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Domestic and commercial hobs and grills included when incorporated in cookers

Task 4: Technical analysis of existing products

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ERA TECHNOLOGY

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4. TASK 4 – TECHNICAL ANALYSIS OF EXISTING PRODUCTS

This document is the task 4 report of the DG ENER lot 23 ecodesign preparatory study on domestic and commercial hobs and grills. Task 4 comprises a general technical analysis of the existing products on the EU-market. For each category of product defined in task 1, an item representing the average current product on the European market will be analysed (identified in task 2). This analysis will serve as input for defining base cases (in task 5).

4.1. GENERAL TECHNICAL DESCRIPTION

4.1.1. Hobs

A hob refers to a set of electric heating elements or gas burners used for heating food fitted into a work surface (built-in), on top of a range cooker with an oven (integral) or as a portable appliance. These use four major types of heating: gas burners and three basic electric types; coil element or solid plate (resistance heating), radiant (e.g. halogen) and induction. Apart from induction, the hob is the primary heat source which is used to heat the cooking vessel which then becomes the secondary heating source, transferring heat to the food within it. Induction heating makes the cooking vessel the primary heating source by generating electrical eddy currents within the ferromagnetic material used for the cooking vessel.[1]

The term ceramic hob is used to describe a ceramic glass cover positioned over several different types of heating elements. The heat is transferred to the cooking vessel through the glass cover mainly by conduction from the glass ceramic to the pot base. The heat source on a ceramic hob can be one of several different types: halogen lamp, ribbon element, standard radiant element or induction. An international patent[2] from 1990 described the use of gas radiating burner units with a number of concentric chambers beneath a ceramic glass cover. These are uncommon in the EU and have poor energy efficiency.

Modern radiant and induction hobs control heat more rapidly than solid plate. A range of different technologies and hob types are available in the EU. Electric induction hobs are the most energy efficient type of electric hob but are more expensive to buy than

[1] Japanese manufacturers have recently launched induction hobs that allow copper and aluminium cooking vessels to be used. These hobs use a higher frequency field (50kHz instead of the conventional 20kHz used for ferromagnetic material induction) which is able to induce a current in any metal; these currents cannot however be induced in ceramic and glass cookware. These are energy-inefficient and are not available in the EU.

[2] EP0467901 WO 90/12255, issued 18 October 1990 for ED Herbert.

other types. Gas hobs can be more fossil carbon efficient[3] in use (this depends on the fuel used to generate electricity and if bio-gas is used) and cheaper to run than electric hobs, and it may be possible to improve energy efficiency as new gas burner designs are developed and this is discussed in task 6.

The mode of operation of hobs in commercial kitchens is different than domestic cooking. Chefs tend to leave hobs on full power and cook food for relatively short periods. If simmering is needed, they use covered gas burners and move the pan to the edge of the heated area. In domestic cooking, the hob is turned down to its minimum power for simmering. There is a tendency in commercial kitchens to leave gas hobs (and gas and electric grills) on all of the time even when not in use. Most users of hobs are relatively low paid and do not pay energy bills and so use hobs in a way that delivers food as quickly as possible. In small restaurants where the owner uses the hob and pays the energy bill, he will turn these off when not in use. In institutions such as hospitals and schools, hobs are turned on only when needed as cooking times are much more predictable.

Test standards for measuring the energy efficiency of some types of gas and electric hobs during heat up only are available and some of these standards also specify minimum energy efficiency expressed as a percentage (see task 1). Standards with measurement methods for energy consumption to include simmering as well as heat up are being developed. The current test standards measure energy efficiency when rapidly heating a test load whereas a lot of domestic cooking time is spent simmering which is not assessed by these standards. There are many comments on the Internet about the inability of domestic burners and hotplates to simmer. Solid plates can be turned down sufficiently but their response time is too slow. Gas burners are powerful enough for rapid heating. When turned down to simmer, the flames are smaller but should be dimensioned to assure stability. A test protocol is integrated in the EN30-1 standard in the part 7.3.2.2 “Resistance to draught”. Therefore, small and medium domestic burners allow simmering, given a minimum size of the pan. In addition, with modern gas hobs, the turn-down ration of 8:1 better allows simmering. The energy from radiant and particularly induction hobs are more easily controlled to allow simmering.

The inability to simmer food results in more energy being used than necessary. The main approach used with domestic hobs currently on the EU market is to enable simmering to be carried out by providing a range of hotplate / burner sizes. The smallest often being referred to as suitable for simmering. The range of hotplate / burner sizes is also important to accommodate different pan sizes as optimum energy efficiency is achieved with pans that match the diameter of the hotplate / burner. Even so, many gas burners are unable to simmer small pans of food. Several manufacturers sell hobs with dual and triple crown burners, mainly to provide higher heat output but

[3] See Annex I for an explanatory note on the environmental impact of energy source: electric or gas

these can be used to achieve a much wider range of heat output if each ring is independently controllable. One very unusual example can provide heat energy from 0.45 MJ/h to 5.9 MJ/h which is a much wider range of heat output than most standard burners and is possible only by using separately controllable multiple ring burners.

Commercial hobs rarely have small gas burners for the reasons explained above but electric induction hotplates are increasingly used which are easy to control. However commercial solid plate electric hobs are still sold in EU which are slow to respond to being turned down and so are often used mainly on full power in commercial kitchens, whether this is needed or not.

According to CECED, there are more gas hob model types than any of the three types of electric hob. There are more radiant hob models than induction with solid plate being the fewest and although this gives an indication of their popularity it will not exactly represent the numbers sold in the EU. According to the UK trade association CESA, the proportions of each type of commercial hob sold on the UK market is 75% gas and 25% electric although the proportion of electric types is increasing due to the problems (and costs) associated with gas supply connection and ventilation of combustion gases. Gas is also more common than electric in commercial kitchens in France and those other countries where piped gas is available.

4.1.2. GRILLS

There are many different designs of grill on the EU market. These can be split into two main types:

- Radiant – where the food is not in contact with the heat source.
- Contact grills – where the food is placed onto the heated grill or griddle surface.

Grill designs include, but are not limited to:

- Solid plate grills – either heated electrically or with gas and widely used for commercial catering. This is in many respects the same as using a frying pan on a hob but where the grill surface is an integral part of the appliance. Heat transfer to the food is efficient by conduction although there will be heat losses from areas of the grill that are not covered by food.
- Many electric ovens have resistance heater elements located at the roof of the cavity which can be used either as an integral radiant grill or to heat the oven.
- Many gas ovens also have integral grills. Those built into domestic gas ovens are generally of two designs.
    - **Conventional grill**: the grill consists of a pressed steel burner, fed via an injector at one end, located beneath an expanded metal fret. The flames on leaving the burner heat the metal fret and cause it to glow red-hot. The combustion products rise by convection through the holes in the

canopy top. This type of design causes uneven cooking, as a result of the burner failing to heat the whole of the fret surface uniformly.

- **Surface combustion grill**: In this design, the injector feeds gas into the primary air intake, which has 80-90% of the air required for combustion. The mixed gas and air travel to the centre of a sealed chamber, which has a fine metal mesh burner surface. Here an ignition probe is located and combustion occurs. The air gas mixture burns withy secondary air to complete combustion at the mesh surface which glows red hot, producing an evenly heated radiant surface across the entire burner.

