to make and the soundest in terms of minimum porosity is one that has uniform wall thickness.
- The sidewalls of die castings and other features perpendicular to the parting line must be tapered, or drafted, as much as possible to facilitate removal from the die.
- The die-casting process can accommodate the coring in of holes into the body of the casting at right angles to the parting line.
- External screw threads can be formed on die castings, but when a precision fit is required, it is recommended that the threads be machined.
- Inserts can be incorporated in die-cast parts where necessary, though with increased cycle time because of the time required to load inserts into the die. Ability to cast in inserts such as pins, studs, shafts, linings, bushings, fasteners, strengtheners, and heating elements.
- Many parts designed for die casting need trademarks, part numbers, indications for dials, etc., incorporated into their surfaces. There are two alternatives. The easy way is to specify that the characters be raised in the casting. This can be accomplished by relatively inexpensive engraving of the die.

Source:
James Bralla - Design for Manufacturability Handbook - McGraw-Hill Professional (1998)

Figures 3.38
Warm smile

Assembly

The assembly was taken into serious consideration during the design phase, given that this process constitutes an important fraction of manufacturing costs and therefore of the final costs of the products. In this regard I have tried to simplify the assembly as much as possible, and also since most of the part are custom made, all the connection have been designed specifically to simplify the assembly process. The assembly starts from the heart of the product, the heating element. **This simple assembly and construction of parts also allows quick and secure disassembly process**, when the product might eventually need maintenance or substitution of parts.

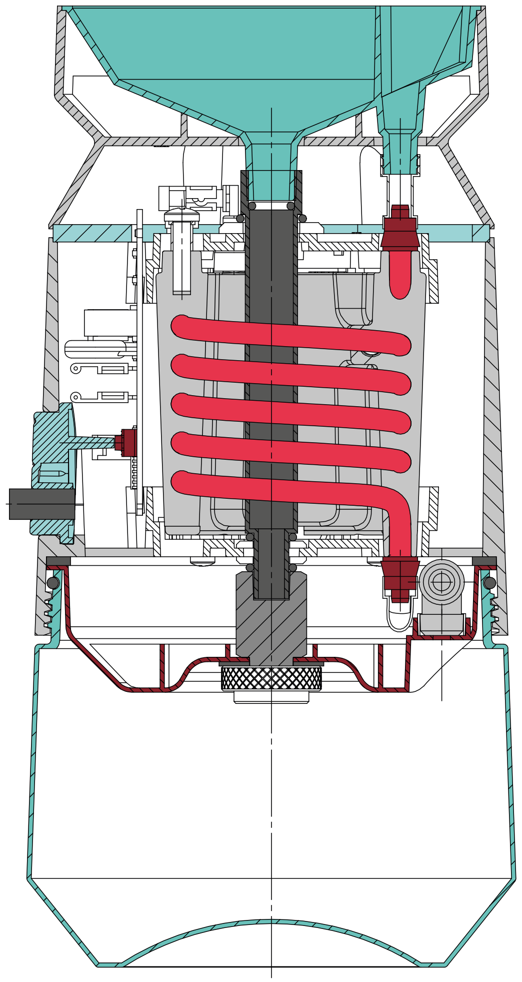


Figure 3.39
Section view

01.
The heating element is the first component to start the assembly process with. The Heated element comes with the electrical connections weldeded to the nichrome wire and the pipes connections already installed on the water pipe terminals.

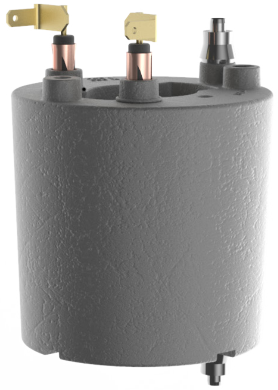
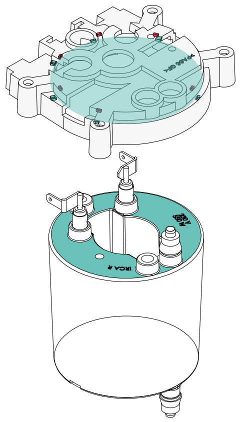


Figure 3.40
Assembly, step 1

02.
One of the core support components is installed on top of the heating element. The core support lays on the heating element with it's teeth, having with it a minimal surface contanct. The main PCB is placed in position.



