Quooker® Energy Analysis

Boiling Water Tap PRO3-VAQ

Boiling & Hot Water Heater COMBI 2.2

Van Holsteijn en Kemna B.V. (VHK)

Elektronicaweg 14

NL-2628 XG Delft

for:

Peteri B.V.

Staalstraat 13

NL-2984 AJ Ridderkerk

Delft, 25 March 2010

Contact VHK: ir. R.B.J. Kemna (r.kemna@vhk.nl)

Contact Peteri: ir. P.H.F. Peteri (p.peteri@quooker.nl)

Management Summary

This report presents an energy analysis of two products produced by Peteri BV: The Quooker PRO3-VAQ for boiling water and the Quooker COMBI for both boiling water and hot water. The analysis is split into two parts: The first part describes the performance of both Quookers when compared to other products producing boiling water. The second part focuses on the performance of the Quooker Combi as a water heater in the light of upcoming minimum energy efficiency requirements and energy labelling of dedicated water heaters.

The first analysis covers all energy related aspects of boiling water products over their whole life cycle – from production to use phase and including end-of-life. The efficiency is based on primary efficiency, so including electric grid efficiency. The outcome shows that the performance of the Quooker PRO3-VAQ as boiling water product is on a par with its electric alternatives such as the electric kettle and the microwave oven. Only the gas-fired hob has a higher efficiency. The Quooker COMBI stands apart with the overall highest efficiency because the standing losses (mainly stand-by energy) of the Quooker COMBI are allocated to both the functionality as a boiling water tap and as a regular water heater in proportion to the energy required for heating the boiling water and the hot water (see also part 2 of the report).

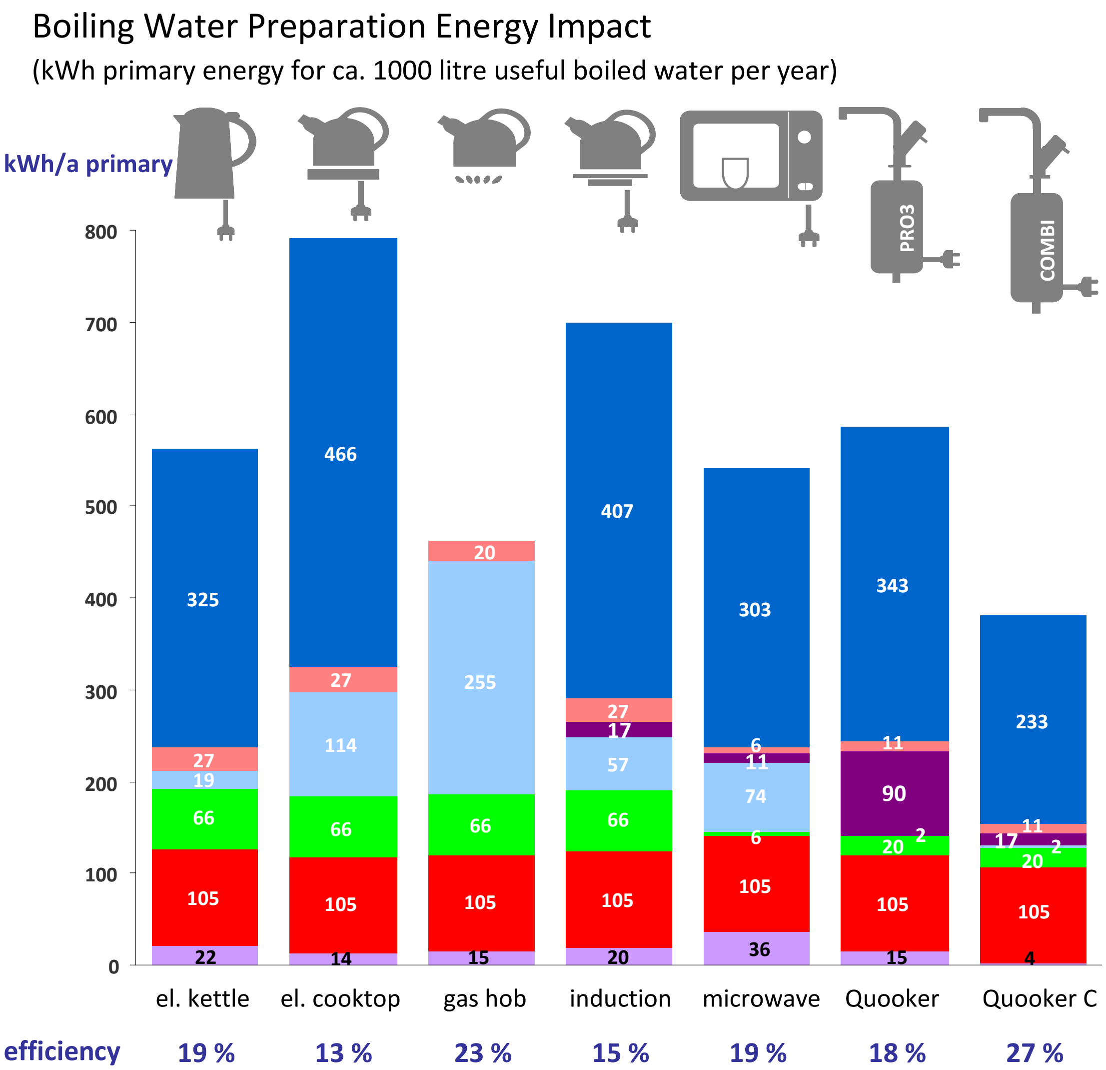
Figure 1 presents the outcome of the integral energy assessment of water boiling.

The second part of the study focuses on the performance of the Quooker Combi as a water heater, following the conventions and methodology laid down for Ecodesign and energy labelling purposes. Normally the declared efficiency of a water heater shall be based on product tests, but for this study the authors have made an assessment based upon generic product specifications and therefore must be regarded as initial estimates. Nevertheless these estimates show that the efficiency of the Quooker Combi is expected to lie within the A/A+ label classes, making it a class-leading product combining the easy installation of small electric storage water heaters with exceptionally low standing losses. Other dedicated water heater typologies such as advanced electric flow-through heaters (no standing losses) or the latest generation of gas-fired flow-through heaters without pilot flame may reach comparable or higher efficiencies, but they require special high power electric outlets or installation of gas pipes and chimneys.

Figure 2 shows the estimated ratings for the Quooker as a water heater.

Van Holsteijn en Kemna,

March 2010



- power generation loss (grid)
- extra boiling time
- standby
- heating (heat loss)
- overdose (over-filling)
- theoretical minimum
- tooling (production, distr., EoL)

Primary energy is the equivalent fossil fuel enthalpy (Gross Calorific Value) used in all stages of boiling water preparation, including electric power generation; here expressed in in kWh (1 kWh prim. = 0,4 kWh el.)

margin of uncertainty : ± 15%

Fig. 1. Energy Impact Boiling Water Preparation

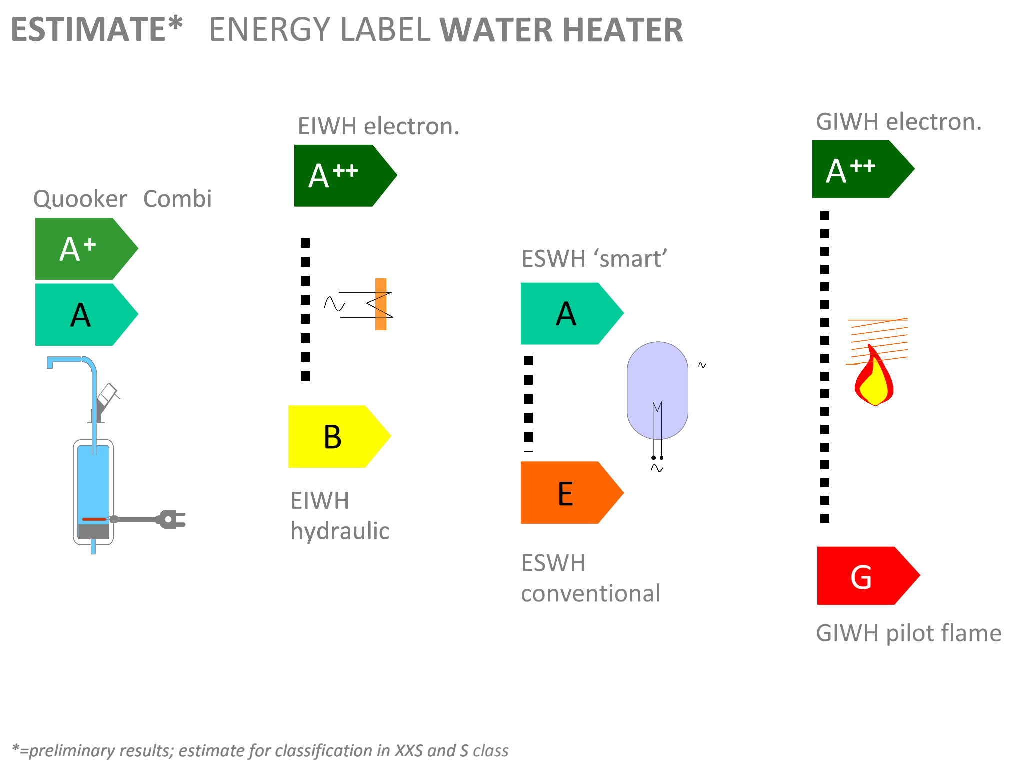


Fig. 2. Estimated EU Energy Label rating

Positioning of the Quooker Combi energy efficiency versus competitors, according to the latest EU energy label proposals (European Commission WD 1.7.2008).

EIWH=Electric Instantaneous Water Heater (electronic or hydraulic control)
ESWH= Electric Storage Water Heater (conventional or with 'smart control')
GIWH= Gas-fired Instantaneous Water Heater (electronic ignition or pilot flame)

(page intentionally left blank)

CONTENT

Part 1: Domestic Boiling Water Preparation

1. Introduction 11
2. Energy analysis boiling 15
   2.1 Introduction 15
   2.2 Tools/ infrastructure 15
      Functional unit 16
      Product life 17
      Partitioning to boiling water applications 17
   2.3 Filling 19
   2.4 Heating 24
      Electric cooking top 25
      Gas hob 26
      Induction heating 27
      Microwave 28
      Electric Kettle 28
      Quooker 29
      Summary 30
   2.5 Seeding and boiling 30
   2.6 Extra boiling time till switch off 31
   2.7 Serving and Keep warm 33
   2.8 Overview 34

Part 2: Water Heater Performance

3. Introduction & EU measures 37
3.1 General 37
3.2 Overview EU measures 37
3.3 Reporting and disclaimer 38
4. Ecodesign 39
4.1 Introduction 39
4.2 Preparatory study: Market data 40
4.3 Energy impact 42
4.4 Rating method 44
5. Energy Labeling 48
5.1 Introduction 48
5.2 Main requirements 49
5.3 Estimate of classification 50
6. Quooker Combi analysis 52
6.1 Introduction 52
6.2 Assumptions and expected results 53
6.3 Calculation 55
6.4 Comparison 59

(page intentionally left blank)

Energy Analysis, Part 1

Domestic Boiling Water Preparation

Comparative analysis

1. Introduction

Subject of the first part of the underlying report is an energy analysis of processes for preparing boiling water in a domestic setting. The analysis is performed following current standards for Life Cycle Assessment and the methodology as established in the context of the European Framework Directive 2005/32/EC (a.k.a. Ecodesign Directive) and its 2009/125/EC recast. Data inputs are derived from verifiable, third party sources. The analysis is performed by energy efficiency specialist VHK, amongst others responsible for the development of the ecodesign methodology (MEEUP) for the European Commission.

The aim of the study is to provide a neutral, unbiased overview of the societal energy impact of the commercial products involved in the preparation of boiled water primarily for hot drinks (coffee, tea, instants) and –where relevant-- foodstuffs that require boiling water for their preparation. The Life Cycle approach includes not only the use phase, but also takes into account production, distribution and end-of-life of the products involved. Where appropriate and significant the analysis takes into account 2nd level impacts such as the efficiency of electric power generation and distribution.

The alternatives being investigated are:

1. Electric kettle
2. Electric cooking top (traditional)
3. Gas hob (traditional)
4. Induction cooking top
5. Micro-wave oven
6. Quooker ‘ boiling water tap’ and combi

These 6 alternatives cover all the base-technologies currently in use:

1. Immersion electric resistance heating, where an electric resistance heating element is integrated in a 1 to 2 litre container body and is practically in direct contact with the water. Main heat transfer mechanism is conduction and during heating the energy losses are small (driving the heating element, dissipation of heat from the water to the container and ultimately the surrounding air). For that reason, despite the inherent losses of electric power generation, the electric kettle is often advertised as the most efficient means to prepare boiling water.
2. External resistance heating, where the heat source is an electric resistance element in a cooking top and the water is heated in a separate 1 to 2 litre container (pot or kettle). Main heat transfer is a mix of conduction and convection. A known characteristic of traditional electric cooking tops is the use of heavy iron plates to ensure an even dispersion of the heat to the pot. In most modern electric cooking

tops, vitro-ceramic material is used as a cooking top instead of the iron plates. The lower thermal inertia of these materials gives a slight (10-20%) energy efficiency improvement, but the principle remains the same. A smooth and straight underside of the pot/kettle is needed to ensure optimum heat transfer (through conduction). External resistance heating is known to be inefficient, both due to the inefficient heat transfer and the power generation losses, but it is included as a reference. In the quantitative analysis only the modern the vitro-ceramic electric resistance cooking top was taken into account.

3. Combustion of fossil fuels (gas), where the heat source is a burner that transfers heat to the pot or kettle predominantly through radiation and convection. The heat transfer process is inefficient, but gas is a primary fuel and the only one of the 6 alternatives that doesn't have the considerable power generation losses. For that reason, gas cooking is often advertised as (one of the) most efficient cooking process(es). Recent variations of the traditional gas cooker are the ' gas-on-glass' and the 'gas-under-glass' cooking tops. With ' gas-on-glass' the burner is placed on top of a vitro-ceramic plate which is easier to clean and possibly aesthetically more attractive, but there is no energy benefit. "Gas-under-glass" cooking tops are equipped with radiation burners that operate under the vitro-ceramic plate and – apart from cleaning and aesthetics—have the energy benefit of also using the waste heat from flue gases to heat separate hot zones. In certain configurations whereby a number of pots are used simultaneously this increases the overall efficiency, but there are as yet no data available that would give a realistic efficiency-evaluation of single-pot applications such as e.g. boiling tea water. For that reason, but also because market penetration of the rare 'gas-under-glass' cooking tops is negligible, the underlying analysis will be limited to traditional gas hobs.

4. Induction heating. This is the process of heating an electrically conducting object (a metal pot or kettle) by electromagnetic induction, where eddy currents are generated within the metal and resistance leads to Joule (I^2R) heating of the metal. It also creates –but this contributes less than 10% of the total heat generated-- magnetic hysteresis losses in a ferromagnetic pot. In short, with induction heating the heat is not provided by the cooking top –which stays relatively cold-- but the water is heated by the pot. The pot or kettle does however have to be preferably of heavier steel or steel alloy . Considering the relatively small heat-up losses (mainly dissipation of heat by the pot) and the fast heat-up it is often claimed to be the most efficient way of cooking.