- Panini grills (sandwich toasters) consist of pairs of hotplates that are pressed against both sides of the sandwich or other food. These are a type of contact grill and both domestic and commercial versions are used in EU. These are often supplied with timers or alarms that indicate when the food is cooked.
- Toasters are a type of cooking appliance that is designed specifically for toasting (or grilling) bread by using a pair of radiant resistive elements placed either side of the bread which is placed vertically in domestic toasters. Some commercial catering toasters use conveyers and so operate continuously. These products might be regarded as a type of electric grill because of the way they grill bread to make toast but they are not normally referred to as a "grill". Domestic toasters usually have two "slots" and some are available with four. If only one piece of toast is required, this requires heat only from one slot but it is not possible for users to switch heat on one slot only and so there are heat losses from the unused slots. Commercial conveyer toasters waste heat when no bread is placed on the conveyer by users unless there are sensors to switch heat on and off which is unusual. Some commercial models have timers so that the heat is on only for a predetermined time after inserting the bread then it switches off.
- Outdoor grills (barbecue grills) are increasingly popular in the EU. These can be electric, gas (natural gas or from bottled LPG) or charcoal. According to one manufacturer, the energy efficiency of grills varies significantly.
- Infrared lamps are used in commercial kitchens to keep food warm and not normally for cooking. They radiate heat to food and so could be regarded as being a type of "grill".

Most grills in the EU cook food on horizontal surfaces, either with a radiant heater positioned above the food or with the food placed onto a hot surface. Domestic gas grills usually have high voltage spark igniters but manufacturers of commercial grills use gas pilot lights to provide a "standby-mode"[4]. Some vertical grills are also on the

[4] Lincat griddles, http://lincat.s3.amazonaws.com/upload/pages/pdf/527/Opus_700_Brochure.pdf

EU market such as domestic electric toasters for bread which are usually vertical and commercial kebab gas grills which are also vertical.

It is not clear whether commercial conveyor ovens are in fact grills. An oven is a heated chamber in which food cooks mainly by convection heat whereas radiant grills operate mainly by radiation of heat from the heat source to the food. Food placed on conveyors that pass through so-called conveyor ovens is heated by a combination of convection and radiation with radiation sometimes being the more important. Two main heating methods are used; radiant heaters, or jets of hot air that impinge the food.

4.2. PRODUCTION PHASE

4.2.1. GAS HOBS

Gas hobs have one or more gas burners with four being the most common number in domestic appliances. Usually hobs are made with burners of two or more different sizes and maximum energy output to accommodate different size cooking vessels. A typical burner design is shown in Figure 4-1.

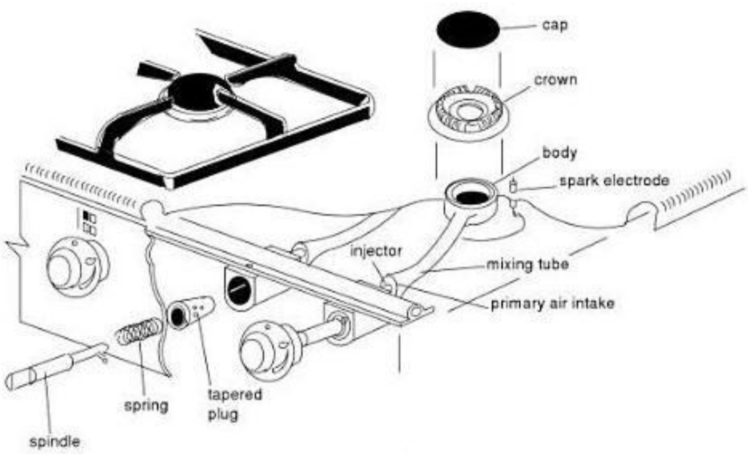

Figure 4-1: Basic design of a gas hob[5]

Gas hobs often contain burners, gas flow controllers and igniters made by specialist component manufacturers such as Copreci S.Coop (Spain) for gas flow control valves and Somipress (Italy) or AEM (France) for burners. Gas hobs need igniters and high voltage spark igniters are the most common type (for domestic gas hobs). Piezoelectric, hot surface or hot wire igniters are very uncommon. Some igniters are manually operated whereas others operate automatically when gas is flowing but is not lit. Pilot lights are no longer used in domestic hobs on the EU market but are still

[5] Gas Installation Technology by R D Treloar, 2005. With thanks for permission to include this diagram Wiley-Blackwell Publishing Ltd.

widely used in commercial hobs. Gas is premixed with some air before it reaches the burner so that a smoke-free bluish flame is produced. Combustion also requires secondary air from around the flame to burn all of the hydrocarbon gases. To avoid carbon monoxide formation, it is essential that some excess air is mixed in the flame but the amount needs to be limited as too much cold air cools the flame and reduces heat transfer efficiency.

In the traditional gas hob each burner is centrally located below a pan support and surrounded by a dish shaped depression to allow for spillages from the cooking vessels that will not flood and extinguish the flame. Control of the power to the burner is typically only by the control of the total gas supply, even though the burner provides a large number of small flames, although some manufacturers market dual burners consisting of inner and outer circular burners or even triple ring burners that are intended to provide more even heat distribution. These give a wider range of heat input and sales in the EU of these types of burner are very small but increasing.

According to EcoTopTen[6], in general the optimum gas burner type for protecting the environment (minimal CO_2 emissions) are classical gas burners and gas burners under glass-ceramic. Covered burners can be less energy efficient and this is indicated by the domestic hob standard EN30-2-1 which gives lower energy efficiency limits for gas burners than open burners. The limit for open burners is 50% whereas covered burners used from cold is 25% or 35% if tested from hot. However one stakeholder has claimed that covered burners can achieve 50% efficiency. The latter may potentially have the advantage in cool climates that indoor air need not be used for gas combustion avoiding the need to heat replacement air but the availability of this design is negligible in the EU.

The energy efficiency of a gas hob is affected by many variables including the jet size, the precision of jet orifices, the inclination of the flame or the distance between the base of the pan and the burner and it is difficult to distinguish and quantify their separate impacts.

However, tests by the CEN/TC 49 working group (gas cooking appliances) with regard to the distance between the base of the pan and the burner, could be performed and showed that if the energy efficiency is improved, the amount of toxic carbon monoxide that is released also increases[7]. With a 3 kW burner, the test results are presented in Table 4-1. A significant improvement in energy efficiency is achieved by reducing the distance from 15 to 10mm without excessive carbon monoxide emission but a further reduction gave minimal improvement and dangerous carbon monoxide levels.

[6] Eco-Top Ten website operated by the Oko Institut (Germany) www.ecotopten.de/prod_kochen_prod.php

[7] CEN/TC 49 WG2 N 113. Rev 1.0 Views of CEN TC 49 experts on EuP lots 22 and 23 January 2010

Table 4-1: Energy efficiency and CO emissions as a function of burner to pan distance

Distance between burner and pan base	Energy efficiency	Carbon monoxide in exhaust gas (EN30-1-1 limit = 1000 ppm)
15 mm	53%	267 ppm
10 mm	57%	288 ppm
5 mm	58%	1320 ppm (above limit)

4.2.1.1 DOMESTIC GAS HOBS

A typical domestic gas hob is presented in Figure 4-4.