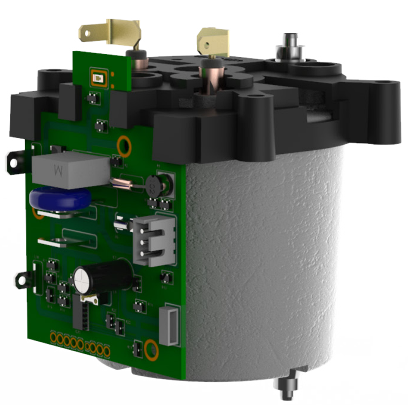
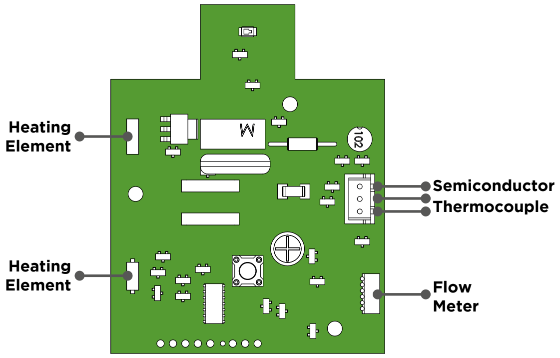


Figure 3.41
Assembly, step 2



03.
The central pipe is placed at the top of the support with it's o-ring and washer. The electronic components - the semiconductor, grounding, first thermocouple - are now installed with their cables attached to the PCB connections.

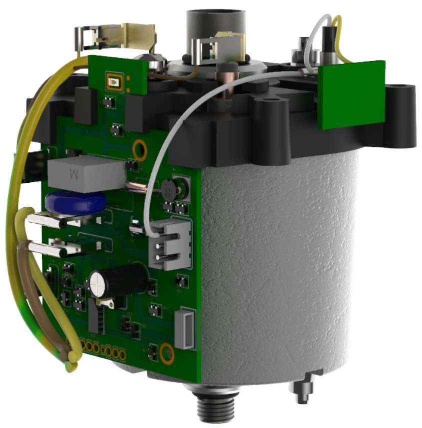
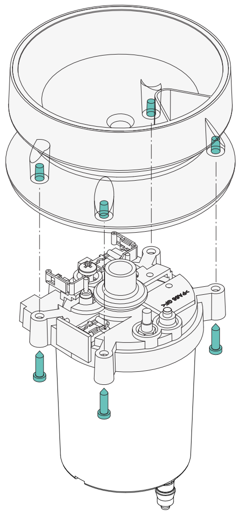


Figure 3.42
Assembly, step 3

04.
The top cover can be screwed to the the core. Four self tapping screws fix the assembly togheter. The funnel of the top cover assembly is also screwed to the central pipe from the bottom.



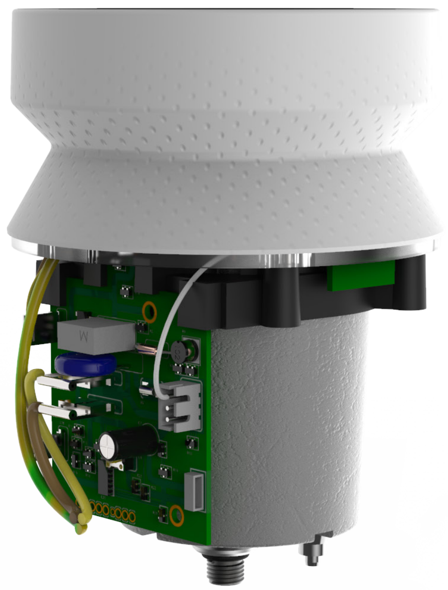
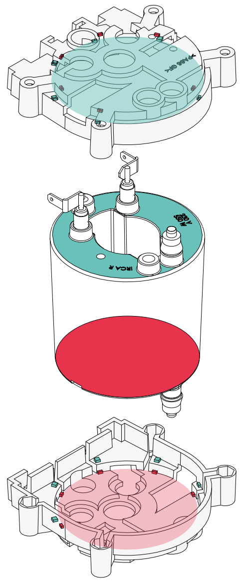


Figure 3.43
Assembly, step 4

05.
The second core support is now installed at the bottom of the heating element. Cables of the flow meter assembly are wired to the PCB. The check valve is screwed to the central pipe; this will fix the support to the assembly.