5. Dielectric heating uses 'micro-waves', electromagnetic waves oscillating at a frequency of typically 2,45 GHz, hence the name 'micro-wave oven'.The water molecules are electric dipoles, meaning that they have a positive charge at one end and a negative charge at the other, and therefore rotate as they try to align themselves with the alternating electric field of the microwaves. This molecular movement represents heat which is then dispersed as the rotating molecules hit other molecules and put them into motion. A characteristic of micro-wave ovens is that the food is heated 'from within', with only small heat transfer losses to the

outside. A further benefit –at least for hot drinks—is the exact dosage of the foodstuffs or drinks . Although research reveals that 23% of U.K. micro-wave oven use is for ‘ hot drinks’ like milk, there is only anecdotal evidence of its use for actually boiling water in a cup for tea or coffee. Furthermore, there some safety concerns for this application (e.g. ‘ superheat’, see later on). Nevertheless, as microwave cooking is in some countries like the UK promoted as a very efficient means of cooking, it is taken into account as an alternative. The archetype micro-wave oven that has been studied is a simple ‘ microwave only’ version. Features of combi-ovens, e.g. with forced convection heat and/or grills, would only be detrimental to the efficiency of the boiling process.

6. Flash boiling is a process by which water stored in a highly (vacuum) insulated small vessel is brought to a temperature of 108 °C through an immersed electric resistance heater. As the vessel is under pressure from the water grid, the water will only start to boil when the tap is opened and the pressure drops to atmospheric conditions. The water is boiled in the trajectory of leaving the tap and before it ends up –at a temperature of 97 °C—in the cup. It is by far the quickest way of preparing boiled water for the user (< 5 s per cup), the heating process takes place practically without loss and by the physical nature of the process there is a guarantee of an equal boiling action throughout the fluid. A further benefit is the exact dosage. The energy penalty is in the standby heat loss of the vessel and the inherent loss of the electric power generation. The energy analysis is based on the original Quooker products with a standby heating loss of 10-11 W. Calculations have been carried out for both the Quooker PRO3-VAQ and the Quooker COMBI. The PRO3-VAQ is a 3 litre tank which delivers boiling water only. The COMBI tank contains 7 litre of hot water and delivers both boiling water via the boiling water tap and pre-mixed warm water (50-60 °C) via the kitchen mixer tap. Recent facsimile products with higher standby heat loss (25 W and higher) are not taken into account, but from the Quooker analysis conclusions for the energy efficiency of facsimile products can be deducted.

Note that the analysis is limited to devices that can actually prepare boiled water, i.e. water that has reached a temperature of 100 °C, i.e. where the ‘decalcification’ process has taken place. Flow-through heaters and other high temperature water heaters that are not able to produce boiled water were not taken into account.

For the boiling process the origin of the heating is relevant and how exactly the heat distribution in the water develops. For a pot or kettle on a gas-hob or an electric plate the hottest spot will be at the bottom. For an induction cooker the ferromagnetic pot is the heat origin, whereas with a microwave heater the heating originates from the water molecules interacting with the electromagnetic waves from the generator. This interaction diminishes as the waves penetrate deeper into the water and therefore –as with an induction cooker-the water is hottest at the surface and the sides and coldest in the middle of a container. Another important element is therefore the shape of the container as this affects the efficiency of the means of heating - For example: Microwave heating is more efficient if the maximum depth is not more than a few centimeters.

Safety concerns

Note that safety was not a subject of the underlying study and VHK would like to state explicitly that it has no grounds to discriminate between the investigated alternatives on the basis of safety concerns Every process that involves boiling water has a potential danger of scalding, burns and injuries.[1] Gas hobs pose an additional fire-hazard. Electric cooking tops have an increased risk of scalding as the cooking top stays hot for a long time after the pot has been removed. Induction cookers pose risks to people with pacemakers or people wearing metal jewelry. Quookers, after having been on the market for over 20 years and having sold over 150.000 units, have not received any reports of scalding but this is no guarantee for the future.

Having said that, it might be worth mentioning the risk of 'super-heating' with boiling water in microwave ovens as it may be a possible explanation of why the preparation of boiling hot drinks in a microwave oven is less popular. As the heating process in a microwave oven evolves very calmly from within the liquid, there is a danger of 'superheating', especially when using very smooth, scratchless surfaces, e.g. a new tea glass, and especially when the water has been previously heated and most of the dissolved gases have been driven out. The liquid does not find any irregularities that can serve as a nucleus for forming water vapour bubbles and actually will not ' bubble' easily. The temperature can then rise above the boiling point (e.g. 101 °C). Once the cup is picked up or the surface is slightly stirred by adding a substance (coffee, tea) this one degree of superheating results in instantaneous flash-evaporation of water (amounting to about 3 litre of water vapour per litre water of 101 °C), causing the boiling water to splash from the cup possibly causing serious burning injuries.

[1] For instance electric kettles are involved in over 7000 accidents annually in the UK 2002. Around 5000 accidents relate to cooker hob, ring, jet & hot plates (scalding). Saucepans or water from it relate to over 4000 accidents, while microwave ovens reportedly are involved over 2500 accidents in the UK in the same year. Hot water taps in the house (kitchen and bathroom, but excluding showers and bath) are involved in 2500 accidents. Source: The Royal Society for the Prevention of Accidents, accident statistics 2002. http://www.rospa.com/hassandlass/reports/2002data.pdf

2. Energy analysis boiling

2.1 Introduction

The quantitative analysis takes into account the stages of the product life cycle, and places a special emphasis on the boiling process:

0. ‘Tools’/infrastructure suggestion: “Pre/post use phases”
1. Filling (dosage)
2. Heating-up
3. Seeding
4. 1st Boiling
5. Boiling to switch-off
6. Serving, keep hot.

2.2 Tools/ infrastructure

As mentioned, the energy analysis takes into account the energy involved in the production, distribution, disposal and possible recycling of the necessary tools. In general for most energy-using products this “energy content” is relatively low compared to the energy consumption during the use phase, which explain the often cursory treatment in Ecodesign studies. Still it may play a role in convenience products such as boiling appliances. The analysis of the mass of the materials is based on literature (e.g. Jungbluth 1997), own measurement data and –for the Quooker-- data supplied by Peteri B.V.. For the evaluation of the ‘energy content’ (GER, Gross Energy Requirement) the VHK EcoReport tool is used, which is the reference for preparatory studies in the context of the Ecodesign Framework Directive. [2][3]

---

[2] VHK, Methodology for Ecodesign of Energy-using Products (MEEUP), Van Holsteijn en Kemna for European Commission, Delft (NL)/ Brussels (BE), Nov. 2005.

[3] EU Framework Directive on Ecodesign of Energy-using Products 2005/32/EC. Recently recast with expanded scope to Framework Directive on Ecodesign of Energy-related Products 2009/125/EC.

Table 1 gives a summary of the material groups used and the energy impact, excluding the strict boiling energy.

At the end of Table 1, there is an assessment that will be used in the remainder of the study. This assessment concerns the functional unit, the partitioning of boiling versus non-boiling applications per appliance and the estimated product life.

Functional unit

The functional unit is the amount of boiling water product consumed. This amount may vary significantly between countries. The UK government Market Transformation Programme (MTP) assumes a gross volume of 1542 litre per year and per household for the electric kettle, which –taking into account one-third over-filling—comes down to a net consumption of 1000 litres/hh/year. In the Netherlands TNO Voeding also calculate a net consumption 1000 litres of boiling water consumption, but only 650 litres is destined for hot drinks and instants and around 350 litres is for secondary applications (vegetables, pasta, etc.). In this analysis we will assume an annual consumption of 1000 litres boiled water equivalent per household per year (see chapter 2.3 “Filling” for more details).

As regards the batch size, i.e. the net consumption per preparation, it will very much depend on habit, the characteristics of the tools, the exact product desired, etc.. In the analysis we will be flexible, i.e. even if the tests are done at too high quantities and therefore very favourable results, the alternatives to the Quooker will be given the ‘*benefit of the doubt*’.

But just for the sake of argument: If the 1000 litre only relates to hot drinks, it would be equal to around 5000 cups (0,2 ltr/cup) or 4000 mugs (0,25 litre/mug) per year. According to the UK MTP, the average British household will use the kettle 1500 times a year, boiling 1 litre each time, of which 0,6-0,7 liter (2-3 mugs) is actually consumed. Per day this is 4,2 times. Taking into account that the average EU household has roughly 2 adults, this is over 5 mugs per person per day. In the UK this would be the actual domestic hot drink consumption; in the Netherlands its only around two thirds, i.e. 3 mugs per person per day that are consumed at home, which seems fairly plausible.

Product life

Reliable data on the product life of cooking appliances is hard to come by. For gas hobs the product life estimates vary between 13,2 and 15 years. For electric cooking tops (and presumably induction cookers) the higher estimates go up to 19 years. Generally, the product life of these appliances is linked to a retrofit/remodelling of the kitchen, which may not lead to discarding the cooking top but for sure its active role in daily food preparation. We estimate an average 'active' product life of 13,2 years. The same will hold true for the Quooker so also 13.2 years is used here. For portable devices, such as the microwave oven, the estimates vary between 8 to 10 years (we assume 8,8 years). For the electric kettle, the UK MTP assumes a product life of 4,4 years.

Partitioning to boiling water applications

From the food consumption statistics it is assumed that for general cooking top appliances around 2/3 is used for boiling water applications (including boiling vegetables) and 1/3 for frying, baking, etc.. For the microwave oven, not usually classified as a boiling water appliance, we will assume the same fraction for the calculation of the energy impact in order not to create an undue advantage/disadvantage. For specialist appliances such as electric kettles and the Quooker PRO3-VAQ 100% of the energy impact for production, distribution and disposal is partitioned to boiling. Finally for the Quooker COMBI, which combines the functionality of a kettle and a storage water heater (see part 2 of this report), the fractions allocated to the respective functions are calculated according the respective average amounts of water being heated for both purposes . Based on the discounted net energy content[4] of the warm tap water produced for warm tapwater in the Ecodesign 'S' (Small) tapping profile (365 days x 0,6 x 2,1 kWh/d= 460 kWh/a) and the boiling water (1000 litres/a x 1,164 kWh/ltr.K x 90K= 105 kWh/a), 19% is allocated to boiling water and 81% to warm water).

---

[4] Note: The tapping profile as used for testing represents the <u>peak</u> power demand (e.g. in weekends). The draft Commission Working Document for Dedicated Water Heaters assumes for annual consumption calculations that the <u>average</u> daily demand equals 60% of this peak demand.

Table 1. Energy analysis of Life Cycle, excluding boiling energy

			el. kettle*	el. cooker	gas hob	electric induction cooking top	microwave oven	quooker solo (3 ltr) incl. tap	quooker combi (7 ltr) incl. tap
Bulk Plastics		kg	89	350	350	2350	600	340	511
TecPlastics		kg	365	0	0	0	0	203	173
Ferro		kg	280	9000	8500	4000	15000	2493	4285
Non-ferro		kg	430	300	700	1000	130	1905	2808
Coating		kg	16	1000	1000	300	1000	0	0
Electronics		kg	100	0	0	300	100	128	174
Misc.		kg	350	1000	1000	4800	3200	1298	1558
Total weight		kg	**1630**	**11650**	**11550**	**12750**	**20030**	**6368**	**9509**
Production	**Materials**	MJ	191	611	681	928	989	401	596
	Manufacturing	MJ	43	98	138	168	310	85	129
	Total	*MJ*	*234*	*709*	*819*	*1097*	*1298*	*486*	*724*
Distribution	**Distribution**	MJ	79	187	187	187	333	133	187
Use phase	**Repairs****	MJ	26	79	80	83	85	77	78
End-of-Life	**Disposal**	MJ	37	61	61	187	109	58	78
	Recycl.	MJ	-31	-70	-70	-137	-102	-57	-76
	Total	*MJ*	*111*	*257*	*258*	*321*	*424*	*211*	*267*
TOTAL ENERGY/UNIT		MJ	**345**	**967**	**1077**	**1418**	**1723**	**697**	**992**
Product life (years)		yr	4,4	13	13	13	8,8	13	13
Partitioned to boiling (%)		%	100%	66%	66%	66%	66%	100%	19%
Boiling energy/year		MJ	78	49	55	72	129	54	14
at 1000 litre/year									
Boiling energy/litre in MJ		MJ/l	0,078	0,049	0,055	0,072	0,129	0,054	0,014
Boiling energy/litre in Wh primary		Wh/l	**22**	**14**	**15**	**20**	**36**	**15**	**4**
Equivalent in Wh electric		Whe/l	**9**	**5**	**6**	**8**	**14**	**6**	**2**

**= average of 60% plastic body and 40% metal body kettle*

***=at 30 service kilometres over 13 year unit product life*

The table shows that the microwave oven has the highest energy-impact in this phase, mainly due to relatively higher product weight, shorter product life and higher distribution losses (import from Asia). The traditional gas and electric cooking tops have a low impact in this phase due to average materials use, local (EU) production and a high product life. The Quooker Combi has the lowest materials impact, because only 19 % is partitioned to boiling. In terms of accuracy, the highest uncertainty is with the induction cooker, where the materials employed had to be estimated. Quooker data has the highest reliability, as it is composed by the manufacturer's bills of materials.

Overall, considering that the absolute theoretical minimum for boiling is 105 Wh/litre[5] , the impact of the production, distribution and end-of-life of the tools at between 1 and 16 Wh of electricity equivalent is relatively modest (<1-15%).

2.3 Filling

Traditional boiling starts with filling the pot. This may seem a fairly trivial act, at first sight unrelated to an analysis of the energy efficiency of boiling, but in fact research shows that on average people tend to overdose the required quantity of water by as much as 50%. In other words, one-third of the water cooked is not consumed but stays in the pot or kettle. This average figure will vary widely, depending on the size and shape of the pot and the quantity of final product (tea, coffee, etc.) desired. Many will claim a rational reason for this overdosing, such as an anticipation of the evaporation or a need to submerge the heating element in an electric kettle, but the most important reason is habit.

The overdosing figure is confirmed by several sources. DEFRA Briefing Notes report that consumers could save some 30% when using the exact dosage in a kettle (meaning that the overdosing is around 50%).[6] A Swiss study on coffee preparation[7] assumes one-third of water to be prepared as an overdose. In the Netherlands, there are two reliable sources that –when combined—indicate (at least) a 50% overdose. One source is the Voedselconsumptiepeilingen (VCP) by TNO Voeding[8], which assesses the actual consumption of hot drinks and boiled products. The other source is the VEWIN water utilities association[9] that periodically assesses the tap-water consumption for specific applications, amongst others the preparation of hot drinks and boiled products. Especially the results for coffee and tea give a 1:1 comparison showing that <60% is actually consumed and 40% is overdose and evaporation losses[10]. But also for boiled vegetables, pasta and rice –where the '

---

[5] Based on cold water temperature of 10 °C, energy = (100-10) K x 1,16 Wh/ltr.K= 104,4≈105 Wh/ltr

[6] UK Dept. of Environment, Food and Rural Affairs (DEFRA), Market Transformation Programme,"BNCK06: Trends in kettle type and usage and possible impact on energy consumption", Version 2.1, 18 Jan. 2008 (last review). www.mtprog.com

[7] Sebastien Humbert*, Yves Loerincik, Vincent Rossi, Manuele Margni, Olivier Jolliet, *Life cycle assessment of spray dried soluble coffee and comparison with alternatives (drip filter and capsule espresso)*, Journal of Cleaner Production 17 (2009) 1351–1358.