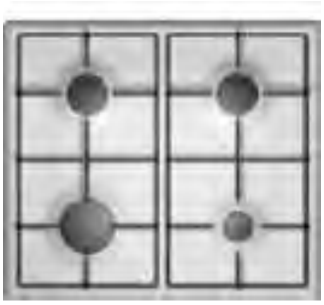

Figure 4-2: Typical domestic gas hobs

- ***Burner design***

Most burners are round with an array of small gas flames around the periphery. A standard design of a domestic gas hob is shown in Figure 4-1 Figure 4-2. Typical domestic hob burners having a maximum power output of more than 3.7 kW are common although some of up to 6 kW are available.

Figure 4-3: Typical domestic hob burners (Source HKI)

There have been some recent developments with other shapes such as “five-point” stars which are claimed to heat the pan base more evenly. Most burners have a single ring of small flames but dual and triple rings are available although these are uncommon but increasing in the EU[8] for both domestic and commercial equipment (see Figure 4-4). By using only the inner ring, simmering is possible but high heat output is achieved by using all three rings. One control valve is used for each ring or in some designs a single controller can be used.

Figure 4-4: Domestic hob burner with inner and outer ring of gas jets (from HKI)

Burners usually have integral igniters and some also have thermocouples that can be connected to the gas control valves.

Matching flame size to pot size is important for maximising heat transfer while minimising heat losses.

- ***Domestic gas hob igniters***

The main type of igniter used is the high voltage spark, especially for domestic appliances. This provides near-instantaneous ignition of the gas although can suffer from several limitations. The high voltage required can cause electromagnetic interference and so systems need to be designed to comply with the electromagnetic compatibility (EMC) directive although this is routine today. The spark electrode surfaces are also affected by contamination and moisture so that these igniters can gradually become less efficient although their useful life is very long and they usually do not need to be replaced.

A relatively recent alternative is the hot surface igniter. These use electrically heated ceramic surfaces that are sufficiently hot to ignite the gas. Originally these took as long as 30 seconds before ignition but some recent designs operate much more quickly. One potential problem is that being made of a ceramic, these could be physically damaged or crack from thermal shock. This technology is rare in the EU but more common in the US.

The most recent innovation is hot wire ignition. These use a proprietary alloy resistance wire that heats up to over 1000°C which ignites the gas. Ignition takes less than 3 seconds, the wire is not affected by contamination and there are no EMC issues.

[8] [8] Somipress cooking divisions' website, for example www.somipress.com/en/Somipressburners/prodotti8.htm

Systems for low voltage or mains voltage are available. This type of igniter is relatively new and is rare in the EU (according to CECED).

- ***Simmer control***

Hobs consist of several different size burners to provide cooking flexibility to the user. The risk of the flame being blown out by drafts if the burner is turned down is addressed as gas burners must comply with EN 30-1 section 7.3.2.2. "Resistance to draughts". This resistance is tested with the flame lift-off limit with the burner set at a reduced position. As a result, standard gas burners that have a "turn-down" ratio of 8:1 should allow secure simmering.

An ideal burner for high heat output sufficient for large pots and also accurate simmering with small pots requires a complex design.

- ***Gas flow control***

Gas control valves are made from either brass or aluminium. The valve restricts the flow of gas to control the heat output. Electronic gas control valves have recently been introduced that provide a variety of functions including:

- Automatic burner ignition – reignites gas if the flame goes out
- Electronic gas flow control – more accurate flow control
- Safety switch that turns gas off after 6 hours use (power management feature)
- Timers to switch off gas after pre-set time
- Touch control.

The accuracy of simmering is determined by the accuracy and versatility of the gas flow controller. These can be continuous or with a number of set levels where more settings gives better precision.

4.2.1.2 Commercial gas hobs

Commercial hobs are designed in a different way. An example of commercial hobs is presented in Figure 4-5, with open burners on the right side and covered burners on the left side.

Figure 4-5: Commercial gas hobs

It is very common for gas hobs to have a gas supply but no mains electrical connection and so the burners are ignited by pilot lights that are small gas flames that burn continuously. Pilot lights are banned in the USA in appliances which have mains electrical connections but pilot lights are common in products on the US market as they often do not have mains electricity supplies. US and EU manufacturers of commercial hobs intentionally do not include electrical connections and use pilot lights as this simple design is very reliable, which is very important in commercial kitchens. Omitting electrical controls also reduces the cost of appliances.

Open burners are usually used for rapid heating although simmering is possible. Covered burners are more often used for low energy input processes such as simmering. These consist of one (or more) burner below the metal cover and the surface temperature decreases away from the central zone so that it is common for users to leave the covered burner on full power continuously and place one or more pots on the cover and move these to control heat input. EN203-2-1 has a minimum energy efficiency for open burners but does not specify a minimum for covered burners although the corresponding EN 30-1-1 standard for domestic gas burners specifies a lower efficient limit for covered burners than open burners.

- ***Burner design***

Commercial burners are usually used for much longer periods and so must be more robust. They may also be more powerful. Lincat commercial ranges have gas burners of 4.9 kW and Vulcan commercial gas burners can be as much as 15 kWh output. Commercial hobs with maximum power of ~7 kW are not unusual. One manufacturer estimates that the minimum power output achievable is ~1KW per burner whereas domestic hob burners can be as low as 0.25 KW.

Electrolux have designed the NXT burner for commercial hobs which can produce a much larger range of flame sizes than standard burners (see task 6).

- ***Commercial Gas igniters***

Unlike for domestic gas hobs, high voltage spark are rarely used to ignite the gas. Most commercial designs use a pilot light, which is a small gas flame that remains permanently on that is positioned close to gas burner to ignite the gas. These are also with commercial gas grill burners. These consume fairly large amounts of gas as used in fairly large numbers and continuously burning (see section 4.4.).

Pilot lights have been banned in the USA since 1990 by NAECA in appliances which have a mains electricity supply[9] although gas hobs with no electricity supply are common in the USA and have pilot lights. The quantity of gas consumed by each pilot light is relatively large as they burn gas 24 hours per day, 365 days per year. Estimates from the US claim that they can consume as much as 40 - 50% of the gas used by a domestic gas oven and for gas burners of range cookers, pilot burners were found to consume more gas than the burners themselves[10]:

$$\frac{\text{Annual useful cooking energy output}}{\text{Annual total energy output}} = \text{Efficiency}$$

Gas hob with pilot burner: Efficiency = 16%

Gas hob without pilot burner: Efficiency = 40%

No figures for commercial appliances are published but are likely to be less as a proportion of total gas use as commercial appliances are used for much longer periods so overall more gas is consumed and the proportion used for pilot lights is therefore less. The amount of gas consumed also depends on the size of the flame and newer pilot lights have smaller flames than older designs. US estimates for each pilot light are quoted at "0.6m^3 gas / day" and "10 GJ/year". Pilot lights are common in EU commercial appliances although alternative ignition technologies are used and will be more energy efficient. But tend to be unreliable in many types of kitchen such as restaurants and hotels as the spark gaps quickly become dirty and then fail to function. EN203-1 specifies the maximum gas consumption by a pilot light (section 6.5.2) at 250W and most manufacturers aim for this figure as smaller flames are more at risk of blowing out in drafts that are common in commercial kitchens due to exhaust ventilation and nearby opening doors. Initial estimates of commercial gas hob stock in the EU is 929,500 appliances. If each has one 250 W pilot light on continuously, the total annual gas consumption is:

0.25 x 929,500 x 24 x 365 = 2,035,605,000 KW = **2TWh per year**.