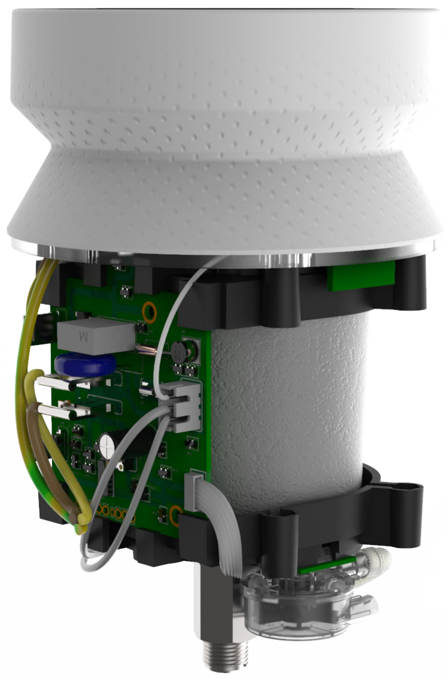


Figure 3.44
Assembly, step 5

06.
The bottom cover assembly is placed at the bottom. Four nuts are inserted in the core support part at the bottom, and the bottom cover can be secured with screws from the bottom.

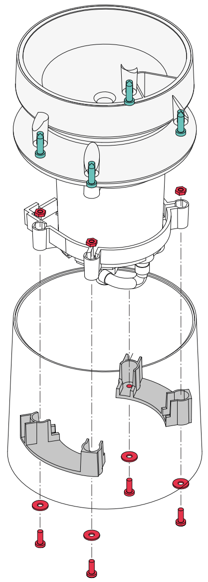
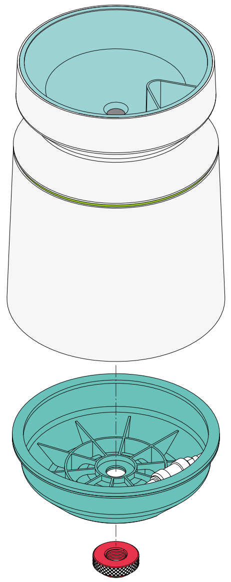


Figure 3.45
Assembly, step 6



07.
The bottom lid assembly pipe's are joined to the water pipe, then all the bottom lid is placed at the bottom. The knurled nut is screwed to the check valve thread, sealing the assembly.

Figure 3.46
Assembly, step 7

08.
The water tank assembly can be screwed to the bottom cover. Now the device is ready to be used, once it is plugged in.