[8] TNO Voeding, Voedselconsumptiepeiling (VCP), latest version 1999 (last complete, next 2010) with a panel of 5989 persons (2 day registration).

[9] VEWIN, Rapportage Waterverbruik Thuis, 31 Jan. 2008. Panel of 2454 households may-sept. 2007 (time & frequency data from personal registrations+ check by technical measurement of flow)

[10] VCP shows a per capita annual consumption of 140 litres of coffee (**341** per household) and 100 litres of tea (**245** per household). Out of the ca. 80 kg of gross potatoes 'consumption' per capita per year (source Dutch CBS, Central Bureau of Statistics), around 20% goes to peelings, 20% is leftovers and a small fraction is consumed in restaurants and as potatoe-products. Ultimately some 42 kg/a of (peeled) potatoes is the net per capita

overdosing' is less-- it is possible to make a fair estimate of the ratio between correct[11] and actual water-usage[12]. The table below gives an overview in terms of boiled water.

Table 2. Boiled water consumption NL

boiled water products	actual consumption litres/ hh/ a		tap water for preparation litres/ hh/ a
coffee	341	= 586	1068
tea	245		
soups	70	= 440	600
cooked potatoes	100		
cooked vegetables	150		
pasta & rice	120		
Total litres per year per household	1026		1668

The temperature of the cold water to fill the pot may vary between just above freezing point (0-2 °C) and 30 °C, depending on the local climate, the time of season and the distance between cold water in the house and the kitchen tapping point. EU water heating standards either use a temperature of 15 °C (e.g. EN 50440) or 10 °C (e.g. EN 13203, EN 12975, etc.) as a year-round European average. The latest proposals (e.g. draft Ecodesign measures in the context of the 2005/32/EC directive) tend to use 10 °C and that is the temperature used in the underlying energy analysis.

---

consumption (86 g/pp/day. source: VCP) , of which 75% is cooked (31 kg) and the rest is baked, etc.. Per household (2,44 persons) the net quantity cooked is 76 kg (31 kg * 2,44) plus an estimated 24 kg of left-overs. In total this is 100 kg of boiled potatoes per household per year. At a 'correct' water dosage of 1 litre per kg, this comes down to **100** ltr. of boiled water per year. The net consumption of other cooked vegetables is roughly the same as the potatoes, but in general they require a larger boiling water volume per kg. Net cooking of **150** litr/year is assumed. Pasta (consumption uncooked produc t 23 g/pp/day) requires plenty of boiling water (1:5-1:10). Total boiling water for pasta is estimated at least at **100** ltr./year. Rice (consumption 14 g/pp/day) requires less water (1:3-1:4). Boiling water consumption is estimated at 10-**20** ltr/yr.. Soup consumption in the Netherlands is fairly high (67 g/pp/day, source VCP). Corrected for 20% boiling loss the annual boiling water consumption is 1,2*67*365*2,44= ca. **70** litre soup/household per year.

[11] 'correct' means appropriate quantity of water for a certain quantity of food (according to guidelines by health and food authorities) for the traditional cooking in a pot, i.e. not for microwave-cooking, pressure cookers and steam ovens where the water quantity may be significantly less..

[12] VEWIN measures a per capita consumption of 1,2 litres/day for coffee and tea (* 2,44 persons per household * 365 days= **1068** litres per household per year) and 1,7 litres/day for food preparation (*2,44*365= 1514 litres/household/year). Of the latter it is cautiously estimated that 40% (**600** litres per household per year) is used for boiling potatoes, vegetables, pasta and rice. The remainder would be cold water for cleaning vegetables, etc.. The total kitchen tap water consumption is 12,6 litres per person per day, of which then 1,2+0,7= 1,9 litres (close to 20%) is used for hot drinks and cooking.

Some people have the habit of filling the kettle with hot water from the regular water heater. Unless they have a very efficient water heater positioned close to the kitchen tapping point, this is not a good idea from the energy efficiency point of view for the small quantities generally involved in boiling water.[13]

So, for a single cup the energy efficiency of this operation is as little as 15% (11,6/78). Of course at higher quantities the energy efficiency is higher and at about 1 litre (4-5 cups) the efficiency of microwave and electric cooking top is about equal.

When preparing hot drinks with a Quooker there are no direct overfill losses. The steam that escapes during tapping with a Quooker is taken into account as an indirect overfilling loss. This evaporation loss is about 1,5 %. When the Quooker is used for cooking potatoes and vegetables and so on the overdosing will be somewhat lower than overdosing with other heating means since the water is already boiled during filling of the pan. There will be less evaporation during the subsequent boiling process so there is less need to overfill (see also text in box on food preparation) Total dosage efficiency of the Quooker is based on the assumption that there will be no overdosing for hot drinks (585 ltr. consumed/585 litr. tapped) but –to be on the safe side—the overdosing with food preparation with a Quooker will be equal to that of other methods (440 ltr. used /600 ltr. tapped). Overall this gives a dosage efficiency of 87% (1026 ltr. used/1186 ltr. tapped). With the evaporation loss added, total dosage efficiency for the Quooker becomes 84%.

---

[13] As a rule-of-thumb the water content of the piping between primary water heater is 0,1 litre per metre of pipe.[13] For instance, if the efficient (e.g. gas-fired condensing combi boiler) primary water heater is in the attic or cellar, assume there would be 10 metres of pipe, which means that for a single draw-off (tapping at 60 °C) around 1 litre of hot water would cool down in the pipe. Assuming a high efficiency for the primary water heater of 60%, the distribution loss would be:

10 (metres of pipe) x 0,1 (litres/metre) x 50 (K difference between 60 °C water in pipe and 10 °C cold water) x 4,2 (kJ/K.litre) /60% (efficiency primary water heater) = 350 kJ per draw-off. → conversion to Wh at 1 Wh=3,6 kJ → 97 Wh.

To this we have to add the energy that is required for the hot tap water actually used. In case this is only 1 cup (0,25 ltr.) this useful energy would be 0,25 x 50 (60°C drawn off -10 °C cold water) x 4,2 (kJ/K.litre)/ 60%= 70 kJ → ca. 20 Wh.

The energy content of the water in this cup is 0,25 x 50 x 4,2= 52,5 kJ (14,5 Wh), so the effective efficiency of heat transfer is a less than impressive 14,5/ (97+20)= 12%.

Of course the distribution loss weighs less when drawing-off e.g. 1 litre (4 mugs), which results in 58/(97+80)= 32% overall heat transfer efficiency which comes close to the worst case efficiency of directly boiling cold water. But still, only at larger quantities and distances of less than 3 m (efficiency of 58/(29+80)=53%) the option of using hot water could become interesting.

The table below summarizes the findings for dosage.

Table 3. Domestic boiling water preparation, over-filling

		el. kettle*	el. cooking top (trad.)	gas hob	electric induction cooking top	microwave oven	quooker solo & combi incl. tap
net boiling water consumption	ltr/year	1026	1026	1026	1026	1026	1026
dosage efficiency	%	62%	62%	62%	62%	95%	84%
boiling water prepared	ltr/year	1668	1668	1668	1668	1080	1186

Boiling energy saving in food preparation

Around two-thirds of boiled water in the household goes to preparing hot drinks like coffee and tea. One of the main energy saving features of the flash-boiling device is in avoiding the 30% overdosing that usually accompanies the preparation of boiled water for tea, coffee in soup. This is a straightforward assessment, backed-up by various third party sources.

The question is whether similar savings could be obtained from using a flash-boiling device in the remaining one-third of boiled water use, i.e. the preparation of foodstuffs like potatoes, rice, pasta and vegetables. This will depend very much on existing habits and cannot be backed up by hard field data. In order not to cast any doubt on the neutral character of the underlying analysis, ***no*** *credit was given to the flashboil-device, i.e. overfilling was considered as for the other methods.*

From a theoretical point of view a good case could be made that using a flash-boil device does not lower your energy bill in food preparation: If you are a disciplined, energy-conscious cook with the proper tools there is probably no energy gain from a flash-boil device.

You would be steaming smaller quantities of vegetables and potatoes (up to 2-3 portions) in a micro-wave oven, boiling larger quantities or food with long preparation times in a pressure cooker and complete the final stage of preparing your rice or soup in a hay box or a vacuum pot[14]*. And on the rare occasions that you can't avoid to boil larger quantities of water in a conventional pot, you would always use a (proper) lid and be very watchful in keeping the proper boiling- and simmer times. The time-saving features of the flash-boil device will not bring you any significant energy merit, because you would own a highly efficient hood with over 90% ventilation waste heat recovery.*

[14] So-called 'thermal cooker'.

If you are that person, a flash-boil device will be of little help in lowering the energy bill of food preparation and certainly not by 30%. If you are not that person, perhaps some of the following may apply…

For instance, there are several sources claiming at least an energy saving of 25% when you are boiling water with the lid on the pot. This effect isn't so much due to the mass of water evaporating –without lid around 5% of mass in bringing a 5 litre pot to the boiling point— but most importantly due to the evaporative cooling effect. The advantage of the Quooker in this respect is that it always brings the water to boil " with the lid on". Better still, the "pot+lid" in this case is a highly-insulated vessel with practically no energy loss.

A flash-boil device can help to define your cooking time more exactly. You can fill the pot with boiled water, put in the food, wait at the stove for probably less than a minute until it is again brought to a simmer and set the cooking timer.

Certain preparations, like pasta and rice, require large quantities of boiling water. For pasta typically a measure of 1:10, meaning 5 litres of water for 500 g of uncooked products is prescribed. Even on a gas stove it typically takes around 20 minutes to bring these quantities of water to boil. For the evacuation of the combustion gases and water vapour most people use a hood, which would consume –estimated conservatively-- around 150W. In other words, for 20 minutes of boiling the electric energy use is some 45 Wh. In terms of primary energy -- at 40% efficiency of the power generation and distribution-- this comes down to 125 Wh, or rather 25 Wh per litre of boiled water. This is not counting the fact that the hood, let us assume at a flow rate of 150 m^3/h, will have evacuated an extra 50 m^3 of warm air from your home in these 20 minutes. To produce this warm air during the heating season, e.g. with an average outdoor temperature of 6 °C over the period from October to April and an indoor air of 20 °C, your boiler (assume gas-boiler with 70% annual efficiency) will use around 300 Wh of primary energy. [15] *This results in 60 Wh per litre of boiled water.*

Together with the previously calculated 25Wh, the total energy penalty of the hood operating for 20 minutes is around 85 Wh per litre. Compared to the net energy content of boiled water of 105 Wh per litre, this is certainly not negligible. On the other hand, we have no hard field data to make any statistically responsible estimate of what the shortening of cooking times contributes in terms of energy saving on ventilation.

[15] Calculation: { 50 m3 x 14 K x 0,33 Wh/K.m3 }/75% = 308 Wh. Note that the 70% boiler efficiency is based on a mid-range condensing boiler (NL. "HR") with nominal generator efficiency of 87/93% + usual distribution, stratification, fluctuation and control losses. The average 6 oC outdoor temperature is typical for an Average EU climate (NL, DE, DK, Northern FR, UK).

2.4 Heating

For the heating process the energy analysis starts far away from the boiling process, namely at the stage of fuel extraction and –for the electrical alternatives—power generation and distribution. A lot can be said about these issues, but actually the 1999 single market for energy and the subsequent European directives (Energy Services directive, Ecodesign directive, etc.) have made it clear that in fact we should consider the issue at a European level. And in line with e.g. Ecodesign preparatory studies the primary energy proportion between fossil fuel and electricity is 1 to 2,5 kWh/kWh.[16]

In other words, for electricity a primary energy loss of 60% is considered.

As a next step, the local heat generation and heat transfer efficiency is taken into account. This is the most visible art of an energy analysis and therefore very often mistaken as the only relevant part. Furthermore, as it is a part of the energy analysis that manufacturers of cooking appliances would like to use commercially, it is important to also take a look at the test standards behind the published energy efficiency figures, especially in relationship to the traditional boiling process. In particular, for reasons of accuracy, reproducibility, costs and sometimes commercial motives, test standards are developed close to reality, but rarely exactly like reality. An extensive discussion of all test standards is outside the scope of the assignment, especially as they are subject to copyright.[17] But we will discuss the one test standard that is in the public domain –the US test standard by DoE—as an example.

---

[16] Actually, when taking into consideration fuel extraction and –transport the ratio is 1,08 to 2,7, but for the sake of simplicity fossil fuel it is considered as 1, whereas for 1 kWh electricity at the plug it is considered that 2,5 kWh of primary energy is needed (efficiency 40%; losses 60%). Note that this figure not only takes into account the strict power generation efficiency, but also fuel extraction, distribution losses, a credit for cogeneration/district heating by the energy industry as well as a projected saving on these issues over an average product life of 10-15 years. As regards the latter, the methodology guidelines for the Ecodesign of Energy-using Products directive (VHK for the European Commission, 2005) indicate for instance a factor 2,91 for the year 2001, whereas –as mentioned—the current official figure as an average up till 2020 is 2,7.

[17] Examples of standards to be obtained from standardization institutes: **EN 50304/ EN 60350: 2009** Electric cooking ranges, hobs, ovens and grills for household use - Methods for measuring performance (built-in, on worktops or floors). **EN-IEC 60705: 1999** Household microwave ovens - Methods for measuring performance; **EN-IEC 61817: 2001** Portable appliances for cooking, grilling and similar functions – Methods for measuring performance. (Some of the tests which are specified in these standards are not considered to be reproducible since the results may vary between laboratories. They are therefore intended for comparative testing purposes only). **ASTM F1521 - 03(2008)** Standard Test Methods for Performance of Range Tops (gas and electric, US). **IEC 705** (International Electrotechnical Commission), Method for Measuring the Performance of Microwave Ovens for Household and Similar Purposes," Publication 705–1988 and Amendment 2—1993.

The US legislator uses a test by which the efficiency of a cooking top is established from heating up not pots with water, but solid aluminium cylinders of certain dimensions.[18] Clearly this avoids the complex phase change from liquid to vapour and is thus better reproducible. On the other hand, as all the heat of the cylinder(s) is counted as useful, it ignores that in real life some energy –notably the energy to heat up the pot or kettle—is wasted.

Furthermore, the US test appears to be modeled after the process of boiling vegetables on all burners/hot plates simultaneously. When the test block reaches 80 °C above its initial test block temperature (10 °C), immediately the energy input rate to 25±5 percent of the maximum energy input rate should be reduced. After 15±0.1 minutes at the reduced energy setting, the surface unit under test should be turned off.

This may seem reasonable for evaluating the preparation of a dinner, but obviously it is not representative of e.g. boiling water to make some tea. Boiling just requires the first part of the test and it typically requires only one burner or hotplate –out of typically 4. This may be very important, depending on the type of cooking top.

Electric cooking top

The traditional electric hotplate usually requires the heating of a heavy iron plate that takes a considerable time to heat up and stays warm for at least 15 minutes after it is turned on. In a typical boiling process, where you switch off after boiling, all the heat content of the iron plate is lost, with probably a very heavy impact on the efficiency. However, as the second stage of the test is executed at only 25% of power, a large part of this energy will actually be counted as useful. As a consequence, the 1997 cooking appliance study by Lawrence Berkeley National Laboratories for the US Dept. of Energy found that on average the traditional electric cooking top –according to the standard test described above—had an efficiency of as much as 71%[19]. In real life and used for boiling tea water in an actual kettle or pot on an electric stove the efficiency is probably half of that (30-40%).