[9] NAECA is National Appliance Energy Conservation Act
http://ees.ead.lbl.gov/projects/current_projects/home_appliances

[10] [10] J. E. McMahon, "US residential cooking products: market and technology status", Energy and Carbon Saving in Domestic Cooking Conference, Milan March 2006. Download from http://www.sabaf.it/opencms/opencms/Risorse/News/eventi/carbJMcMahon.pdf

- ***Simmer and burner control***

Sealed or covered gas burners are used to give better simmer control, especially in commercial hobs where the pan is moved to the edge of the burner which is not actually turned down and so wastes energy.

Options for energy conservation with commercial gas hobs are uncommon but several manufacturers sell hobs with a sensor that switches the gas off when the pot is removed and re-ignites the gas when a pot is placed on the burner (see task 6). The energy efficiency / consumption of the gas burners is similar to all other burner designs without sensors when used for cooking but overall it would use far less energy because of this control feature. However, one manufacturer has said that in their trials, reliability was affected when the sensor became contaminated by grease and food deposits

4.2.2. ELECTRIC HOBS

There are three main types of electric hotplate which operate in different ways. Pot design is important for electric hotplates and need to have flat bottoms to give good thermal conduction for solid plate and radiant designs and optimal distance to induction coils:

Solid plate – there are two basic types both of which have a spiral of resistance wire (Nichrome) either within a spiral “ring” or within a sold plate. These designs are the least energy efficient as the heating element has surfaces that are not in contact with the cooking pot from where heat losses occur. Heat transfer is primarily by conduction so occurs efficiently only where the pot and ring touch. As these hotplates age, they corrode and distort so that their surface becomes uneven. Cooking temperature control is difficult as these are relatively slow to respond to changes in the hob controls due to their high thermal mass. Use of this type of hotplate is declining in the EU for range cookers and built-in hobs but they are still used in low price domestic portable cooking appliances and in some commercial appliances. Hobs are usually sold with a range of ring sizes to accommodate large and small pots as areas of the hotplate not covered by the pot are a source of significant heat loss.

Radiant – Radiant element hotplates use electrical resistance wire or ribbon (usually Nichrome) with a current that is sufficient to make it “glow” red hot so that most heat is transferred to the cooking pot by conduction via the glass-ceramic to the pot base and physical contact is necessary. Some designs also include infrared lamps. As the thermal mass of the heating elements is relatively low, these cool rapidly when the current is reduced giving much better temperature control than solid plate hotplates although the response time is not as fast as that of an induction hob because some heat is retained by the glass ceramic. Radiant hobs are supplied with a range of hotplate sizes as areas of the hotplate not covered by the pot are a source of significant heat loss.

Induction – This is an electric heating method where the hob itself is not specifically heated. Just below the surface of the hob is a planar copper coil that is fed electrical power via a medium frequency inverter at 20 – 200 kHz. This alternating current induces eddy currents in nearby metallic objects such as the pan. The induced currents heat the metal as a result of the material's electrical resistance according to:

$$\text{Power} = I^2R \text{ (where I = current and R = resistance)}$$

Specially designed cooking pots are used which have ferromagnetic metallic bases that couple efficiently to the AC signal and so becomes hot although any ferromagnetic steel flat-bottomed pot is suitable. Pots are usually steel or magnetic stainless steel whereas Pyrex glass pots cannot be used and the Japanese higher frequency designs that use copper and aluminium pots have poor energy efficiency. The energy efficiency of induction hobs is higher than that of solid plate and electric radiant hobs during heat up as the pan is heated directly and energy is not wasted heating the cooker itself. During subsequent cooking, the difference in energy consumption is somewhat smaller as the hob does warm up due to heat losses from the induction electronics and conduction of heat away from the pot to the hob surface. Hotplate size is much less important however as induction heating only heats the steel pot so there is no heat loss from large area induction hotplates used with small pots. There are energy losses from the induction electrical control circuitry that generates the medium frequency current applied to the coil and these occur during heat up at full power and during simmering.

The medium frequency coil needs to be located at a certain distance from the pan base for optimum coupling efficiency. The heat energy H generated in the pan is inversely proportional to the square of the coupling distance d:

$$H \propto 1/d^2$$

Therefore the hob needs to be designed with the correct distance between the coil and the pan and various designs are used to achieve this, as presented in Table 4-2.

Table 4-2: Relationship between induction frequency and coupling distance[11]

Induction frequency (kHz)	Coupling distance (mm)
1 – 3	3 – 6
10 – 25	2 – 3.8
50 - 450	1.5 – 2.25

Various designs of copper inductor coils have been used including foils, tapes and round and stranded wire. Various designs of stranded wires are used but the best are called Litz wires which consist of woven or twisted multiple strands, with each strand having a thin insulating coating[12]. Tape is the cheapest but also the least efficient

[11] "Practical Induction Heat Treating" ASM International 2001
[12] http://en.wikipedia.org/wiki/Litz_wire

whereas twisted stranded wire is the most efficient and most expensive[13] although Litz wires offer the best overall performance / price ratio. Induction hobs in EU now commonly use Litz wires. There are very few induction hob electronics manufacturers. EGO[14] is one of the biggest although some hob manufacturers make there own induction electronics. Unlike solid plate and radiant, pot size is less important as heat is not lost from uncovered areas of the induction hotplate although small pots on large induction hotplates are less energy efficient than large pots on matching size hotplates.

Electric hotplate control - this is more flexible for all three main types of electric hotplate than with gas as heat out put can be controlled within much larger ranges as there is no risk at very low heat output unlike with very small gas flames. As mentioned above there is a delay in response to changes in the settings due to retained heat in the solid plate or glass ceramic materials which can result in overheating if the controls are not adjusted early enough. This can be difficult to achieve manually as adjustments are needed, for example, at a time significantly before boiling occurs in order to simmer. Control of induction hotplates is much faster.

4.2.2.1 DOMESTIC ELECTRIC HOBS

CECED data for hobs in Table 4-3 shows the maximum and minimum power ratings of standard, round electric domestic hobs of each of the three main types available on the EU market in 2008.

Table 4-3: Smallest and largest power rated standard round electric domestic hotplates on the EU market (2008)

Type	Lowest rated hotplate (W)	Highest rated hotplate (W)
Induction	1200	4600
Radiant	600	3200
Solid plate	600	3200

The power rating of electric hotplates is proportional to their diameter. In comparison, standard gas domestic hob burners range from 1000 to 3700 watts but there are a few designs that have lower rated power output and some with higher rated power output. The ability to control simmering depends on the precision of the controller as well as the hotplate / burner diameter and design.