Figure 3.47
Assembly, step 8

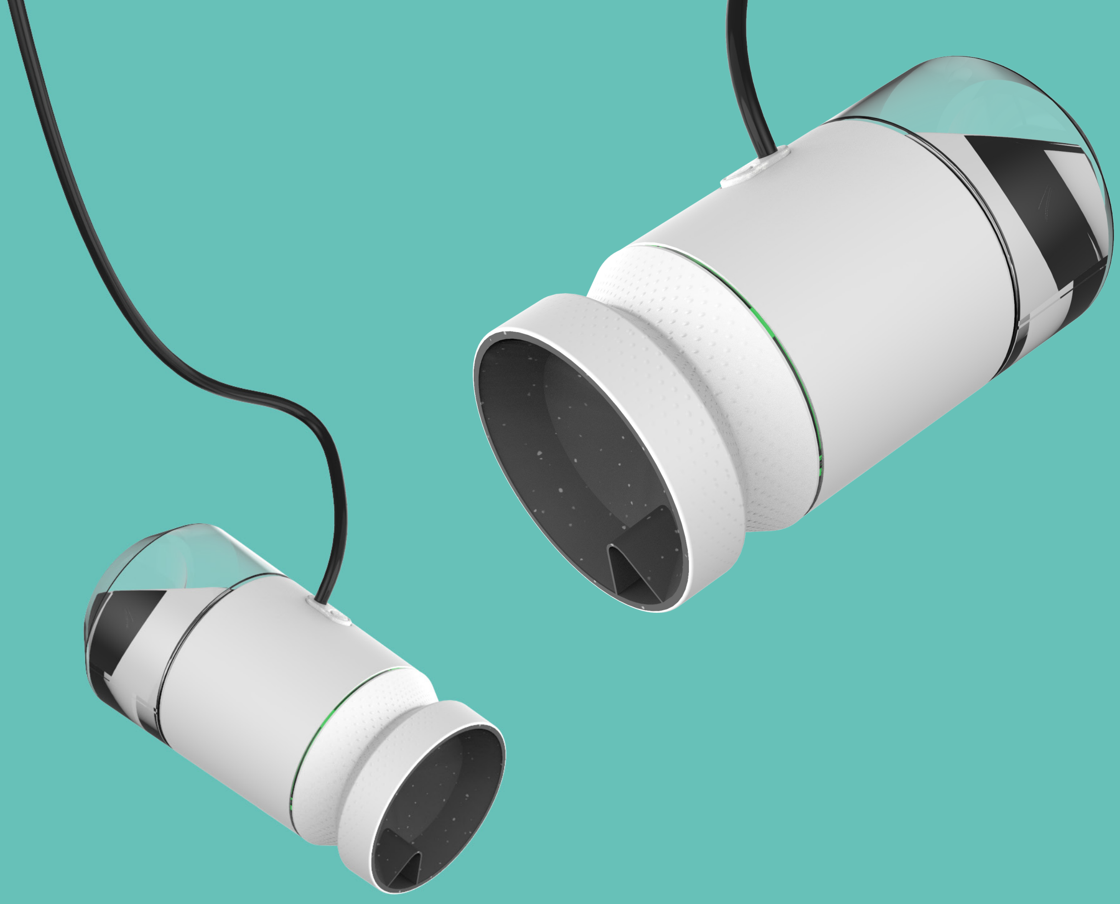


Figure 3.48
Assembly, step 9

Figures 3.50
Dawn

Conclusions

The purpose of this project was to design an home appliance capable of heating water without wastes in terms of electrical energy and water. As shown in different studies the electric kettle is a widespread appliance used by millions of people all over the world, and their wastes, even small ones, can lead to a dangerous and warning situation. **As a new awarness of the limits of earth resourses rise we need to provide people with better performing solutions.** This master thesis have tried to show that new solutions are already available and feasible.

Now, speaking of the project results only, **are two minutes too much for pouring a cup of hot water?**
Probably yes, but this result was given by some project constraint that I had when I designed the device. First, **I used as a reference the heating element of the coffee machine that I disassembled.** That heating element was using a certain component dimension, the water pipe diameter, that I used as a reference to make sure that also my product could be producible with nowadays standard parts. The water pipe diameter gave me a certain water flow rate, and this value gave me that result after all the calculation. I tried to create a balance between the electrical power supply and the amount of water that flows through the device. Would be the product still feasable if we would use other components that are not available on the market, that we would have to make? Yes, but as a master thesis project my aim was to make the product feasable and easy to produce, and mostly, **my aim was to show that new methods for heating water that are more sustainable and convenient are possible with nowadays technologies and resources**.

How to reduce the pouring time?
If we wanted to make a product with the same characteristic of 0W electric kettle but with an improved performance we would have to change the water pipe diameter of the heating element, in order to increase the water flow rate. For example, if we would double the diameter dimention we would get this results:

r pipe (m)	0,005
A pipe (m^2)	0,07853981634
l pipe (m)	0,7
Time (s)	8,284023669
P (KW)	2,2
Velocity	0,0845
Water flow (m^3)	0,000006636614481
Delta t (°C)	79,30486109

Chart 3.1
Double pipe diameter plotted datas

With this increase of the water pipe diameter, with the same water pipe lenght of my concept (700 mm), we would have to increase to electrical power from 550 W to 2.200 W in order to get a temperature delta range of 80°C. This would allow us to get a water flow rate of 6.6 ml per second. **This improvement would allow the user to pour a cup (250 ml) in less than 40 seconds.** Of course these changes in power supply and physical dimensions would change the dimentions and proportions of the kettle.

In conclusion, I can say that I am satisfied for the level of detail achieved in this project and research, and I hope I have raised an awarness to the reader about the silent problem of wastes of resources that accours everyday when we make ourself an hot beverage.
The variety of subject areas covered made the development of this product very interesting, stimulating curiosity towards the concept of water heating. **I have been able to put into practice many of the concepts assimilated throughout the studies,** concepts belonging to different disciplines, which have come to merge in a single project, 0W electric kettle.