---

[18] U.S. Office of the Federal Register. 1995b. *Code of Federal Regulations, Title 10, Energy. Part 430, Subpart B, Appendix I: Uniform Test Method for Measuring the Energy Consumption of Cooking Tops, Conventional Ovens, Microwave Ovens, and Microwave/Conventional Ranges.* Washington, DC. 1995

[62 FR 29237, May 29, 1997]

[19] Lawrence Berkeley National Laboratory, *Technical Support Document for Residential Cooking Products (Docket Number EE-RM-S-97-700) Vol. 2: Potential Impact of Alternative Efficiency Levels for Residential Cooking Products*, Prepared for US Dept. of Energy, Berkeley, CA 94720, US, 1997.

This is confirmed by a 2006 Intertek study for the UK Dept. of Environment (DEFRA) comparing e.g. the efficiency of A-rated micro-wave ovens (efficiency around 60%) with a traditional electric cooking top, where for heating small quantities of liquid (1 cup) the micro-wave used half the energy.[20]

Still, in the underlying study, not the traditional electric cooker is considered, but the modern version where the resistance heating element –with a considerably lower thermal mass—is located under a ceramic glass plate. In a recent test of Stiftung Warentest (9/2009) 10 electric ceramic plate cookers achieved on average an efficiency of 73% when heating up 1,5 litre of water from 15 to 90°C. Finding a middle value the underlying study assumes an efficiency of **60%** for the heating process of smaller quantities of boiled water with an electric ceramic cooking top.

Gas hob

Also the fact that 4 burners/plates of a hob are operated simultaneously may be significant for cooking top solutions whereby the waste heat of a burner/plate is used to heat another hot spot on the cooking top. An example is the 'gas-under-glass' solution ,mentioned in the first chapter, where the flue gases of a radiation gas burner are conducted to a hot spot that is heated by those hot fumes. The resulting efficiency is impressive (up to 80%), but for boiling tea-water on a single plate it is not a representative figure. For –amongst others— this reason we limit the analysis to the traditional gas hob.

In the previously cited study LBNL 1997 found an average efficiency of 39,9% for gas hobs. In real-life, with an actual gas kettle instead of an aluminium block and with the application of boiling water, the outcome would be considerably lower. Only taking into account the energy lost in heating the pot, the energy efficiency would be 10% lower, e.g. around 35%. [21]

On the other hand, recent gas burner technology has improved since 1997 and the best available technology by leading Italian gas valve manufacturers is some 25% more efficient.[22] Applied to the boiling application this could mean that the heating efficiency rises to 45-50%.

---

[20] DEFRA, Market Transformation Programme,"BNCK07: Comparing energy use in microwave ovens with traditional electric fuelled methods", Version 1.2, 14 July 2009. www.mtprog.com

[21] Specific heat: Iron/steel 0,44-0,5 kJ/kgK; Copper 0,38 kJ/kgK; Aluminium 0,88 kJ/kgK. Assumed average is 0,5 kJ/kgK. Average mass of small pot/kettle 0,4 kg. Temperature heat-up 80 K (from 20 to 100 °C). Energy lost in heating small pot/ kettle: 80 (K) x 0,5 (kg) x 0,5 (kJ/kgK)= 20 kJ . Conversion 1 Wh=3,6 kJ→ 20 kJ= 5,55 Wh. Compare to theoretical minimum for boiling e.g. 0,5 litre of water this is around 10%.

[22] Roggema, P., European Report: Energy Saving in Gas Cooking, Appliance Magazine, June 2006. http://www.appliancemagazine.com/editorial.php?article=1431&zone=208&first=1

But currently only a small portion of the market will employ this technology. The underlying study estimates a **40%** efficiency for a gas hob in the application of boiling water. Conversion to kWh gas is based on the ratio 1 m3 gas equals 35.2 MJ (gross calorific value) equals ca. 10 kWh (1 kWh = 3.6 MJ).

In this context, it is relevant to mention that the efficiency is calculated on Gross Calorific Value (GCV) of the fuel, as is customary in most parts of the world. In contrast, European test standards often use energy efficiency based on the Net Calorific Value (NCV) of the fuel, which gives an inflated 10% higher efficiency value. The difference between the two is a matter of definition. The gas combustion process is a reaction of e.g. methane[23] with oxygen, producing carbon-dioxide, water vapour and heat (exothermic reaction).[24] The NCV value only takes into account the reaction heat, whereas the GCV value also includes the so-called ' latent heat' that can be released when the water vapour condenses.

Finally it is worth mentioning that a fraction of up-market gas hobs is connected to the electric power supply to support e.g. electronic ignition. As we are only looking at traditional gas hobs this will not be taken into account, but the UK MTP considers that standby consumption may be as much as 5 W electric. At 8000 h standby, 66% partitioning to boiling this contributes 26 kWh electric per year, or rather (at 40% efficiency for power generation) 66 Wh primary per litre of boiled water.

Induction heating

Manufacturers generally advertise induction cookers as 90% efficient. The US DoE states a 84% efficiency using their standard test methods. A recent test of Stiftung Warentest (9/2009) of 7 induction cookers revealed an efficiency of around 80% when heating up 1,5 litre of water from 15 to 90°C. Jungbluth[25] reports that single tests of boiling 1 litre of water on induction cookers yields efficiencies of not more than 60-72%. No test reports of boiling smaller quantities of water on an induction cooker were found, but typically efficiencies would be even lower. Nevertheless, following the principle of giving induction cookers *the benefit of the doubt*, we will assume an efficiency of **75%.**

---

[23] Most of the EU gas grid uses methane (>95%), but there is also town gas, bottled gas (propane, butane), etc. In the US ethane is common.

[24] Reaction: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + heat$

[25] Jungbluth, N., Life-Cycle-Assessment for Stoves and Ovens, UNS Working Paper No. 16, ETH Zurich (CH), Aug. 1997.

As regards standby electricity consumption, induction cookers are typically an up-market product with lots of fancy electronic features, such as overheat detection, touch control, timers, etc.. Although recently some models are advertised as having only 1 W standby electricity consumption, most installed models will feature between 4 and 8W. [26]

On an annual basis (8600 h standby) and assuming 3 W this results in an electricity consumption of 26 kWh. Partitioning 67% to boiling applications, this means a non-negligible contribution of 17 Wh electricity per litre of boiled water (at 1000 litres boiling water per year), or rather 43 Wh of primary energy. Although in due time the Commission Regulation on standby losses will force the industry to reduce its standby loss to 1 W, it is realistic for a snapshot of the current situation to assume at least the 3 W mentioned.

Microwave

The study of LBNL for US DoE shows an average energy efficiency of the microwave oven in a standard test (heating a container with water) of around 56%. For the most efficient micro-wave ovens reach an efficiency of 64%. For the underlying analysis we will assume 60% efficiency. Energy losses are caused by the power supply, microwave generator, turntable, lighting (25W) and controls.

The Australian government reports an average 2003 passive standby energy consumption of 3,0 W (all models) in 2003, down from over 6 W in the 1990's.[27] In the UK similar data are used for 2008, with 3,6 W for electronic models (0 W for models with a clock timer). In European policy scenario's this standby energy use should be reduced to 1 W by 2015, but for the moment 2 W is a realistic average. Calculated as with the induction cookers this results in a specific primary energy consumption of 28 Wh primary energy per litre.

Electric Kettle

In certain optimistic publications, also from NGO's, the energy efficiency of an electric kettle is advertised as over 95-97%. In specific studies, the efficiency is estimated at around 90% taking into account heat dissipation at the heating element, the energy to heat up the heater body, etc.

---

[26] Nipkow, J, Bush, E, Standby consumption of household appliances, Swiss Agency for Energy Efficiency for the Swiss Federal Office of Energy, Zurich June 2003. (measurement of 4 induction cookers)

[27] National Appliance and Equipment Energy Efficiency Committee, *Australia's Standby Power Strategy 2002 – 2012, Microwave ovens product profile*, Canberra, 2003.

Furthermore, as most kettles (>70%) are now ‘ cordless’, meaning that the heater body can be separated from a base plate that stays in place, there appears to be a trend towards adding features to the base plate. The UK reports that additional features include:

- Water filter kettles that have an electronic filter-change reminders
- A keep-hot facility to keep hot water on stand-by
- Extended illumination features (flashing LEDs, colour indicators, internal illumination)
- Kettles with a whistle function on boil
- Kettles with temperature selectors.

All in all, some of these features will also be working when the kettle is not in use, causing a standby electricity use of 1,5 W. The keep-hot function to keep a half-full kettle warm may even use 66 W (see paragraph 2.7).

The VHK energy analysis will use a **90%** electric kettle efficiency and no standby consumption.

Quooker

In June 2008 the Danish Electricity Saving Fund (Elsparefonden) asked the Danish Technological Institute (DTI) to perform an energy consumption test of the Quooker ‘ boiling water tap’.[28]

Despite a number of serious flaws in the DTI test and the report VHK will take into account some aspects.

For instance, it is easy to calculate the heating up of the tap (pipe). The outer parts of the Quooker tap are thermally insulated from the hot water channel and the dosing valve housing. The mass of these parts is taken from the bill of materials. These outer parts will heat only slightly up to around 35 °C from 20 °C ambient when tapping 1 litre of boiling water. The total mass of these parts is 0,6 kg (brass and zinc), and the specific heat of brass and zinc is 0,38 kJ/kg.K. This yield a heat loss of 0,6*15*0,38=3,4 kJ or 1 Wh. The ‘hot’ inner ‘parts –mainly brass – have a total weight of about 0,25 kg. With an estimated temperature of 70 °C after tapping, the heat loss of these parts is 0,38*50*0,25=5 kJ or 1,3 Wh . The total heat loss due to dispensing of the water is then 2,3 Wh. At a cold water temperature of 10 °C (as in Ecodesign proposal), this is a little over 2% of the total heat content of the water

[28] Paulsen, O., Madsen M.P., Test of the Quooker (project nr. 1344617-02), Danish Technological Institute (DTI) for the Danish Electricity Saving Fund (Elsparefonden), June 2008.

and the strict energy efficiency of heating is around 98% (104,4 Wh /(104,4+2,3) Wh per litre).

Convection losses to the cold water grid will be negligible at proper mounting of the appliance and will –if they exist—be attributed for 99% to the standby loss and in part be recuperated as useful heat during tapping.

The 2% evaporation loss suggested by DTI is plausible and is taken into account in the VHK analysis, but this was already taken into account in the over-filling paragraph.

In the paragraph on 'extra boiling time' the overheating aspect will be taken into account, i.e. the Quooker stores water at 108 °C and strictly for the first boiling slightly over 100 °C would have been enough. The extra 8 °C represents an energy cost (not necessarily a ' loss').

As regards the standby loss, we will take the manufacturer's declaration, but as it is a rounded figure (10 W) we will assume a worst case of 10,5 W. For the Quooker COMBI, which combines the functionality of a kettle and a storage water heater (see part 2 of this report), the same method for partitioning the standby loss to the respective functions was chosen as for the tooling part. The average daily use of boiling water is 19% of the total amount, the rest is warm water. According to this ratio the standby loss was partitioned.

Summary

The table below summarizes the findings of paragraph 2.4.1 to 2.4.6.

Table 4. Domestic boiling water preparation, heating and standby

		el. kettle*	el. cooking top (trad.)	gas hob	electric induction cooking top	microwave oven	quooker solo incl. tap	quooker combi incl. tap (19 % of solo)
heating efficiency	%	90%	60%	40%	75%	60%	98%	98%
standby	W	0	0	0	2,0	1,3	10,5	2,0

2.5 Seeding and boiling

The process of seeding and boiling influences only 2-3 % of the overall energy efficiency and this energy use is already included in the heating energy from standard tests. There are little differences between the alternatives that use a container, but the Quooker has the advantage that it doesn't have to overcome the hydrostatic pressure, because the seeding and boiling takes place in a fraction of a second in the micro-bubbles leaving the tap. The following is a description of the general boiling process solely for the benefit of better general understanding.

The first bubbles already form at a temperature of 60-70 °C, usually at the hottest spot and or at a microscopic contamination, scratch or other type of irregularity that can start of as *nucleus* for the bubble. These first bubbles hardly contain water vapour, but they are a consequence from dissolved gases being driven out of the water. As a result the first micro-bubbles are filled with oxygen and nitrogen from previously absorbed air. They are important as a starting point for the larger bubbles later on, that do contain water vapour as the temperature locally rises to the boiling point. These larger water vapour bubbles start to exist as heat causes the molecules of water to move faster and faster. When they are moving fast enough, they break away from the other molecules and change from a liquid to a gas. The molecules of water leap into the tiny gas bubbles mentioned earlier. This forms a bubble of water vapour. When the bubble gets large enough, it breaks free and begins to rise. One can say that they exist because the water vapour pressure is higher than the atmospheric pressure plus –for a small fraction—the hydrostatic pressure in the pot.

The initial bubbles will at first not float towards the surface of the water but sit at the bottom (or another hotspot) until they have enough buoyancy (are large enough) to detach themselves. As they try to rise to the surface they will encounter the colder parts of the water in the pot, causing the water vapour to condense and the bubbles to implode. The microscopic implosions cause a relatively higher pitched noise and indicate a stage of the boiling process known as ' seeding'. Together with conduction and the convective circulation in the pot, this seeding process helps the mixing of the water and thereby an equal heat distribution throughout the fluid.

At a certain point the implosions –and the higher pitch noise that goes with it—stops as the bubbles are big enough and water is warm enough for the bubbles to rise to the surface. After some seconds of relative silence the pre-dominant noise becomes a lower pitch 'bubbling' as the bubbles burst at the surface and the water vapour in the bubbles is released at the surface. If the pot doesn't have a lid some of the bubbles pop, but most do not. Instead they shrink and disappear as they now condense against the colder air. In a pot with a lid (or in a kettle) the air above the water surface also heats up quickly and in that case most bubbles will pop. As the bubbles appear all over in the pot, we say that the water is ' boiled'.

2.6 Extra boiling time till switch off

It usually requires some extra time (20-30 seconds) before the burner or the electricity is turned off. Specifically, the thermostat of the electric kettle needs some time to reach the cut-off temperature and a gas-kettle requires some time to build up enough pressure to operate the whistle.

In an energy analysis it may seem that this extra boiling time is a total loss. However, for the particular application of preparing tea-water at least a part of the extra boiling time may be functional in improving the *'quality'* of the boiled water.

In the Quooker for instance, the energy required for the 'extra boiling' time is replaced by the equivalent extra energy required to heat the water to a storage temperature of 108 °C, so 8 °C higher than strictly necessary for boiling. Heating from a temperature of 100 °C to 108 °C, this 8 °C extra represents 8K x1,173 Wh/kgK= 9,4 Wh/kg extra energy consumption. In terms of storage losses this 8 °C higher temperature does not cause a noticeable extra heat loss, because the storage vessel is fully vacuum insulated and the standby heat loss (10,5W) is due only to edge effects.

For making quality tea, it is important that the boiling process transforms the calcium compounds in the tap water to avoid a spotty 'dirty' layer floating on the surface of the tea water. It is not only unattractive, but also affects the taste. The transformation process is a consequence of the boiling water driving out the dissolved gases, amongst others carbon-dioxide (CO_2) both in free form and –most importantly—in a compound with calcium. What remains is a non soluble calcium compound that sinks to the bottom; the water becomes 'softer'.[29]

As mentioned before, the water in a kettle or pot is not what is called an *ideally mixed fluid*: there are always temperature differences. Even if the bubbles are popping up all over the fluid there is still no guarantee that a temperature of 100 °C is reached in all spots. And as such this extra boiling time may give a better performance and a better *'quality'* of boiled water. On the other hand, if the extra boiling is too long all oxygen from the water disappears and this has a negative effect on the quality of the tea.