Glass ceramic cooker tops are increasingly popular especially over electric radiant and induction hobs and also below gas hobs. There are two main glass-ceramic manufacturers in the EU; Schott and Eurokera.

[13] J. Acero, et al., "The domestic induction heating appliance: An overview of recent research," in Applied Power Electronics Conference and Exposition, 2008.

[14] Manufacturer of induction and other hotplate technologies http://www.egoproducts.com/Induction.130.0.html?&L=1

4.2.2.2 COMMERCIAL ELECTRIC HOBS

Commercial electric hobs are supplied mainly either as part of a range, built-in units or as portable appliances which may be solid plate, induction or, radiant. Commercial induction hobs, are made with single- and dual-element units designed for commercial kitchens. Commercial hobs are not very different to domestic versions except that they may be larger with higher maximum power output.

4.2.2.3 POWER OUTPUT CONTROL OF COMMERCIAL HOBS

As described above, there is a tendency to leave commercial hobs in some types of kitchen on continuously. Induction hobs are ideal in this situation as they are energy efficient because heat energy is consumed only when a pot is placed on the inductor – even if the hob is turned on.

4.2.3. GRILLS

Grill design varies considerably, the main parts are:

- Heat sources
    - Nichrome wire resistance heating either as bare wire or inside silica tubes.
    - Gas heating of various designs – usually the flames impinge on a metal grid which glow red emitting infrared heat for radiant grills. Flames impinge metal plates or grids in contact grills.
- Insulation behind the heat source is mainly to prevent external surfaces that could be touched or are in contact with walls or furniture becoming too hot but will contribute towards energy efficiency as the radiated heat output depends on the radiating metal being very hot so minimising heat losses in directions away from the food will be beneficial.
- Domestic and commercial grills may be fitted with temperature control devices, timers, etc
- Igniters for gas grills.
- Food contact surfaces of contact grills are often blackened steel as this is good for heat radiation. Bright metal surfaces are however used for some commercial grills as these do not radiate heat where no food is in contact to minimise radiative heat losses. Grill pans are used under horizontal radiant grills.

4.2.3.1 DOMESTIC GRILLS

Indoor grills

- Radiant grills - electric elements made of nichrome wire that glow “red hot” and radiate infrared energy in all directions and gas flames that heat a metal mesh to red heat so that it radiates infrared energy.
- Contact grills – there are several designs of domestic contact grills on the EU market. One type is a horizontal blackened or Teflon coated (non-stick) steel plate that is electrically heated. These usually have a flat surface or ridged surfaces and are used for cooking a wide variety of food directly on the steel surface. Grills that heat both sides of food simultaneously are also common in the EU and are referred to as “Panini grills”. The food contact surfaces are usually blackened or Teflon coated steel, electrically heated and have various shaped surfaces. Domestic gas powered indoor grills that are separate from gas range cookers are very uncommon although gas outdoor grills are sold in fairly large numbers.
- Toaster – these are used mainly for heating bread products. Most domestic toasters have 2 or 4 vertical slots that are electrically heated using nichrome wire heated electrically to red heat so that heat transfer is by infrared radiation. Insulation behind the radiating elements is used for safety not for energy efficiency. It is usually not possible to use one slot as these units are designed with one control per pair of slots (although one brand has products that allow users to select one slot only). Heat is wasted if only one slot is used but two are heated. Power level is controllable in some models so that bread is cooked quickly to produce toast but lower power levels are used for warming or defrosting. Some toasters have timers and more advanced models have browning sensors that switch off the heat when the food is cooked.

Outdoor grills

Barbecue grills are increasingly used in the EU. These are types of horizontal grill which have electric, gas (natural gas or LPG) or charcoal as energy sources. Food is suspended on grids above the heat source (burning charcoal, radiating elements or gas).

Charcoal as a fuel is excluded from this study as it is not a fossil fuel. However significant quantities of charcoal are used in the EU in outdoor grills and according to a recent study, most of this is not from sustainable sources being from virgin forests in Asia and Africa and so its use threatens bio-diversity in these regions[15]. This is a concern for two reasons. Where forests are destroyed and not replaced with new forests, the carbon tied up in the plantlife (as well as the trees) is released causing a net increase in global CO2 causing global warming. Secondly, it is not possible to replace virgin forests that have huge varieties of species some very rare, if they are

[15] “Charcoal versus LPG grilling: A carbon-footprint comparison”, Eric Johnson, Environmental Impact Assessment Review 29 (2009) 370–378.

cleared and then replaced by secondary forests. New growth tends to have a limited variety of species with most uncommon and rare species missing.

It is not possible to design charcoal grills to use only sustainable sources of charcoal and so this issue cannot be resolved directly by eco-design of the grill and a different approach is needed although the amount of unsustainable charcoal used would be reduced by using more energy efficient charcoal grills. Charcoal grills emit far more CO_2 (kg CO_2 per use) than gas grills as CO_2 is emitted during charcoal manufacture and a lot of charcoal is burned after cooking is complete.

4.2.3.2 COMMERCIAL GRILLS

As with commercial hobs, grills may be left on at full power continuously in some types of commercial kitchens such as restaurants but used only when needed in others such as institutional kitchens where cooking is more predictable. The reason is that in restaurants, cooks cannot wait for the grill to reach its operating temperature and so they turn them on when cooking begins and off when all customers have gone. There are many types of commercial grill such as:

- Salamander grill where radiant heat is directed onto food from above. Gas and electric versions are available in the EU.
- Single heating surface contact grills which are large and relatively thick metal plates heated from below electrically or by gas and food is placed directly onto the metal plate. This design is similar to commercial covered gas hobs on which pots and pans are placed on the metal plate. Unlike domestic contact grills, these often have bright metal surfaces which is usually chromium plated steel. Bright metal surfaces are poor heat radiators and so heat losses in areas with no food are minimised. Cooking is mainly be conduction.
- Commercial Panini grills are also common and usually electrically heated. These have a fixed lower hotplate and a hinged upper hotplate that is brought down onto the food being cooked. These vary in design considerable with a variety of heat contact surface morphologies that depend on the intended cooking process. Blackened steel is usually used but heat transfer is mainly by conduction. Panini grills are available with more than one cooking zone.
- Radiant grills are nearly always electrically heated from beneath glass ceramic on which food is placed.
- Kebab grill is a vertical grill designed specifically for cooking kebabs. This uses a gas or electrical radiant heat source to cook the food

- Toasters – some commercial toasters have conveyers that pass bread between pairs of electrical radiant heaters

Gas igniters

As with commercial gas hobs, commercial gas grills usually use pilot lights to ignite the burners. According to manufacturers, this is because electric high voltage spark and piezo igniters are not sufficiently reliable mainly due to food and grease contamination which is much greater than on domestic appliances. Gas output of each pilot light is limited to 250W by EN 203-1 and so annual consumption in the EU will be:

Assume 1 pilot light per appliance with an estimated stock of 349,300 commercial gas grills in EU:

$$0.25 \times 349{,}300 \times 24 \times 365 = 764{,}967{,}000 = 0.76 \text{ TWh / year}$$

Pilot light gas consumption will be a relatively small proportion of a 6KW grill on full power for 10 hours per day but may be significant in lower power grills that are used much less frequently.