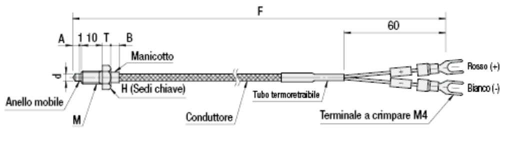
04. References

Datasheets

Montaggio a vite_Sensori di temperatura/Attacco a vite/Termocoppia K		MiSUMi
Codice componente **MSNDM6**		20200228171126

Measurement Object	Sensori di temperatura	**Tipo di sensore di temperatura**	Termocoppia
Tipo di termocoppia	Termocoppia K	**Sheath, Protecting Tube Material**	[Stainless Steel] EN 1.4301 Equiv.
Punto di contatto misurazione temperatura	Con collegamento a massa	**Operating Environment**	Standard
Operating Temperature Range(°C)	0～180	**Number of Elements**	1
Sheath, Protecting Tube Shape	[With Screws] Con montaggio a vite	**Guaina, diametro tubo di protezione(Ø)**	3.5
Misura filettatura	m6	**Tipo di terminale**	Terminale a crimpare a forcella
Lunghezza conduttore (F)(m)	2	**Misura filettatura**	M6x1.0

MSNDM (Termocoppia K)



Per N.6-1 e 8-1, il filo in smalto è avvolto attorno all'estremità del manicotto.

Valvole di ritegno pneumatiche_Valvola di non ritorno in resina		MiSUMi
Codice componente **CVPC4-M5B**		20200327123728

Tipo	Standard	**Profilo**	[Dritto] Dritto
Materiale corpo principale	PBT	**Materiale guarnizione**	NBR
Lato di ingresso, porta P	Accoppiamento a singolo effetto	**Lato scarico, porta A**	Con filettatura
Gamma di pressioni d'esercizio(MPa)	0～0.9	**Area sezione effettiva(mm²)**	2.6
Area sezione effettiva [classificazione](㎜ ²)	5 o inf.	**Tipi di porta di collegamento**	M
Vite di montaggio nominale	M5×0.8	**Diametro tubo applicabile(φ)**	4
Senza trattamento olio	Applicazione olio per turbine	**-**	-

Ensinger

TECAMID 66 GF30 black

Designazione Chimica
PA 66 (Poliammide 6.6)

Colore
nero opaco

Densità
1.34 g/cm^3

Additivi
fibre di vetro

Dati rilevati immediatamente dopo lavorazione meccanica (clima standard Germania).

Caratteristiche principali
- rigidità molto elevata
- resistente a diversi oli, grassi e carburanti
- buona resistenza all`usura
- resistenza meccanica molto elevata
- elevata stabilità dimensionale
- buona temperatura di distorsione termica
- facilmente saldabile e incollabile

Settori di applicazione
- ingegneria meccanica
- tecnologia aerospaziale e dei velivoli
- industria automobilistica

Proprietà meccaniche	*parametri*	*valore*	*unità*	*norma*		*commenti*
Modulo elastico (prova di trazione)	1mm/min	5500	MPa	DIN EN ISO 527-2	1)	(1) Per test di trazione: provino tipo 1b (2) Per test di flessione: distanza supporti 64 mm, provino normato. (3) Provino 10x10x10 mm (4) Provino 10x10x50 mm, modulo rilevato tra 0,5 e 1% di compressione. (5) Per test Charpy: distanza supporti 64 mm, provino normato. (6) Provino spessore 4 mm
Resistenza a trazione	50mm/min	91	MPa	DIN EN ISO 527-2		
Tensione di snervamento a trazione	50mm/min	91	MPa	DIN EN ISO 527-2		
Allungamento a snervamento	50mm/min	8	%	DIN EN ISO 527-2		
Allungamento a rottura	50mm/min	14	%	DIN EN ISO 527-2		
Resistenza a flessione	2mm/min, 10 N	135	MPa	DIN EN ISO 178	2)	
Modulo elastico (prova di flessione)	2mm/min, 10 N	4700	MPa	DIN EN ISO 178		
Resistenza a compressione	deformazione 1%/2%/5% 5mm/min, 10 N	25/46/104	MPa	EN ISO 604	3)	
Modulo elastico (prova di compressione)	5mm/min, 10 N	4100	MPa	EN ISO 604	4)	
Resistenza agli urti (Charpy)	max. 7,5J	97	kJ/m^2	DIN EN ISO 179-1eU	5)	
Durezza a penetrazione di sfera		216	MPa	ISO 2039-1	6)	