Despite all the positive things that are said about the extra boiling time, it is still clear that a significant part should be seen as a real energy loss. With kettles and pots on a cooking top this loss is fairly unpredictable as it depends on how quickly the consumer will react to the water boiling. With electric kettles that have an automatic switch-off the effect is measurable and there we can observe that the switch-off time is longer when the quantity of water is smaller. A single test in a small electric kettle (1 ltr.), the boiling of 1 mug (0,25 litre) may take as little as 1 minute, but the extra time of around 30 seconds poses a very heavy extra 50% burden on the energy costs. From several single tests a widely differing results could be observed. For the energy analysis we will assume that the extra boiling time is 15 s per 0,5 litre for most appliances, except the microwave (10 s) and the quooker (0 s).

---

[29] The formula is: hydrogencarbonates (solubale) <-> carbonates (not soluable) + carbondioxide. Chemically:

$Ca(HCO_3)_2$ (soluble) <-> $CaCO_3$ (not soluble) + CO_2 + H_2O;

Mg (HCO_3)$_2$ (soluble) <-> $MgCO_3$ (non soluble) + CO_2 + H_2O.

The effect, for instance with a heating element of 2 kW is in the order of 2 x 2 x 15/3600 = 17 Wh/litre. For electric appliances this translates into 42 Wh of primary energy.

The figures presented are related to the extra boiling time *per tapping*. For the energy per litre boiled water that is actually consumed the extra-boiling energy per tapping is multiplied by the overfilling factor derived from table 3:

(boiling water prepared) / (net boiling water consumption)

The table below summarizes the findings.

Table 5. Domestic boiling water preparation, energy costs of extra boiling time

		el. kettle*	**el. cooking** top (trad.)	**gas hob**	**electric** induction cooking top	**microwave** oven	**quooker** solo&combi incl. tap
Power	kW	**2**	**2**	**1,5**	**2**	**1,1**	**1,6/ 2,2**
Extra heating time per tapping	s	15	15	15	15	10	na
Extra heat per tapping	Wh	8,3	8,3	6,3	8,3	3,1	na
2 tappings x 0,5 per litre	Wh/l	16,7	16,7	12,5	16,7	6,1	9,4
Extra heat per litre consumed	Wh/l	27,1	27,1	20,3	27,1	6,4	11,2

2.7 Serving and Keep warm

Last stage: preparing and serving the hot drink… Although in many instances this stage has no energy implications, there are also exceptions whereby the hot drink is kept hot.[30]

For instance, the UK MTP has calculated a scenario with the keep-warm kettle that uses 66 W to keep a half-full kettle warm. In comparison to a standard kettle, which is used 1542 times and is assumed to consume 0,11 kWh/use, the keep-warm kettle is used only 70% of that figure, reflecting its possible benefit of not having to reboil the water. But the keep-warm kettle is assumed to use its hot plate function 40 minutes a day (243 h/yr). The end result calculated by the researchers gives an increase of energy consumption of 46% for the keep-warm kettle (169,6 versus 248 kWh/a).

[30] Compare that from LCA studies of traditional coffee-maker some 20-25% can be attributed to the keep-hot function.

2.8 Overview

The table below calculates the total energy impact of boiling water products over their lifecycle. The first table shows first the subtotals in $kWh_{electric}$ (and for the gas hob in kWh_{gas} = $kWh_{primary}$) to facilitate also possible economic calculations.

Table 6. Domestic boiling water preparation, total per litre and year

		el. kettle	el. cooking top	gas hob (primary energy)	electric induction cooking top	micro-wave oven	Quooker PRO3-VAC incl. tap	Quooker combi 2.2 incl. tap
Power	kW	**2**	**2**	**1,5**	**2**	**1,1**	**1,6**	**2,2**
Tooling (production, distribution, EoL)	Wh	**9**	**5**	**15**	**8**	**14**	**6**	**2**
Boiling (use phase)								
Theoretical minimum (Tcold=10 °C)	Wh	**105**	**105**	**105**	**105**	**105**	**105**	**105**
Over-filling & evaporation loss factor		**1,63**	**1,63**	**1,63**	**1,63**	**1,05**	**1,20**	**1,20**
Heating	Wh	**189**	**284**	**426**	**227**	**184**	**127**	**127**
Standby (incl. storage), 8600h/yr	Wh	**0**	**0**	**0**	**17**	**11**	**90**	**17**
Extra boiling*	Wh	**27**	**27**	**20**	**27**	**6**	**11**	**11**
Subtotal/litre (Wh electric, Wh gas)	Wh	225	316	461	279	216	235	157
Subtotal/ year (kWh el., kWh gas)	kWh	225	316	461	279	216	235	157
Total primary energy (el. X 2,5)/year	kWh	563	791	461	698	540	587	392
Primary energy efficiency	**%**	**19%**	**13%**	**23%**	**15%**	**19%**	**18%**	**27%**

**= including overdosage*

The focus of the second table below is on a transparent partitioning of the energy losses and is the basis for the summary. Given the uncertainties in the analysis, as indicated in the previous paragraphs, the accuracy of the primary energy efficiency is estimated to be no larger than 15%.

Table 7. Domestic boiling water preparation, total kWh primary energy per 1000 litres

	electric kettle	electric cooking top	gas hob	induction cooking top	microwave oven	Quooker PRO3	Quooker COMBI
tooling (production, distr., EoL)	22	14	15	20	36	15	4
theoretical minimum	105	105	105	105	105	105	105
overdose (over-filling)	66	66	66	66	6	20	20
heating (heat loss)	19	114	255	57	74	2	2
standby	0	0	0	17	11	90	17
extra boiling time	27	27	20	27	6	11	11
power generation loss (grid)	325	466	0	407	303	343	233
TOTAL	563	791	461	698	540	587	392
primary energy efficiency	**19%**	**13%**	**23%**	**15%**	**19%**	**18%**	**27%**

Energy Analysis, Part 2

Quooker® Combi

water heater function

(page intentionally left blank)

3. Introduction & EU measures

3.1 General

This second part of the report gives an overview of the energy performance of the Quooker Combi in its capacity as a normal water heater (without taking into consideration the extra boiling function) and the most important market trends with regards of the energy performance of small water heaters. The energy analysis is based on the latest proposals and the methodology as established in the context of the European Framework Directive 2005/32/EC and the 2009/125/EC recast. The study is performed by international energy efficiency specialist VHK, amongst others responsible for the development of the ecodesign methodology (MEEUP) for the European Commission.

The study was sponsored by Peteri B.V., but with the explicit assignment that the study should be unbiased and impartial. VHK has used verifiable external references and third party assessments wherever possible.

3.2 Overview EU measures

Undoubtedly the most important development in the water heater market in the coming years will be the introduction of new EU legislation. Although the political process is not yet concluded and VHK can base its evaluation only on current proposals, yet to be confirmed, it is clear that this legislation will have a considerable impact on water heater sales and R&D in the coming decade.

More specifically, new imminent EU legislation entails

- EU Ecodesign of Energy-related Products Directive 2009/125/EC, recast of 2005/32/EC (' Ecodesign of Energy-using Products'), introducing Ecodesign measures that will result in

  –an energy efficiency rating method for water heaters and

  –minimum energy efficiency performance standards (' MEEPS')

- EU Energy Labelling Directive approved Nov. 2009 (recast of 92/75/EC), introducing :

  –a mandatory energy label for hot water appliances, featuring

  –an efficiency rating A to G with extra classes A+, A++, A+++ on top, based on the methodology developed under the Ecodesign Directive.

- EU Energy Performance of Buildings Directive approved Nov. 2009 (EPBD, recast of 2002/ /EC:

  –Member States shall apply minimum energy performance for new buildings, certification of existing buildings, etc. <u>including</u> efficiency evaluation of hot water appliances.

-In the considerations it is recommended that the EU Member States shall use in their national EPB legislation (e.g. EPC in the Netherlands) the Ecodesign methodology.

Furthermore, water heaters using renewable energy sources (solar, heat pump) will be subject to the requirements of the new (recast) RES Directive, also approved Nov. 2009.

3.3 Reporting and disclaimer

The following chapters will discuss each of these policy measures and a final chapter will give an overview of the expected performance of the Quooker Combi according to the current proposals.

Disclaimer

The underlying VHK study was conducted using the best of current knowledge, but several of the documents are not final and corrections/amendments may follow from the internal consultations and/or input from Member States in the Regulatory Committee.

VHK assumes no liability for material or immaterial damages if the readers give an interpretation to these documents or statements in the underlying report that do not take into account these restrictions.

4. Ecodesign

4.1 Introduction

Water heaters were elected as a priority subject for measures in the context of Directive 2005/32/EC. The European Commission Preparatory Study for this subject ('Lot 2') started in February 2006 and was concluded September 2007. The study was performed by VHK for the European Commission and involved 7 consultations (meetings) with stakeholder experts and was concluded with a public workshop 10/11 Sept. 2007 in Brussels. Preparatory study reports can be consulted at the website www.ecohotwater.org In December 2007 the results were presented to the Ecodesign Consultation Forum of Member States and stakeholder representatives ' for information'. In the Consultation Forum on 28 February 2008 the European Commission presented its first Working Document (WD, proposal for measures). A second amended version of the Working Document was published in June 2008 ('WD June 2008') and presented at the Consultation Forum in July 2008.

Specifically for the technical annex (' Annex IV') an extra round of written stakeholder expert consultation took place in August (deadline 31.8.2008). Based on that consultation a new version of Annex IV was published 16 Sept. 2008. Since then, the measures are being prepared by the Commission internally, which involves the preparation of an impact analysis and a number of consultations (inter-service consultation, impact assessment board, etc.). The latest informal estimate of Commission officials is that the final stage of legislative process, i.e. most importantly the Vote in the Regulatory Committee, will be concluded in the first quarter of 2010.

The legal format that so far has been followed is that of a Commission Regulation, i.e. the provisions of the legislation will be valid immediately after publication without the necessity of incorporating the measures in national law (as is the case with Directives and which may lead to several extra years of delay). Having said that, the Regulation does usually foresee an adaptation period of at least 9 months before the measures become mandatory. In the meanwhile, manufacturers may usually implement part or whole of the provisions, e.g. labeling, on a voluntary basis.

VHK will highlight some of the findings of the preparatory study as the energy impact and a general overview of the performance of existing (smaller) water heaters.

4.2 Preparatory study: Market data

The figures below give an overview of the EU stock and sales of water heaters and specifically the (smaller) electric storage water heaters.

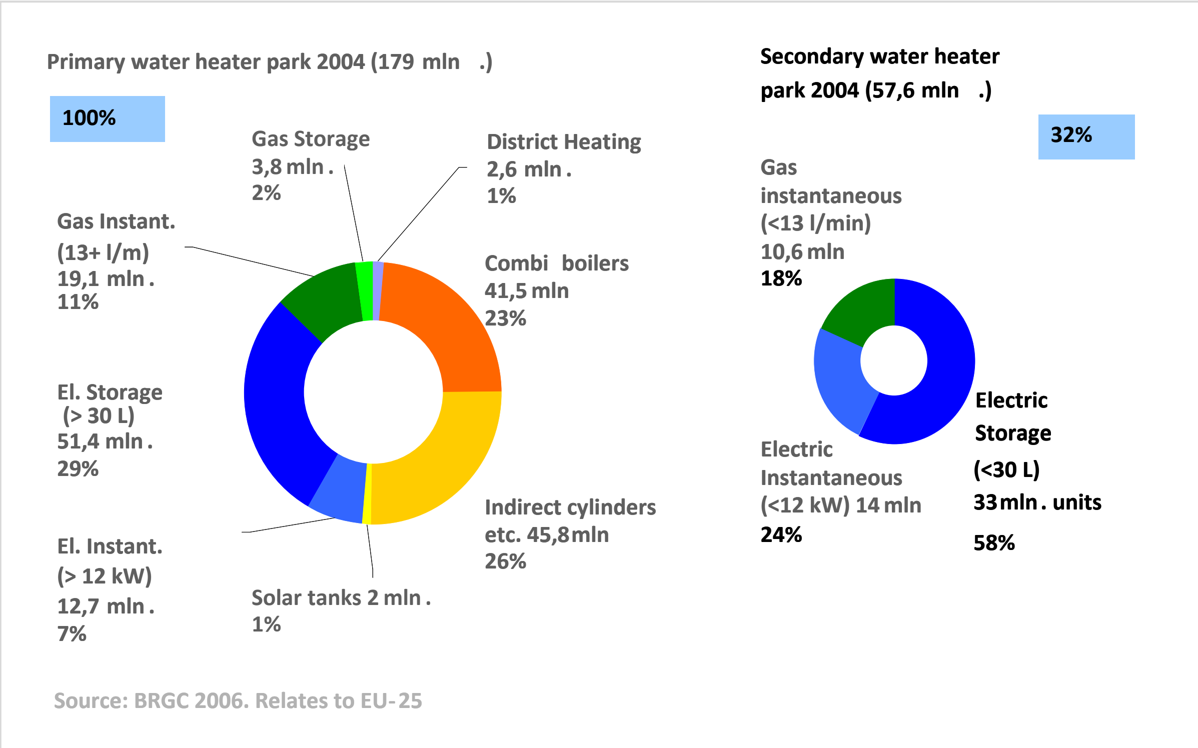


Fig. 1. EU-25 Installed stock water heaters 2004. Includes 33 mln. Electric storage water heaters <30 (pressurized and unpressurized.

Figure 1 shows that the main market for the Quooker Combi consists of 57,6 mln (EU 2004) secondary water heaters, i.e. water heaters that are used in addition to a primary (main) water heating and which for the most part will be employed as ' kitchen only' appliances but there is also –in the UK and Ireland—a significant share of electric showers included as part of the electric instantaneous water heaters

Over 80% of the secondary water heaters use electricity as an energy source; the gas-fired instantaneous solutions are most popular in Southern Europe (Spain, Portugal). Around 58% of the total secondary water heaters are small electric storage water heaters, i.e. with a storage volume of less than 30 litres.

Please note that District Heating water heaters represent a very small fraction of EU total and are predominantly part of the ' indirect cylinders' in Fig. 1.

As the sales figures below demonstrate, more than half of the small electric storage water heaters are of the unpressurized type, i.e. operating at atmospheric pressure, and are especially popular in Germany. The pressurized types, i.e. directly linked to the water grid and the segment where the Quooker Combi is active, represent annual sales of 0,9 mln. units per year.