4.2.4. Bills of materials

There are many different hobs and grill designs among the products available on the EU market. Five categories of products were identified, according to their annual energy consumption at the EU level. For each category, an average product representative of a hob or a grill currently in stock in the EU-27 was determined. Thanks to data provided by stakeholders in response to project questionnaires, bills of materials (BOM) were gathered. These BOMs are not detailed and the materials were selected from the ones available in the EcoReport tool. Equivalence between materials had to be found, and will be explained in Task 5.

- **Domestic electric hobs**

The BOM presented in Table 4-4 refers to a built-in, domestic electric hobs comprising four cooking zones and using the radiant technology.

Table 4-4: Bill of materials of typical domestic electric hobs

Component	Weight in g	Category	Material or Process
CASING			
Casing back	2710	3-Ferro	**25-Stainless 18/8 coil**
Screws	6.72	3-Ferro	**22-St tube/profile**
Screens	520	3-Ferro	**22-St tube/profile**
KB support	121	1-BlkPlastics	**8-PVC**
Aluminium bar	219.6	4-Non-ferro	**26-Al sheet/extrusion**
Ceramic glass	3230	7-Misc.	
HEATING ELEMENTS			
Radiant heating element 1200W	385	4-Non-ferro	**25-Stainless 18/8 coil**

Component	Weight in g	Category	Material or Process
Radiant heating element 2200W	530	4-Non-ferro	**25-Stainless 18/8 coil**
Radiant heating element 1200W	385	4-Non-ferro	**25-Stainless 18/8 coil**
Radiant heating element 2500W	610	4-Non-ferro	**25-Stainless 18/8 coil**
CONTROL TECHNOLOGY			
Electronic board	489.2	6-Electronics	**98-controller board**
MISCELLANEOUS			
Internal cable	56.0	4-Non-ferro	**29-Cu wire**
Main cable	340.0	4-Non-ferro	**29-Cu wire**
Silicone seal	90.0	2-TecPlastics	**16-Flex PUR**
Silicone glue	16.0	2-TecPlastics	**14-Epoxy**
TOTAL weight	**9708.5**		

Domestic gas hobs

The BOM presented in Table 4-5 refers to a four-cooking zone, domestic built-in gas hob.

Table 4-5: Bill of materials of typical domestic gas hobs

Component	Weight in g	Category	Material or Process
CASING			
housing	2,030.0	3-Ferro	**21-St sheet galv.**
hob cover	1,425.0	3-Ferro	**25-Stainless 18/8 coil**
HEATING ELEMENTS			
burner tube	155.0	4-Non-ferro	**28-Cu winding wire**
burner lid	195.0	3-Ferro	**24-Ferrite**
MISC.			
pan support	1,587.0	3-Ferro	**24-Ferrite**
COMPONENTS PURCHASED SEPARATELY			
gas tap	480.0	4-Non-ferro	**31-CuZn38 cast**
hobs burners	1,000.0	4-Non-ferro	**27-Al diecast**
manifold	200.0	3-Ferro	**21-St sheet galv.**
switch harness			
copper	48.0	4-Non-ferro	**28-Cu winding wire**
PVC	32.0	1-BlkPlastics	**8-PVC**
ignition switch			
PTFE	112.5	2-TecPlastics	**11-PA 6**
Copper	22.5	4-Non-ferro	**28-Cu winding wire**
Ceramic	15.0	7-Misc.	**54-Glass for lamps**
knobs	32.0	1-BlkPlastics	**4-PP**
spark plugs			

Component	Weight in g	Category	Material or Process
stainless steel	30.0	3-Ferro	**25-Stainless 18/8 coil**
PTFE	6.0	2-TecPlastics	**11-PA 6**
Ceramic	24.0	7-Misc.	**54-Glass for lamps**
Thermocouple	250.0	4-Non-ferro	**30-Cu tube/sheet**
Power cable			
Copper	75.0	4-Non-ferro	**28-Cu winding wire**
PVC	75.0	1-BlkPlastics	**8-PVC**
TOTAL weight	**7,794**		

- **Domestic grills**

Due to the large panel of domestic grill designs, no typical Bill-of-Material could be determined.

- **Commercial electric hobs**

The BOM presented in Table 4-6 refers to a four-cooking zone, commercial free-standing electric hob.

Table 4-6: Bill of materials of typical commercial electric hobs

Component	Weight in g	Category	Material or Process
CASING			
Top shelf	7,100.0	3-Ferro	**25-Stainless 18/8 coil**
Frame rear sheet	1,800.0	3-Ferro	**25-Stainless 18/8 coil**
Frame side sheets	8,400.0	3-Ferro	**25-Stainless 18/8 coil**
Control panel	800.0	3-Ferro	**25-Stainless 18/8 coil**
Feet casing holders	1,400.0	3-Ferro	**25-Stainless 18/8 coil**
Door	3,400.0	3-Ferro	**25-Stainless 18/8 coil**
Other components	14,400.0	3-Ferro	**25-Stainless 18/8 coil**
HEATING ELEMENTS			
Electric resistance	2,200.0	3-Ferro	**25-Stainless 18/8 coil**
Resistance support	12,000.0	3-Ferro	**25-Stainless 18/8 coil**
Heated plate	16,400.0	3-Ferro	**25-Stainless 18/8 coil**
CONTROL TECHNOLOGY			
Thermal sensor	120.0	7-Misc.	
MISC.			
Knobs	40.0	2-TecPlastics	**11-PA 6**
Handle	120.0	2-TecPlastics	**11-PA 6**
Thermoplastic polymers	5,400.0	1-BlkPlastics	**4-PP**

Component	Weight in g	Category	Material or Process
Elastomers	1,000.0	2-TecPlastics	**15-Rigid PUR**
Aluminium	1,200.0	4-Non-ferro	**26-Al sheet/extrusion**
Stainless steel	4,300.0	3-Ferro	**25-Stainless 18/8 coil**
TOTAL weight	**80,080**		

- **Commercial gas hobs**

The BOM presented in Table 4-7 refers to a four-cooking zone, commercial free-standing gas hob.

Table 4-7: Bill of materials of typical commercial gas hobs

Component	Weight in g	Category	Material or Process
CASING			
Top shelf	6600,0	3-Ferro	**25-Stainless 18/8 coil**
Frame rear sheet	1100,0	3-Ferro	**25-Stainless 18/8 coil**
Frame side sheets	4,500.0	3-Ferro	**25-Stainless 18/8 coil**
Control panel	1,700.0	3-Ferro	**25-Stainless 18/8 coil**
Pan holders	24,000.0	3-Ferro	**23-Cast iron**
Other elements	2,700.0	3-Ferro	**25-Stainless 18/8 coil**
HEATING ELEMENTS			
Burners	6,400.0	3-Ferro	**23-Cast iron**
Other elements	2,000.0	4-Non-ferro	**26-Al sheet/extrusion**
MISC.			
Knobs	40.0	2-TecPlastics	**11-PA 6**
Handle	120.0	2-TecPlastics	**11-PA 6**
Thermoplastic polymers	5,100.0	1-BlkPlastics	**4-PP**
Elastomers	500.0	2-TecPlastics	**15-Rigid PUR**
Iron	3,500.0	3-Ferro	**22-St tube/profile**
TOTAL weight	**58,260**		

- **Commercial electric grills/fry-tops**

The BOM presented in Table 4-8 refers to a 1-cooking zone, commercial free-standing electric grill/fry-top.