Proprietà termiche	*parametri*	*valore*	*unità*	*norma*		*commenti*
Temperatura di transizione vetrosa		48	°C	DIN EN ISO 11357	1)	(1) Da fonte pubblica. (2) Da fonte pubblica. Sono necessari test individuali specifici secondo le condizioni applicative.
Temperatura di fusione		254	°C	DIN EN ISO 11357		
Temperatura di esercizio	a breve termine	180	°C	-	2)	
Temperatura di esercizio	a lungo termine	110	°C			
Dilatazione termica (CLTE)	23-60°C, long.	5	10^{-5} K^{-1}	DIN EN ISO 11359-1;2		
Dilatazione termica (CLTE)	23-100°C, long.	5	10^{-5} K^{-1}	DIN EN ISO 11359-1;2		
Calore specifico		1.2	J/(g*K)	ISO 22007-4:2008		
Conducibilità termica		0.39	W/(K*m)	ISO 22007-4:2008		

Proprietà elettriche	*parametri*	*valore*	*unità*	*norma*		*commenti*
Resistività superficiale	elettrodo in argento, 23°C, 12% um. rel.	10^{14}	Ω	DIN IEC 60093	1)	(1) Provino spessore 20 mm (2) Due to the black colourant and moisture uptake of the material the electrical insulation properties cannot be 100% guaranteed, despite single measurements suggesting otherwise. (3) Provino spessore 1 mm
Resistività di volume	elettrodo in argento, 23°C, 12% um. rel.	10^{14}	Ω*cm	DIN IEC 60093	2)	
Rigidità dielettrica	23°C, 50% um. rel.	35	kV/mm	ISO 60243-1	3)	
Resistenza alla corrente di dispersione superficiale (CTI)	elettrodo in platino, 23°C, 50% um. rel., solvente A	550 / 475	V	DIN EN 60112		

Altre proprietà	*parametri*	*valore*	*unità*	*norma*		*commenti*
Assorbimento d'acqua	24h / 96h (23°C)	0.1 / 0.2	%	DIN EN ISO 62	1)	(1) Ø ca. 50mm, h=13mm (2) (+) Resistenza limitata (3) Corrispondente significa che non è indicato nell'elenco ufficiale UL (yellow card). L'informazione può provenire dalla materia prima, dal semilavorato o da una stima. Sono necessari test individuali specifici secondo le condizioni applicative.
Resistenza all'acqua calda / soluzioni alcaline		(+)		-	2)	
Resistenza agli agenti atmosferici		(+)				
Infiammabilità (UL94)	corrispondente a	HB		DIN IEC 60695-11-10;	3)	

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Data: 2018/02/20

Versione: AE

BTA412Y-600B

3Q Hi-Com Triac

12 September 2018 Product data sheet

1. General description

Planar passivated high commutation three quadrant triac in a SOT78D (TO-220AB) internally insulated plastic package intended for use in circuits where high static and dynamic dV/dt and high dI/dt can occur. This "series B" triac will commutate the full RMS current at the maximum rated junction temperature without the aid of a snubber. This device has high T_j operating capability and an internally isolated mounting base.

2. Features and benefits

- 3Q technology for improved noise immunity
- High commutation capability with maximum false trigger immunity
- High surge capability
- High $T_{j(max)}$
- Isolated mounting base with 2500 V (RMS) isolation
- Planar passivated for voltage ruggedness and reliability
- Triggering in three quadrants only
- Very high immunity to false turn-on by dV/dt

3. Applications

- Electronic thermostats (heating and cooling)
- High power motor controls
- Rectifier-fed DC inductive loads e.g. DC motors and solenoids

4. Quick reference data

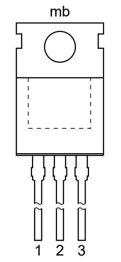
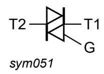
Table 1. Quick reference data

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DRM}	repetitive peak off-state voltage			-	-	600	V
$I_{T(RMS)}$	RMS on-state current	full sine wave; $T_{mb} \leq$ 116 °C; Fig. 1; Fig. 2; Fig. 3		-	-	12	A
I_{TSM}	non-repetitive peak on-state current	full sine wave; $T_{j(init)}$ = 25 °C; t_p = 20 ms; Fig. 4; Fig. 5		-	-	140	A
		full sine wave; $T_{j(init)}$ = 25 °C; t_p = 16.7 ms		-	-	153	A
T_j	junction temperature			-	-	150	°C
Static characteristics							
I_{GT}	gate trigger current	V_D = 12 V; I_T = 0.1 A; T2+ G+; T_j = 25 °C; Fig. 7		2	-	50	mA