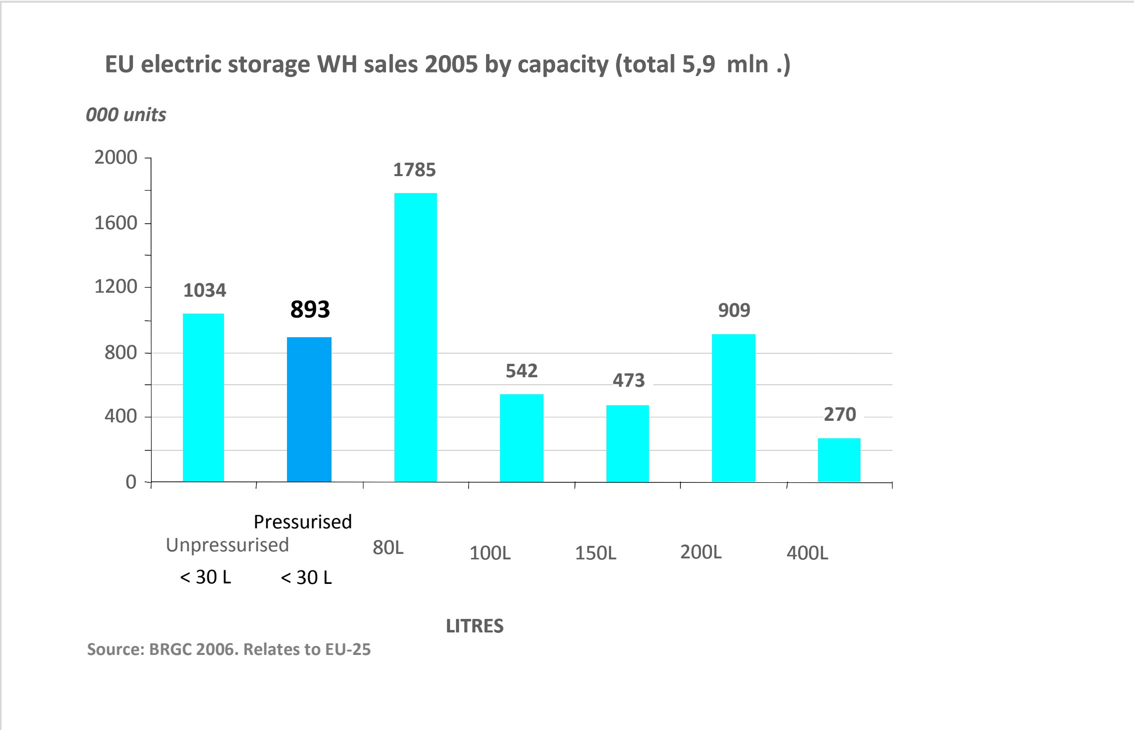


Fig. 2. EU-25 Electric storage water heater sales 2005. The Quooker share is included in the 0,9 mln. Units <30 ltr. (pressurized)

The preparatory study only gives anecdotal prices, with Germany in the high price range (DE average unit price up to € 436 for a pressurised 30 litre unit) and Italy in the lower price range (IT unit price for a pressurised 10 litre unit € 70). But if we assume € 200 as an EU average unit price, the EU market for pressurized electric storage water heaters <30 litre represents an estimated value in consumer prices (incl. VAT) of € 180 million (EU 2005). In manufacturing selling prices (excl. VAT and wholesale/retail margins) the market will be less than € 100 million.

Overall, the water heater market in the EU is 17 mln. units/ year at a total value of € 4-5 billion (manufacturing selling prices, 2005). This includes dedicated water heaters and ca. 15% of combi-boiler prices. The pressurized electric storage water heaters <30 litre thus represent around 2-3% of this total in terms of value.

4.3 Energy impact

In 2005 water heaters, including the water heating function of gas- and oil-fired central heating boilers, consumed 3790 PJ primary energy (ca.86 mtoe) and emitted 6% of all fuel-related CO2 in the EU-25, i.e. 220 Mt CO2 equivalent on an EU-25 total of 3904 Mt CO2 in 2005.

As the following charts show, this makes water heaters the 3rd largest energy consumer in the household, after space heating boilers and –not included in the scope of the Ecodesign Directive—cars.

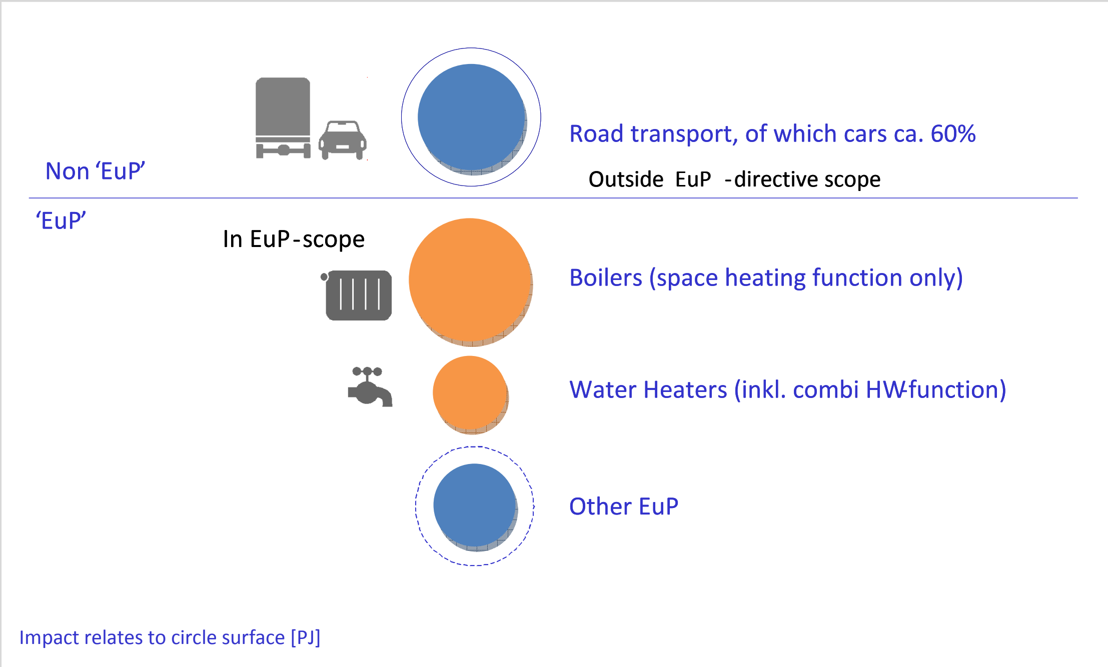


Fig. 3. Relative share of water heaters in total EU water heater

In terms of primary energy and carbon emissions water heaters are more important than such publicity-sensitive items such as lighting or refrigerators.

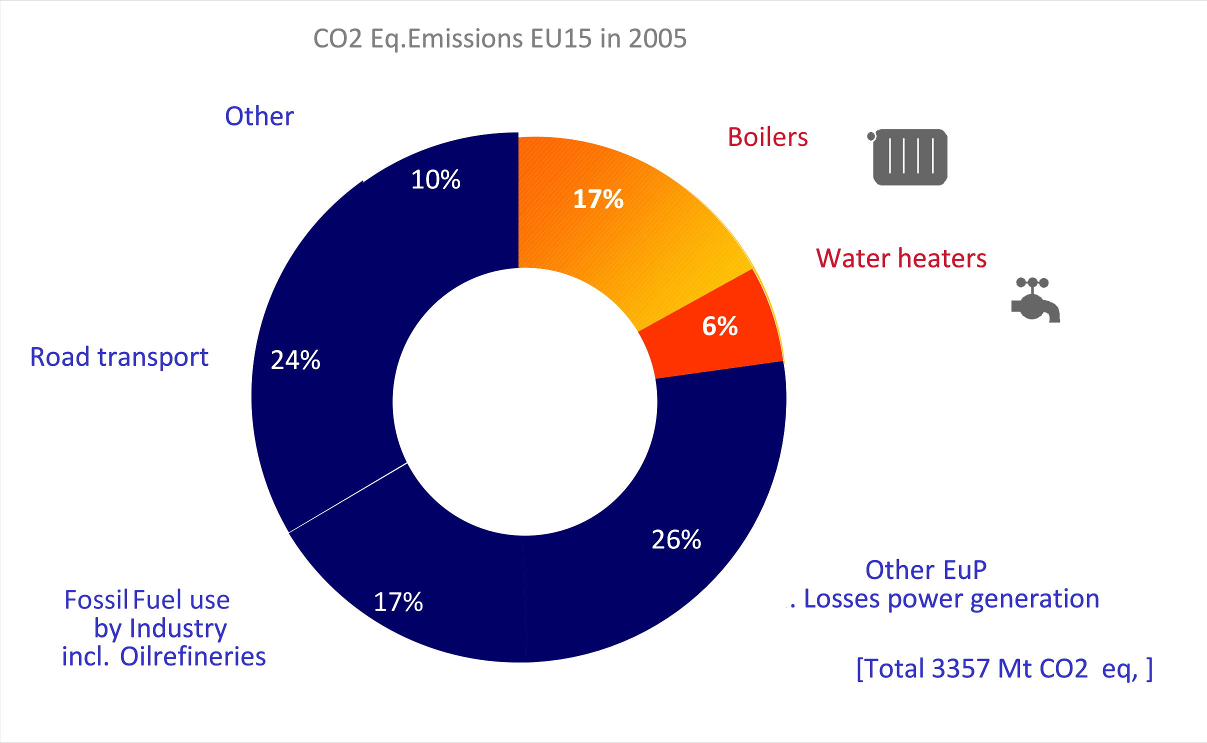


Fig. 4. Relative share of water heaters in total EU-15 Fuel related greenhouse gas emissions

The preparatory study concludes that

"the improvement potential is considerable. At Least Life Cycle Cost (LLCC) targets on average an energy saving of close to 35% per unit can be achieved with respect of the Base Case. With Best Available Technology (BAT) the energy efficiency improvement can be over 60%. Carbon emission reductions per unit are in the same order of magnitude. For NOx the saving is 29-39% in the "Realistic" scenario 2020-2025. An extra 15-20% saving can be achieved with an additional emission limit value of 20 ppm for fossil-fuel fired water heaters without renewables. This would bring the EU in line with best international legislative practice.

The projected carbon saving at mandatory LLCC-target minimum levels is 71-105 Mt CO2 equivalent in 2020-2025, which constitutes a 2,2 % saving on energy-related carbon emissions in the EU. The energy saving in 2020-2025 is 1270-1890 PJ (29 – 43 mtoe).

The LLCC-targets are not technology-specific (no bans), but mostly based on measured primary energy efficiency according to tapping patterns in harmonised standards. The values found are corrected for distribution losses as well as recovery of envelope- and standby losses for space heating.

Water heater efficiency is very much dependent on the load. For that reason specific LLCC-targets are set for each size class/ tapping pattern. For small single-point appliances primary energy efficiency is set at 24%, whilst for largest collective and non-residential water heating installations levels of over 90% are required, prompting the use of renewables or –if it is included in the scope- mini-CHP (Combined Heat and Power)."

The preparatory study does not make an assessment of the relative contribution of the market segment that is of interest to the Quooker Combi, i.e. the pressurized electric storage water heaters with a volume <30 litres. A ballpark estimate can be made if we assume that for households that have a secondary water heater (32% of total) a maximum of 1/3 of the hot water is produced by this secondary water heater. This would mean that around 10-11% of the total water heaters energy consumption of the EU is due to secondary water heaters. Of this, the pressurized electric storage water heaters with a volume <30 litres represent around 25%, so around 2,5-3% of the total water heater energy consumption in the EU.

4.4 Rating method

The rating method proposed according to the latest Working Document of the Europeam Commission (1.7.2008) is based on

- Primary energy efficiency, i.e. it takes into account a power generation and – distribution efficiency of 40% (see fig. 5);
- A holistic approach, i.e. it also takes into account the energy effects of water heater distribution losses;
- Test procedures based on 24h load profiles.

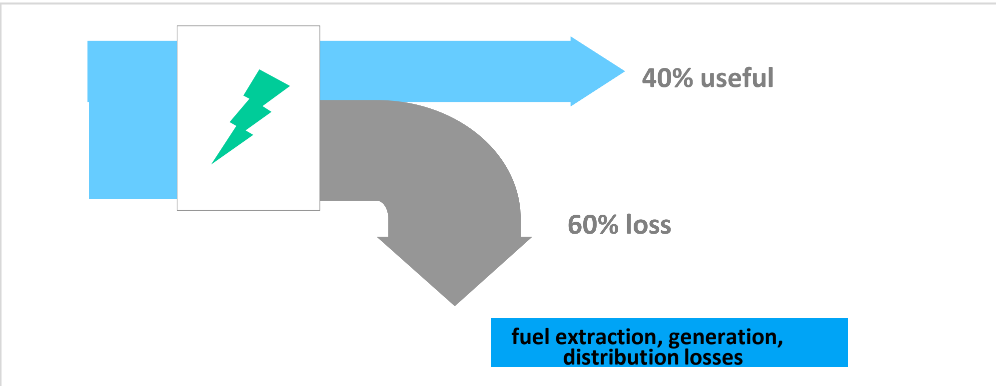


Fig. 5. Power generation and distribution losses as assumed in WD June 2008

The tapping profiles or ' load profiles' are part of the Ecodesign methodology and represent typical usage situations. In short:

- XXS (extra small): for hand wash applications and/or kitchen with dishwasher;
- XS (very small): for electric showers;
- S (small): kitchen only or smallest possible multi-point (1 small shower included);
- M (medium): average profile, includes kitchen use and normal showers; family of 2-3 persons;
- L (large): as M but also including a small bath. Typically family of 4 pp;
- XL (extra large): as M but also including a number of large baths. Typically family >4 pp;
- XXL (XX large): including very large baths (Jacuzzi, etc.). Typically very large family or small multi-family homes.
- 3XL (XXX large): Medium multi-family, small sports facilities. 8 x ' M' profiles
- 4XL (XXXX large): Large multi-family, larger sports facilities. 16 x ' M' profiles

All in all, the tapping profiles cover most hot water applications, except swimming pool heaters. The smaller load profiles are inspired by prEN 50440 and the larger ones by EN 13203-2, with some overlap in the middle (S, M, L profiles).

The tapping profiles specify a 24h load profile (actually 15 h with first tapping at 7:00h and last tapping at 21:30h) with a number of draw-offs and draw-off start times. Per draw-off the useful energy content in kWh, minimum useful temperature (to start counting 'useful energy content') in °C, a minimum flow rate in kg/s and a typical tapping temperature are given. For some draw-offs there is a minimum peak temperature that needs to be reached during tapping. There is no explicit 'comfort' criterion, like in EN 13203-1, but any energy consumption before reaching the minimum useful temperature is actually lost, which implicitly puts a penalty on long waiting times. And of course, also the minimum flow rate is an indication of comfort.

In order to improve the prognosis as regards the actual energy consumption that a consumer can expect, and also to guarantee a smooth incorporation into EPB-type of legislation, the distribution losses are an integral part of the efficiency calculation, following from a look-up table. Also there are some extra provisions for ' smart control', i.e. a bonus for e.g. storage types that lower the storage temperature during off-peak hours.

Furthermore, but this is probably less relevant for the Quooker Combi, there are certain provisions for night-tariff appliances and there are certain ' rules': As the load profile becomes smaller also the limit-values and lower labeling classes become lower and therefore it becomes easier to get a high ranking. To avoid that manufacturers declare certain products with a tapping profile that is too low for their size there are some extra provisions.