Table 4-8: Bill of materials of typical commercial electric fry-tops

Component	Weight in g	Category	Material or Process
CASING			
Top shelf	3,780.0	3-Ferro	**25-Stainless 18/8 coil**
Frame rear sheet	1,080.0	3-Ferro	**25-Stainless 18/8 coil**
Frame side sheets	5,040.0	3-Ferro	**25-Stainless 18/8 coil**

Component	Weight in g	Category	Material or Process
Control panel	480.0	3-Ferro	**25-Stainless 18/8 coil**
Feet casing holders	840.0	3-Ferro	**25-Stainless 18/8 coil**
Door	2,040.0	3-Ferro	**25-Stainless 18/8 coil**
Other elements	14,400.0	3-Ferro	**25-Stainless 18/8 coil**
HEATING ELEMENTS			
Electric resistance	1,600.0	3-Ferro	**25-Stainless 18/8 coil**
Grid	6,500.0	3-Ferro	**23-Cast iron**
CONTROL TECHNOLOGY			
Thermal sensor	30.0	7-Misc.	
MISC.			
Knobs	40.0	2-TecPlastics	**11-PA 6**
Handle	120.0	2-TecPlastics	**11-PA 6**
Thermoplastic polymers	7,070.0	1-BlkPlastics	**4-PP**
Elastomers	700.0	2-TecPlastics	**15-Rigid PUR**
Aluminium	3,430.0	4-Non-ferro	**26-Al sheet/extrusion**
Stainless steel	7,420.0	3-Ferro	**25-Stainless 18/8 coil**
Iron	9,100.0	3-Ferro	**22-St tube/profile**
Cast iron	1,540.0	3-Ferro	**23-Cast iron**
Ceramic	140.0	7-Misc.	**54-Glass for lamps**
TOTAL weight	**65,350**		

- **Commercial gas grills/fry-tops**

The BOM presented in Table 4-9 refers to a 1-cooking zone, commercial free-standing gas grill/fry-top.

Table 4-9: Bill of materials of typical commercial gas fry-tops

Component	Weight in g	Category	Material or Process
CASING			
Top shelf	4,410	3-Ferro	**25-Stainless 18/8 coil**
Frame rear sheet	1,260	3-Ferro	**25-Stainless 18/8 coil**
Frame side sheets	5,880	3-Ferro	**25-Stainless 18/8 coil**
Control panel	560	3-Ferro	**25-Stainless 18/8 coil**
Feet casing holders	980	3-Ferro	**25-Stainless 18/8 coil**
Door	2,380	3-Ferro	**25-Stainless 18/8 coil**
Other elements	16,800	3-Ferro	**25-Stainless 18/8 coil**
HEATING ELEMENTS			
Burners	3,200	3-Ferro	**23-Cast iron**
Other elements	1,000	4-Non-ferro	**26-Al sheet/extrusion**
CONTROL TECHNOLOGY			

Component	Weight in g	Category	Material or Process
Thermal sensor	30	7-Misc.	
MISC.			
Knobs	40	2-TecPlastics	**11-PA 6**
Handle	120	2-TecPlastics	**11-PA 6**
Thermoplastic polymers	5,530	1-BlkPlastics	**4-PP**
Elastomers	700	2-TecPlastics	**15-Rigid PUR**
Aluminium	2,660	4-Non-ferro	**26-Al sheet/extrusion**
Stainless steel	6,020	3-Ferro	**25-Stainless 18/8 coil**
Iron	10,360	3-Ferro	**22-St tube/profile**
Cast iron	2,240	3-Ferro	**23-Cast iron**
Ceramic	140	7-Misc.	**54-Glass for lamps**
TOTAL weight	**64,310**		

4.3. DISTRIBUTION PHASE

The package volume is the most relevant parameter when it comes to describing the distribution phase. This volume directly determines the number of products that can be carried in a specific means of transportation, which contributes to the impacts of the distribution phase. The total weight of the packaged product is also a key element influencing the impacts of the distribution phase, but it is available though the Bill of Materials presented in section 4.2.4. , and thus will not be covered here.

4.3.1. DOMESTIC APPLIANCES

Table 4-10 presents the package volume of domestic built-in hobs. This data was collected from brochures and websites of the main European manufacturers (identified in Task 2).

Table 4-10: Package volume of domestic built-in hobs

	Number of models in the sample	Packaged volume (m^3)		
		Minimum	Maximum	Average
1 cooking zone				
Gas	1	0.031	0.031	0.031
2 cooking zones				
Gas	6	0.025	0.031	0.028
Induction	4	0.025	0.041	0.031
Radiant	7	0.025	0.035	0.028
Solid plates	5	0.025	0.030	0.027

	Number of models in the sample	Packaged volume (m³)		
		Minimum	Maximum	Average
3 cooking zones				
Gas	5	0.053	0.053	0.053
Induction	27	0.035	0.071	0.052
Radiant	4	0.044	0.055	0.048
4 cooking zones				
Gas	40	0.053	0.090	0.061
Induction	28	0.035	0.069	0.055
Mixed	13	0.054	0.072	0.061
Radiant	20	0.035	0.061	0.045
Solid plates	7	0.040	0.054	0.047
5 cooking zones				
Gas	9	0.062	0.103	0.078

The technology used in hobs does not seem to impact the size of the appliance, which is mainly determined by the number of cooking zones. For hobs with 4 cooking zones, the ones operated by gas are slightly bigger.

In general, the range of package volume is wide. This arises from two main factors:

- The thickness of the hobs: newer hobs are much thinner than old models
- The package used by the manufacturer: products may have the same size but a different package, resulting in a difference in the packaged volume.

For portable hobs, the manufacturers usually do not provide the package volume, but only the external dimensions. All portable hobs are electric (solid plate or induction) and there are usually one or two cooking zones. Table 4-11 presents the data collected from the websites of 8 manufacturers[16].

Table 4-11: External volume of domestic portable hobs

	Number of models in the sample	External volume (m³)		
		Minimum	Maximum	Average
1 cooking zone				
Induction	6	0.006	0.009	**0.007**
Solid plate	2	0.005	0.007	**0.006**
2 cooking zones				
Induction	5	0.013	0.018	**0.015**
Solid plate	4	0.011	0.014	**0.013**

[16] Bartscher, Clatronic, Kenwood, Lacor, Riviera, Techwood, Unold, White and Brown

As for built-in hobs, induction and solid plate portable hobs have a comparable size, although induction hobs are slightly bigger. The main factor influencing the size is the number of cooking zones. For a type of hob, the range of external sizes is small. The package may differ according to the manufacturer, and thus the range of packaged volume may be wider.

Domestic grills are very diverse and no data was gathered concerning their packaged volume.

4.3.2. COMMERCIAL APPLIANCES

The commercial appliances covered by the Lot 23 study are very diverse. Nevertheless, it is possible to differentiate three main categories:

- Portable appliances: appliances small and light enough to be moved.
- Ranges: free-standing appliances with a hob or a grill on top of a cabinet or an oven.
- Table tops: only the top part of the range, which can be purchased separately to be adapted to an existing table.