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
		V_D = 12 V; I_T = 0.1 A; T2+ G-; T_j = 25 °C; Fig. 7		2	-	50	mA
		V_D = 12 V; I_T = 0.1 A; T2- G-; T_j = 25 °C; Fig. 7		2	-	50	mA
I_H	holding current	V_D = 12 V; T_j = 25 °C; Fig. 9		-	-	60	mA
V_T	on-state voltage	I_T = 18 A; T_j = 25 °C; Fig. 10		-	1.3	1.5	V
Dynamic characteristics							
dV_D/dt	rate of rise of off-state voltage	V_{DM} = 402 V; T_j = 125 °C; (V_{DM} = 67% of V_{DRM}); exponential waveform; gate open circuit		1000	-	-	V/µs
		V_{DM} = 402 V; T_j = 150 °C; (V_{DM} = 67% of V_{DRM}); exponential waveform; gate open circuit		600	-	-	V/µs
dI_{com}/dt	rate of change of commutating current	V_D = 400 V; T_j = 125 °C; $I_{T(RMS)}$ = 12 A; dV_{com}/dt = 20 V/µs; (snubberless condition); gate open circuit		20	-	-	A/ms
		V_D = 400 V; T_j = 150 °C; $I_{T(RMS)}$ = 12 A; dV_{com}/dt = 20 V/µs; (snubberless condition); gate open circuit		8	-	-	A/ms