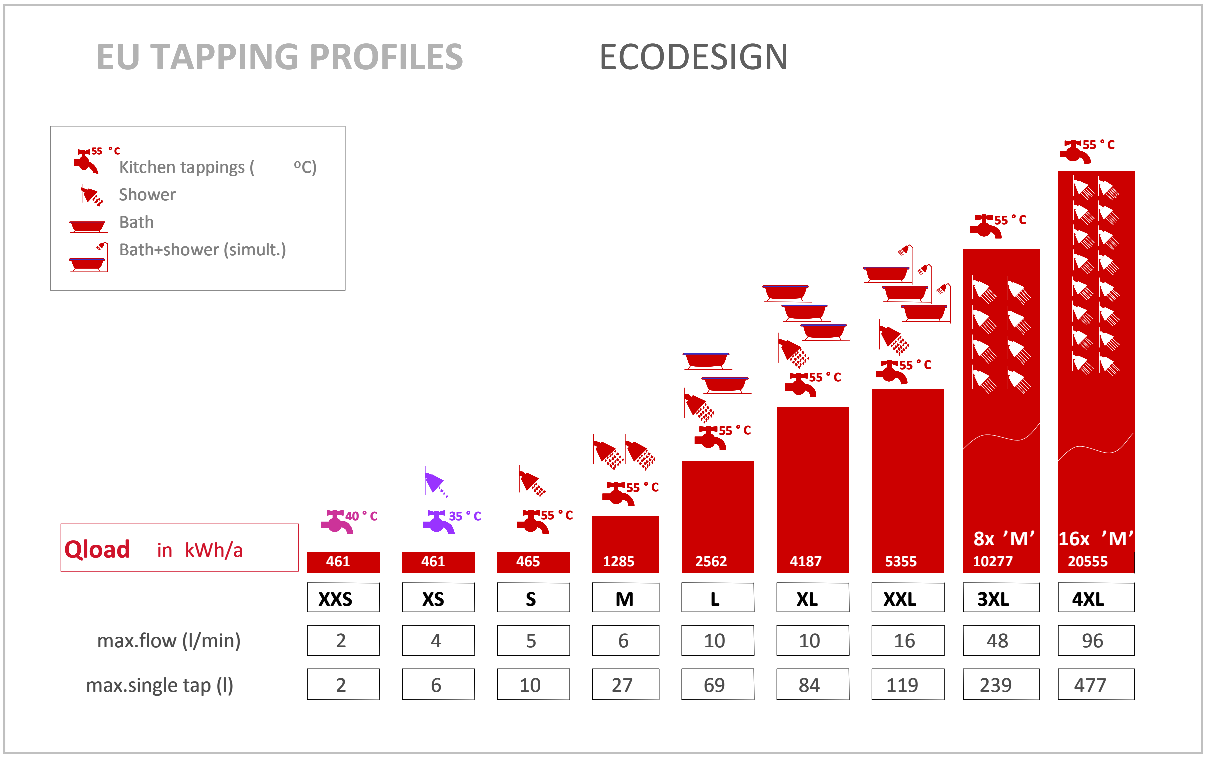


Fig. 6. EU Tapping Profiles. Proposal European Commission Working Document June 2008 (presented at Consultation Forum, Brussels, July 2008)

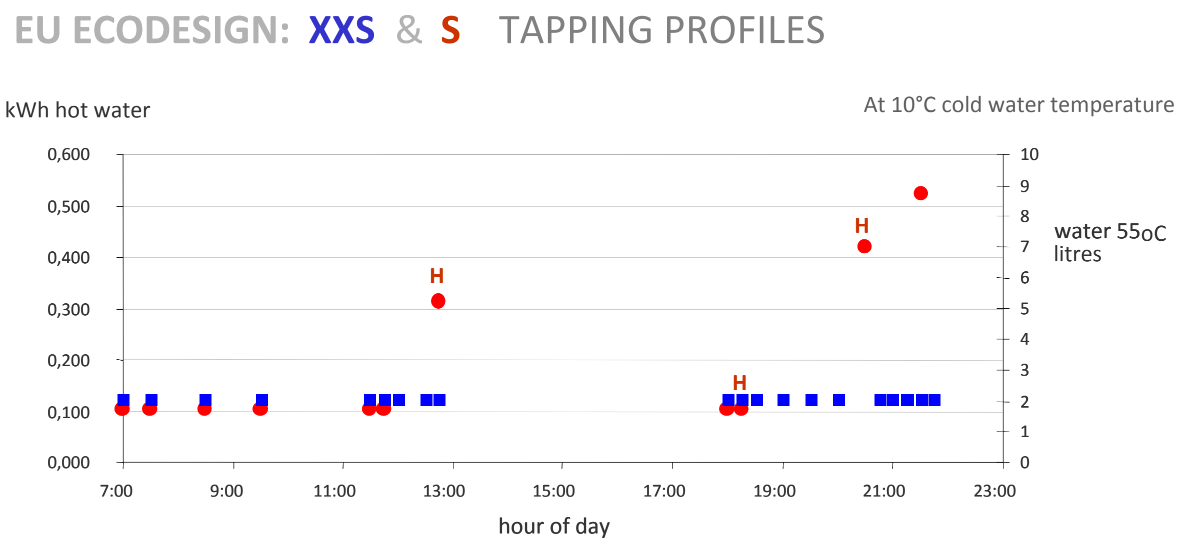
The diagram below provides a more detailed overview of the tapping profiles relevant for the Quooker Combi, i.e. the XXS and the S class.

In summary, the following characteristics and requirements are currently proposed:

- Primary energy rating against tapping profiles XXS to 4XL (electric and gas are compared on the same primary efficiency scale)
- Minimum efficiency level *(current proposal)*
    - First tier (ca. 2011): XXS 22% , S 26%
    - Second tier (ca. 2014): XXS and S: 32%

Tapping profiles relevant for Quooker Combi are: XXS & S

Chapter 6 provides some estimates as to how the Quooker Combi will perform when subjected to the tapping profiles above.



XXS - PROFILE : 20 drawoffs, min. flow rate 2 ltr./min, min. useful temperature 25°C.

S - PROFILE:

7 small drawoffs-	as XXS, but min. flow rate 3 ltr ./min
1 small & hot	as ‘small’, but min. useful temperature 40°C
2 medium & hot	4 ltr ./min, min. useful temp. 10°C, peak temp. 55°C
1 larger	5 ltr ./min, min. useful temp. 45°C

Fig. 7. EU Tapping Profiles XXS and S. Detailed examples of draw-off times, volumes, flow rates and temperatures. Source: Proposal European Commission Working Document June 2008 (presented at Consultation Forum)

5. Energy Labeling

5.1 Introduction

Already at the outset in 1992 'water heaters' were explicitly a priority subject in the EU Directive on Energy Labeling 92/75/EC. Nonetheless, in the past 17 years the water heater industry and the standardization committees have not succeeded in formulating harmonized performance and test standards that would allow the Commission to implement specific measures that are effective and fair.

With the help of the new rating methodology under the Ecodesign directive this is set to change… Also, with the final decision on the rating classes, including A+, A++, A+++ on top of the A-G scale (approved Nov. 2009), the Commission also will have the possibility to realize enough differentiation between the various water heater types and effectively bring about market transformation. This new classification will be part of the recast (new) Energy Labeling directive that has been approved by the Parliament and Council Nov. 2009.

As a result, the WD June 2008 proposes one labeling scale with 10 classes, where the water heaters will be evaluated on the basis of their primary energy efficiency . And this primary energy efficiency will –indirectly—constitute a fairly good indication of the fuel-related CO2 emissions (greenhouse gas emissions, relevant for climate change). This will allow 'green' consumers and governments with their incentive programs to make a comparison across all energy platforms (electric, fossil fuel, solar, ambient heat) and technology types (storage, instantaneous types).

Furthermore, but this will require multiplication with the local energy tariffs and the primary energy factor, the labeling will be the basis for economic evaluations, i.e. the energy bill to be expected. In this context it is relevant that the primary energy factor employed is the same for the whole of Europe and amounts to 40% for power generation and distribution, whereas at the same time there is no correction for fossil fuel correction. In other words, if an energy label of a gas-fired water heater mentions ' kWh' this is immediately the annual gas consumption in kWh that consumers may expect at reference usage conditions. For electric water heaters, the ' kWh' figure on a label needs to be multiplied by a factor 0,4 to find the estimated annual electricity consumption at reference conditions.

The energy consumption of conventional (e.g. gas, electric) water heaters will be climate-independent, but for some renewable water heaters such as solar-assisted water heaters or air-source heat pump water heaters the climate will be taken into account, i.e. there will be a differentiated rating for an ' Average' (Strasbourg, FR) , ' Warmer' (Athens, GR) and a ' Colder' (Helsinki, FIN) climate. From the 3 ratings an individual consumer can make a fair estimate of the actual consumption to be expected in his/her climate zone.

Although no final decision has been made on the lay-out of the label, the current proposals indicate that the primary rating, i.e. the most visible A-G etc. rating, will be on the highest declared tapping profile. On the same label there may be ‘ secondary’ ratings for lower tapping profiles that the manufacturer declares.

5.2 Main requirements

EU Energy Labelling Directive (recast)

approved Nov. 2009, recast of 92/75/EC:

–Mandatory energy label for hot water appliances

–Efficiency rating A to G with extra classes A+, A++, A+++ on top.

Fig. 8 shows an example of a possible label design

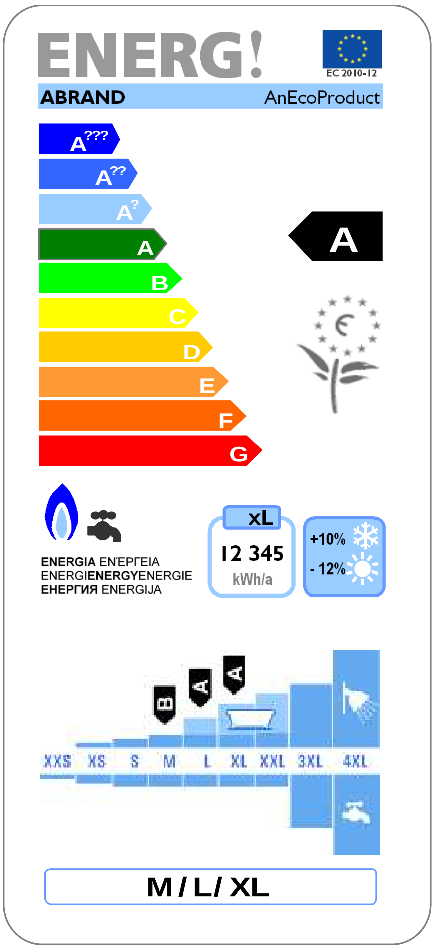


Fig.8. Illustration: One of the preliminary designs for a water heater energy label Working Document June 2008 (presented at Consultation Forum)

5.3 Estimate of classification

In its presentation at the stakeholder's workshop Sept. 2007, VHK presented an estimate of the relative performance of current water heaters on the market. This estimate is intended as an illustration, as test data according to the different size classes was/is not available

Furthermore, during the course of the consultations of 2008 the European Commission has changed (made less severe) some of the class limits with respect of what was proposed in the preparatory study. Especially for the smaller size classes (XXS to M) the class limits were set at a lower level, meaning that electric water heaters –according to the latest proposals— can now achieve higher classifications.

Class	XXS	XS	S	M	L	XL	XXL	3XL	4XL
A+++				AHP 3,5	AHP 3,5	AHP 3,8	GSHP	GSHP	GSHP
A++				AHP 3	AHP 3	AHP 3,3	AHP 3,6		GSHP
A+	EIWH E 8	EIWH E 8			COMB Scd	GAHP 1,4	GAHP 1,4	AHP 3,6	GSHP
A	EIWH H 8	EIWH H 8		AHP 2,5	GIWH 40 I	COMBI Scd		GAHP 1,4	AHP 3,6
				COMB Scd		SOLGAS 6	SOLGAS 10	SOLGAS 25	SOLGAS 50
				GIWH 21 E					
B	BC	BC	GIWH 18E	SOLES 3	SOLGAS 3		SOLGAS 6		
				COMB LT	COMB LT				
C			GIWH 18 I	EIWH 23E	GSWH sm	GSWH sm	COMB cd		
	ESWH 10	ESWH 20	BC			SOLEI 6	CYL 250		
			EIWH 18E			CYL 150	SOLEI 10		
			ESWH 30sc						
D			EIWH 18H	BC	SOLEI 3			SOLEI 25	
E			ESWH 30	ESWH 80	BC		SOLEI 6		
					GSWH P	GSWH P	GSWH P	GSWH P	GSWH P
F			GIWH 18 P	GSWH 80 P	ESWH 80	BC	BC	BC	BC
						ESWH 150	ESWH 250		
G				GIWH 21 P					

Legend: Blue cells= electric; Green cells=gas-fired; White cells=BaseCase (mixed); **BC**=Base Case; **GIWH**=Gas Instantaneous + value (kW) + letter (P=pilot flame; I=water-tubine ignition; E=electronic); **GSWH**=Gas Storage + value (ltr. Tank)+ letter (P=pilot flame; sm=electronic, smart control); **ESWH**=electric storage + value(ltr. Tank)+ letter (sc=smart control; no letter=standard); **EIWH**=electric instantaneous + value (kW) + letter (H=hydraulic control; E= electronic); **SOLES**= solar-assisted electric storage + value (collector area); **SOLEI**= solar assisted electric instan-Taneous + value (collector area); **SOLGAS**=solar assisted gas-fired + value (collector area); **CYL**= LT and indirect cylinder + value (ltr. Tank); **COMB LT**= instantaneous LT gas combi-; **COMB cd**= condensing gas with small smart control storage; **AHP**= electric (ventilation) air heat pump + value (COP); **GAHP**=Gas-fired absorption heat pump + value (COP); **GSHP**= electric ground source heat pump (water/water).

Fig. 9. Estimate of label class score in the preparatory study Task 7, based on the class limits in that study (VHK, Sept. 2007)

The above classification shall be used as a comparison basis for the Quooker Combi, but with the adjustment of 1 or 2 classes for the classes XXS and S that follow from the latest class limits proposed by the Commission. In other words, the ESWHs (Electric Storage Water Heaters) could now become class B or even A. The electronic EIWHs (Electric Instantaneous Water Heaters) could become A++ in the XXS and XS class, and the hydraulic ones could become A in the XXS and XS class. In class XS, the electronic EIWHs could at best become B, and the hydraulic versions could at best become C. GIWHs (Gas-fired Instantaneous Water Heaters) with pilot-flame will probably stay in the F to G class.

6. Quooker Combi analysis

6.1 Introduction

The Quooker Combi has a dual functionality as a boiling water tap and as a normal 'kitchen only' water heater. It is produced by Peteri B.V. in Ridderkerk, serving the Dutch market but also expanding into the Northern part of Europe (UK, Scandinavia, Germany, France etc.). The characteristics of the main products of the company are given in the table below.

Quooker VAQ & COMBI

Technical specifications

Table 8. Quooker products, technical specifications

	Quooker VAQ is not actually needed here (we only consider the Combi)		**Quooker COMBI** (and COMBI+)	
Peteri B.V. Indications				
Reservoir	PRO3-VAQ	PRO7-VAQ	COMBI 2.2	COMBI 3.0
Voltage	230 V	230 V	230 V	230 V
Power	1600 W	3000 W	2200 W	3000 W
Volume	3 ltr.	7 ltr.	7 ltr.	7 ltr.
Heat-up time	10 minutes	15 minutes	20 minutes	15 minutes
Stand-by power	10 W	10 W	10 W	10 W
Reservoir height	40 cm	47 cm	47 cm	47 cm
Reservoir diameter	15 cm	20 cm	20 cm	20 cm
Hole for tap	32 mm	32 mm	32 mm	32 mm
Max. Pressure	8 bar	8 bar	8 bar	8 bar
Safety	maximum temperature			
	pressure valve 8 bar			
Water valve	ceramic			
HiTAC® water filter	High Temperature Activated Carbon			
Temperature control	na	na	thermostatic	
Temperature control range	na	na	50-65°C	50-65°C
Volume equivalent at 40°C	na	na	27 ltr. *	27 ltr. *
Volume equivalent at 60°C	na	na	15 ltr. *	15 ltr. *
Bracket available	yes	no	no	no
Storage temperature @1,5 bar	108 °C			
+Flow temperature @ 1bar	100 °C (boiling)			
Serving temperature	93 °C			

** At t_{cold} = 15 °C*

The analysis will not take into account the extra functionality and energy consequences of the boiling water function (see Part 1), but will strictly look at the way it would be evaluated according to the latest proposals of the European Commission under the Ecodesign directive for domestic water heaters.