5. Pinning information

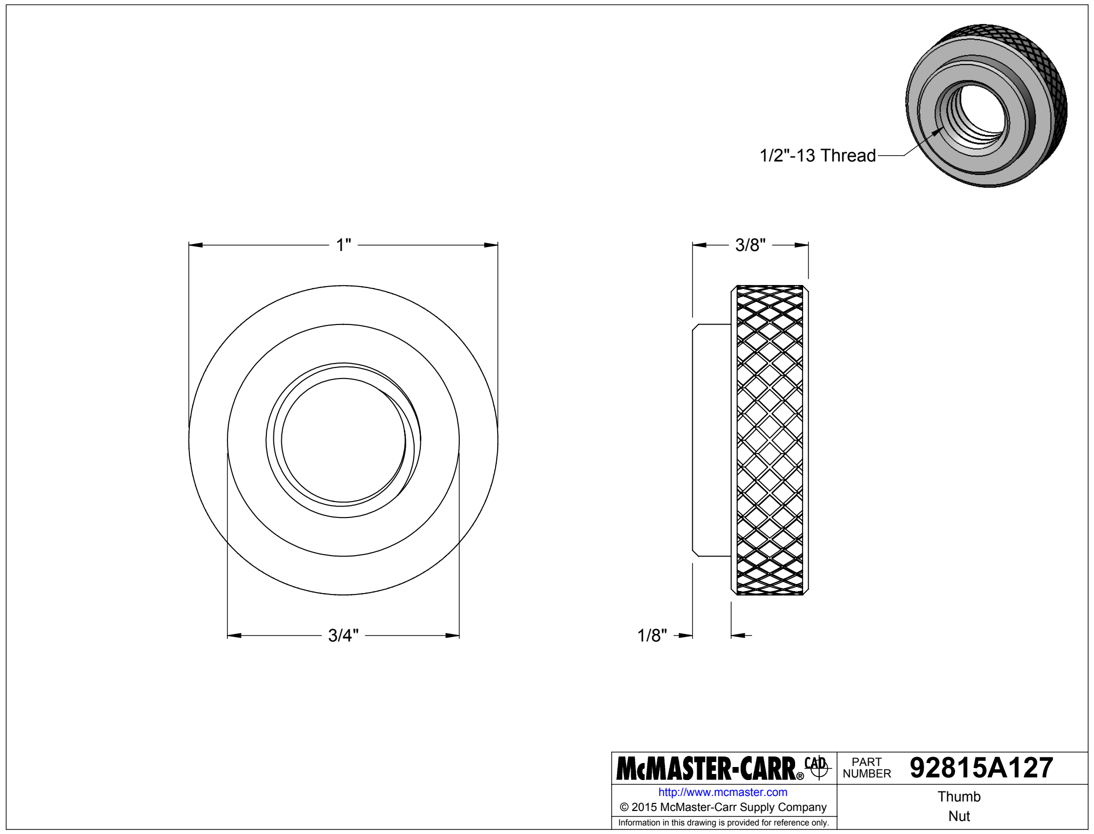
Table 2. Pinning information

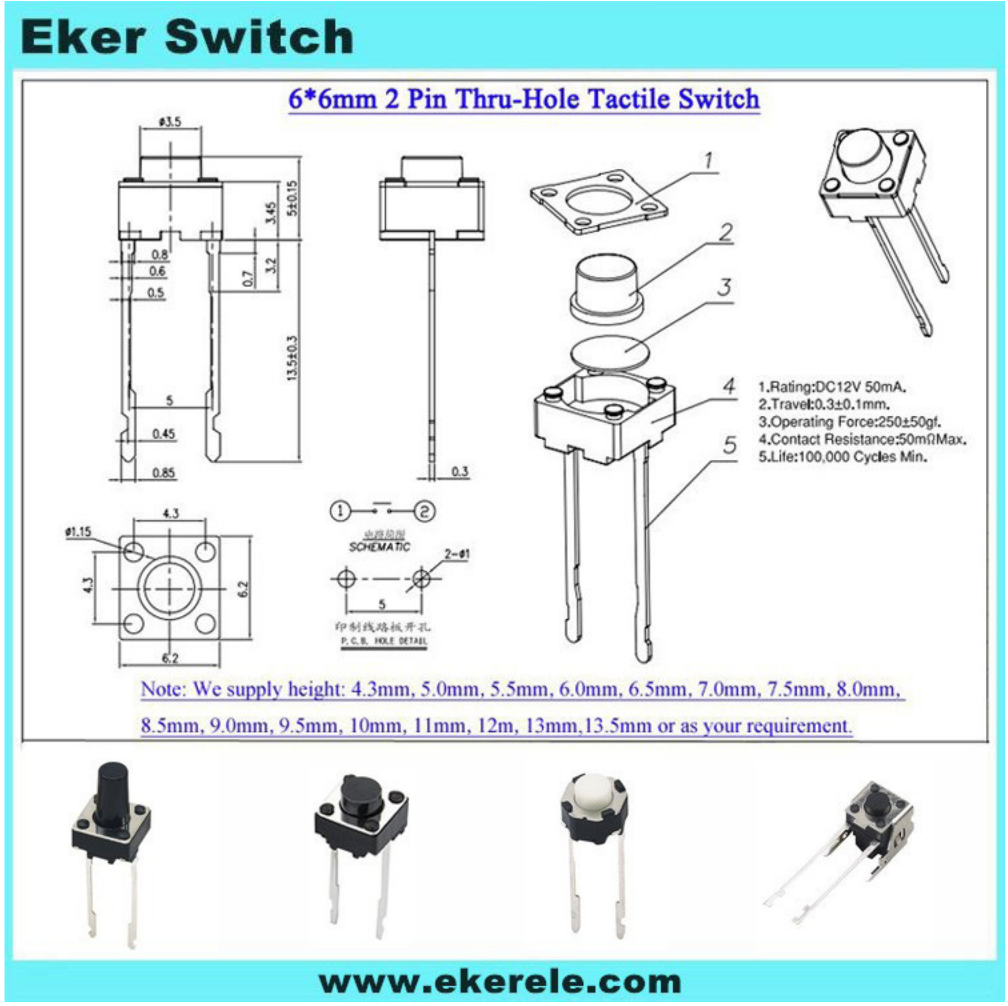
Pin	Symbol	Description	Simplified outline	Graphic symbol
1	T1	main terminal 1	 TO-220AB (SOT78D)	
2	T2	main terminal 2		
3	G	gate		
mb	n.c.	mounting base; isolated		

6. Ordering information

	Attacchi a innesto rapido_KQ2T, raccordo istantaneo colore bianco - D'estremità a "T" centrale	MiSUMi
	Codice componente **KQ2T06-01AS**	20200327131750

Tipo	[Accoppiamento ad azione singola] Ad azione singola/filettatura	**Tipo raccordo**	Screw Mount Branch
Liquido applicabile	Water / Air	**Materiale corpo principale**	[Resina PP] PP
Applicazione	Standard/Mini	**Materiale filettatura**	[Resina PP] PP
Materiale guarnizione	[EPDM] EPDM (rivestimento in fluoro)	**Montaggio a vite, diramazione**	[Raccordi a T] Giunto a T con doppio attacco
D.E.1 tubo applicabile(φ)	6	**Connection Type**	R
Connection screw	1/8	**Number of Connection Tubes(pc.)**	2
Colore	Bianco	**Specifiche**	Con sigillante
Profilo pulsante di rilascio	Circonferenza perfetta	**Colore pulsante di rilascio**	Grigio chiaro
Specifiche personalizzate	N/D	**-**	-





Additional Index

Figures

Charts

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