In other words, the Quooker Combi will be evaluated as an electric storage water heater with a 7 ltr. storage volume for water of 108 °C. This is equivalent to a 'normal' storage water heater holding holding around 15 litre at 55-60 °C.

The calculation will be made for the smallest load profiles, i.e. XXS and S (XS is intended for electric showers only). With the current volume of 7 litres at 108 °C this is also the maximum achievable with the Quooker Combi, because at the most –with a cold water temperature of 10 °C—it can deliver about 800 Wh of hot water equivalent. This is more than enough for ' S' , with a largest tapping of 512 Wh, but it is not enough for the 1400 Wh that the largest tapping required in the 'M' profile.

6.2 Assumptions and expected results

The main difference between a 'normal' electric storage heater and the Quooker Combi is, that the best 'normal' storage water heater of 15-20 litres would have standby loss of at least 30-35 W. Due to the unique high-vacuum technology employed by Peteri B.V. the Quooker Combi only has an energy loss of 10-11 W (assumed 10,5 W→ 90 kWh/year at 8600 non-use hours per year).

Partial vacuum alternatives do not exist for 15-20 litres, but the fact that the best known partial vacuum solution of 10 litres[31] has a standby energy loss of 22 W indicates that also a partial vacuum solution for a vessel of 30 liters will consume almost 3 times more in standby than a Quooker.

Like all ESWH the Quooker Combi is using electricity and electric resistance heating. The local generation efficiency is high (assumed 98%), but given the power generation and – distribution efficiency of 40% this appears not to be a very energy efficient solution when compared to gas-fired water heaters.

However,

- 36% of Europeans have little choice as they are not connected to the gas grid or have the storage facilities for either oil or LPG

  of those, over ¾ (29% of total) have no choice but to install an electric storage WH, because their fuse box will not support an electric instantaneous WH (>3 kW).

[31] E.g. Inventum Modesto

- Choosing a secondary heater in a kitchen may be an energetically preferable alternative to using a distant primary WH for small draw-offs with long distribution pipes. Even if it is an electric one… especially if there are

  –chimney problems for gas-/oil fired solutions

  –anti-legionella laws that prohibit use of DH only (exception Scandinavia)

  –safety (e.g. ventilation) considerations

  The main alternative for small electric 'kitchen only' water heaters is gas-fired instantaneous types, but due to especially the pilot flame their annual efficiency is very low (<27%) or –with electronic ignition—they are very expensive. And they need a chimney...

- And of course looking only at the energy source is inappropriate, the total primary energy balance is to be taken into account

6.3 Calculation

The table below shows the two load profiles XXS and S

Table 9. Tapping profiles Ecodesign rating (draft WD 2008)

	XXS				**S**			
	Qtap	f	Tm	Tp	**Qtap**	f	Tm	Tp
h	**kWh**	l/ min	°C	°C	**kWh**	l/min	°C	°C
07.00	**0,105**	2	25		**0,105**	**3**	**25**	
07.05								
07.15								
07.26								
07.30	**0,105**	2	25		**0,105**	**3**	**25**	
07.45								
08.01								
08.05								
08.15								
08.25								
08.30	**0,105**	2	25		**0,105**	3	25	
08.45								
09.00								
09.30	**0,105**	2	25		**0,105**	3	25	
10.00								
10.30								
11.00								
11.30	**0,105**	2	25		**0,105**	3	25	
11.45	**0,105**	2	25		**0,105**	3	25	
12.00	**0,105**	2	25					
12.30	**0,105**	2	25					
12.45	**0,105**	2	25		**0,315**	4	10	55
14.30								
15.00								
15.30								
16.00								
16.30								
17.00								
18.00	**0,105**	2	25		**0,105**	3	25	
18.15	**0,105**	2	25		**0,105**	3	40	
18.30	**0,105**	2	25					
19.00	**0,105**	2	25					
19.30	**0,105**	2	25					
20.00	**0,105**	2	25					
20.30					**0,420**	4	10	55
20.45	**0,105**	2	25					
20.46								
21.00	**0,105**	2	25					
21.15	**0,105**	2	25					
21.30					**0,525**	5	45	
21.30	**0,105**	2	25					
21.45	**0,105**	2	25					
Qref	**2,100**				**2,100**			

Qtap=useful energy content of draw off (kWh, calculated with cold water temperature 10°C)

f=flow rate (l/min)

Tm=minimum temperature to be reached during draw-off from which counting of useful temperature starts (°C)

Tp=minimum peak temperature to be reached during draw-off (°C)

Qref=accumulation of Qtap per load profile (useful energy content/day)

For both profiles the total theoretical minimum energy requirement per day is 2,1 kWh.

The efficiency calculation according to Annex IV (16.9.2008) of the Commission Working Document is as follows

The efficiency of a water heater is the ratio between the delivered energy in the hot water for the tapping pattern for its size (XXS - 4XL) and the consumed energy converted to primary energy. The consumed energy is the result of the test of the water heater with adjustments for:

- Waste heat from the heater that contributes to space heating;
- Smart controls that can increase water heater efficiency (bonus is 10%);
- Distribution losses that is different for different types of water heaters and load profiles.

The efficiency of the water heater is then

$$etawh = \frac{Qref}{Qnet + Qwdistr - Qre\mathrm{cov}\,er}$$

where:

Qref is the delivered energy for the 24 h tapping pattern for the size of the water heater (XXS - 4XL) from Table 9, in kWh.

Qnet is primary energy consumption, with conversion factor 2,5 for power generation, taken from test with correction for smart controls

Qnet* = (*Qfuel+2,5****Qelec***)*(1−0,1***dhwsmart***)

Qdistr is the annual distribution loss that is typical of this water heater depending on its size and type. It is given in Table 10 (from Annex IV of the Working Document). Values take into account only distribution losses inside dwellings. For collective/centralized systems as well as circulation systems extra distribution losses and –in case of an extra store—storage losses are to be taken into account in application-oriented measures.

Qrecover is waste heat from the water heater that is useful as space heating, dereived from heat loss ***Qrwaste*** and recovery rate ***qrecov***:

Qrecover = qrecov* Qrwaste

The declared efficiency of electric water heaters must be limited to 40% (***etawh*** <= 0.40 for ***Qfuel*** = 0), which is a necessary condition to apply because the formula could give a higher eficiency for electric (instantaneous) water heaters with smart controls.

The water heater efficiency can thus also be described as:

$$etawh = \frac{Qref}{(2{,}5 * Qelec) * (1 - 0{,}1 dhwsmart) + 2{,}5 * Qdistr - qre\operatorname{cov} * Qrwaste}$$

where (when applied to the Quooker Combi):

Qelec is the consumption of electricity during test with relevant 24 h tapping pattern in kWh; *Quooker Combi: 10,5W x 24= 252 Wh standby + 2100 Wh water tapped =2352 Wh/day * 1/0,98 (generation efficiency)= 2400 Wh/day*

dhwsmart is indicating the presence of smart controls from par. 4.4 and 4.5 (yes = 1, no = 0); *Quooker Combi: 0*

Qdistr is the daily distribution loss ; *Quooker Combi (from table 10): 70 Wh/day x 2,5 = 175 Wh*

qrecov is the percentage of waste heat recovered for space heating. It depends on boiler position, noise level, outer volume, and air intake. It is given in Table 11 (Table 9 of the WD). It varies from 0 (for outdoor installations) to 32% (for small electric water heaters). *Quooker Combi: 32%*

Qrwaste is the recoverable waste heat in the room of the water heater. For conventional Products it is the total heat loss minus the heat in the flue gas, ***Qfluegas*.** It can be expressed as:

Qrwaste [conventional] ***= Qelec - Qref***

where ***Qfluegas*** **= 0** for electric water heaters

Quooker Combi: Qrwaste= Qelec – Qref = 2400 – 2100 = 300 Wh/day

The efficiency of the Quooker Combi can be calculated as

$$etawh[Quoo\text{ker}] = \frac{2100}{(2{,}5 * 2400) * (1) + 2{,}5 * 70 - 0{,}32 * 300} = 35\%$$

Please note that according to the latest Commission proposal the tolerance on the declaration is ±7%, therefore a declaration of 35% efficiency means that for monitoring the efficiency should be between 32,5% and 37,5%.

Table 10. Determination of distribution losses *Qdistr* in kWh per day

parameter = Qdistr [kWh/a]										
air_intake	**volumeb**	**Load profile**								
[−]	**[m³]**	**XXS**	**XS**	**S**	**M**	**L**	**XL**	**XXL**	**3XL**	**4XL**
none (electric)	<=0,5	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,07
	>0,5	0,36	0,36	0,55	1,09	1,09	1,09	1,09	2,19	4,37
room sealed	<=0,1	0,07	0,07	0,36	0,55	1,09	1,09	1,09	2,19	4,37
	>0,1, <0,15	0,36	0,36	0,55	0,73	1,09	1,09	1,09	2,19	4,37
	>=0,15	0,36	0,36	0,55	1,09	1,09	1,09	1,09	2,19	4,37
open	any value	0,36	0,55	1,09	1,09	1,09	1,09	1,09	2,19	4,37

Table 11. Determination of heat recovery parameters

boilpos	**air_intake**	**volumeb**	**noiseh (noisew)**	**qrecovb_winter Oct.-Apr.**	**qrecovb_summer June-Aug.**	**(qrecov) All year**
[-]	[-]	[m³]	[dB(A)]	[%]	[%]	[%]
indoor (= 1)	3 (electric)	≤ 0.5	≤ 35	85%	-71%	32%
			>35, ≤ 44	55%	-46%	21%
			> 44	25%	-21%	9%
		> 0.5	any value	25%	-21%	9%
	1 or 2 (fossil fuel)	≤ 0.15	≤ 44	85%	-71%	32%
			> 44	25%	-21%	9%
		≤ 0.5, > 0.15	≤ 44	55%	-46%	21%
			> 44	25%	-21%	9%
		> 0.5	any value	25%	-21%	9%
outdoor (= 0)	any value	any value	any value	0%	0%	0%

Comparing this outcome to the rating scale (see below, from WD 1.7.2008), the Quooker Combi would thus qualify as an ‘A+’ for the XXS class. In the S-class it would qualify for ‘A’.

Table 12. Water Heater Energy Labeling lower class limits (WD, 1.7.2008)

From 1 Jan 2009	XXS	XS	S	M	L	XL	XXL	3XL	4XL
A+++	53	61	72	80	98	112	124	140	150
A++	44	53	55	66	82	92	104	110	120
A+	35	38	38	54	68	76	84	96	96
A	32	35	35	45	56	62	72	80	86
B	29	32	32	39	46	50	60	64	64
C	26	29	29	36	37	40	40	40	40
D	23	26	26	33	34	34	36	36	36
E	20	23	23	30	30	30	32	32	32
F	17	20	20	27	27	27	28	28	28
G	<17	<20	<20	<27	<27	<27	<28	<28	<28

Legend: blue is estimated Quooker Combi score, orange is estimated average product score

6.4 Comparison

The efficiency for a ‘ normal’ (20-30 liter) small storage water heater with 35 W standby loss (840 Wh/day) and the same generator efficiency of 98% can be easily calculated in the same way and would result in

$$etawh = \frac{2100}{(2{,}5*3000)*(1)+2{,}5*70-0{,}32*900} = 28{,}4\%$$

For an XXS size this is a ‘C’ just below the limit between B and C class. If the manufacturer can control his production tolerances within a tight bandwidth (tighter than ± 7% of the declared value) it will probably be declared a ‘B’.

For an S size this is a ‘D’ just below the limit between C and D, probably to be declared as a ‘C’.

Figure 10 gives an indication on the positioning of the Quooker Combi with respect of other types.

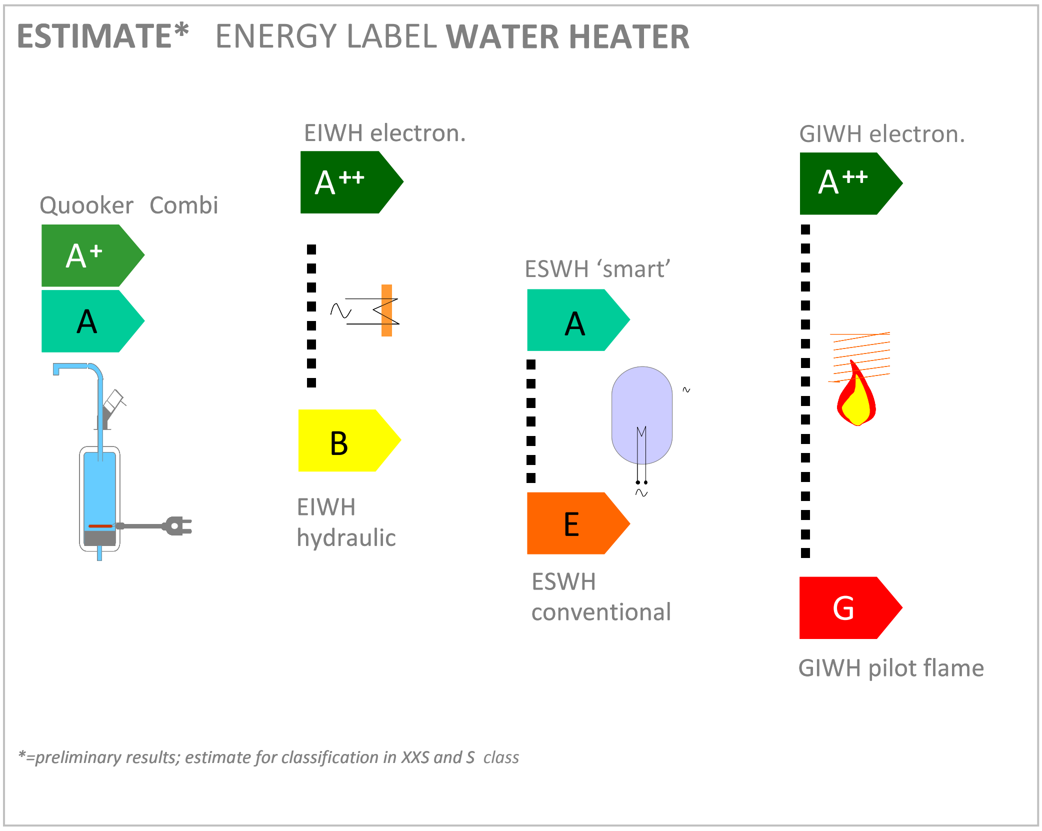


Fig. 10. Positioning of the Quooker Combi energy efficiency versus competitors, according to the latest EU energy label proposals (European Commission WD 1.7.2008).

EIWH=Electric Instantaneous Water Heater (electronic or hydraulic control)
ESWH= Electric Storage Water Heater (conventional or with 'smart control')
GIWH= Gas-fired Instantaneous Water Heater (electronic ignition or pilot flame)