Portable appliances are usually induction hobs, or small grills. Few European manufacturers sell this type of commercial appliance. Table 4-12 presents the external volume of commercial portable appliances from three European manufacturers[17].

Table 4-12: External volume of commercial portable hobs

	Number of models	Minimum volume (m^3)	Maximum volume (m^3)	Average volume (m^3)
1 cooking zone				
Induction	11	0.014	0.022	0.018
2 cooking zones				
Induction	5	0.019	0.038	0.032

For ranges and table-tops, manufacturers design a series of appliances, with standard dimensions, so that several appliances can be placed side by side to form a worktop. Appliances of the same series have the same height and depth, and usually a standard width. The width of an appliance in the series is a multiple of this standard. The actual dimensions of the appliance depend on the manufacturer and the series, but the most common depths are 600mm, 700mm and 900mm. Table 4-13 presents the standard dimensions of some series produced by 7 European manufacturers.

[17] Bartscher, Bonnet, Lacor.

Table 4-13: Standard dimensions of series produced by 7 European manufacturers

	Depth (mm)	Cook top height (mm)	Range height (mm)	Standard width (mm)	Standard range volume (m3)
Angelo Po					
Alpha	900	240	720	400	**0.259**
Concept	600	220	930	350	**0.195**
Gamma	700	240	900	350	**0.221**
Omega	1100		720	400	**0.317**
Bertos					
Macros 700	700	290	900	400	**0.252**
Maxima 900	900	290	900	400	**0.324**
Plus 1200	1200		900	450	**0.486**
Plus 600	600	290	900	300	**0.162**
Bonnet					
Optimum	920	270	900	400	**0.331**
Premium	950	270	900	500	**0.428**
Electrolux Professional					
Elco700HP	700	250	850	400	**0.238**
Elco900	930	250	850	400	**0.316**
Thermaline 800	800		800	400	**0.256**
Thermaline 900	900		800	500	**0.360**
Thermaline S90	900	400	900	500	**0.405**
Fagor Industrial					
600series	600	290	850	400	**0.204**
700series	700	290	850	350	**0.208**
900series	900	320	850	425	**0.325**
Lincat					
Opus700	737	300	955	400	**0.282**
Silverlink 600	600	290	900	300	**0.162**
Metos					
Metos650	650	295	850	400	**0.221**
Metos700	700	280	900	400	**0.252**
Metos900	900		900	400	**0.324**

The standard range volume is the volume of the smaller appliance of the series, like hobs with two cooking zones on a cabinet. Range cookers with four cooking zones on top of an oven are usually twice as big. Range cookers including hobs with six cooking zones are three times the standard volume.

These volumes apply for range cookers including grills as well as for hobs, as generally, the series produced by the commercial appliances manufacturers include hobs and grills.

4.4. USE PHASE (PRODUCT)

Unlike domestic ovens, there is no obligation for energy labelling of hobs or grills and so manufacturers do not routinely measure energy consumption using a standard test procedure (except for gas hobs). Therefore, standardised energy measurement of individual models of hobs and grills for cooking food is not available. However, there are standards that specify the minimum energy efficiency for commercial and domestic gas hobs.

Table 4-14: Minimum energy efficiencies of hobs specified by European Standards

Standard	Type of hob hotplate	Minimum energy efficiency (%)
EN 30-2-1:1998 / A2:2005 Domestic gas hobs	Uncovered gas burners	≥ 52% (rapid heating water by 70°C)
	Covered gas burners from cold	≥25% (rapid heating water by 70°C)
	Covered gas burners from hot	≥35% (rapid heating water by 70°C)
EN 203-2-1:2005 Commercial gas hobs	Open burners	≥ 50% (rapid heating water by 70°C)
	Covered burners	No requirement
EN 60350: 2009 Domestic electric hobs and EN 61817:2001 domestic portable electric hobs	Method for measurement of energy consumption given but minimum efficiency is not specified	

Existing standards measure energy efficiency during heat up only and so do not reflect performance when cooking food. New standards are being developed to measure the total energy consumed by hotplates and burners during “average cooking processes” although the test conditions needed for electric hotplates and gas burners will need to be different and so these two types cannot easily be compared. Pot size, load and test conditions will all be different.

No minimum energy efficiency standard is specified in the EU for domestic or commercial electric hotplates or for all types of grill. There has been some research carried out to determine energy consumption of hobs although energy consumption is not the same as efficiency. Energy consumption is the amount of energy consumed to perform a specific task and this data is useful for comparison of different models and types of hotplate. Energy efficiency is the proportion of the available energy that is absorbed by the “load” (food) during a cooking process and this can be expressed as a ratio or as a percentage.

4.4.1. Hobs

Research has shown that of the types of electric hob available in the EU, induction hobs are the most energy efficient can be achieved (Bosch estimate that 75% of the electricity consumed can be converted into useful heat for cooking)[18]. Estimates of the differences between each type vary however because the results depend on the measurement method used and no standard method has been available. It has been estimated that during the heat up stage, induction hobs consume as much as 30% less energy than other electric hotplate types but the difference in energy consumed during subsequent cooking is much smaller.

There is published data that compares energy consumption of the main types of hob, mostly for heat up only, which is summarised below:

1. US data from 1996 is rather old but shows the differences that may exist with stocks of hobs in the EU[10]. This research by the US Department of Energy appears to be for heating water (no simmer) and compares energy efficiency of the main hotplate types (plus gas).

Table 4-15: Electrical efficiency of hob types from US DoE (and gas as primary energy efficiency)

Design type	Electrical energy Efficiency (and gas primary energy efficiency
Gas	40% (primary energy)
"Coil" (solid plate)	74%
Halogen	75%
Radiant	72%
Induction	84%

2. Comparative measurements carried out in India with portable appliances have been reported. These were based on heating water to boiling without a lid on the pan and for cooking rice which would include bring water up to boiling and then simmering with a lid[19]. The energy efficiency of cooking rice is calculated using the formula described in this publication.

Table 4-16: Energy efficiency of boiling water and cooking rice on portable hotplates and gas burner

Design type	Energy efficiency boiling water (no lid)	Energy efficiency cooking rice (includes simmer)
Induction	88%	84%

[18] Bosch on-line catalogue, April 2011 http://www.bosch-home.com/Files/Bosch/Sg/sg_en/Document/BSH-Built-in%20SGP%202008.pdf

[19] "Energy consumption benchmark studies on parboiled rie cooking in Kerala, Energy Management Centre, Kerala. Downloaded from: http://www.keralaenergy.gov.in/Downloads/ENERGY%20CONSUMPTION%20BENCHMARK%20STUDIES%20ON.pdf

Electric coil	70%	65.7%
Gas (LPG)	~64% (primary energy)	60% (primary energy)

In these tests, the gas burner performed better than in the US DOE tests, presumably because the potable LPG burner design is different to a range burner and the measurement method is different.

3. More recent research has been published by VHK which compares boiling water using 7 heating methods including electric kettles and a microwave oven[20]. The results include electricity generation losses, standby losses, energy lost after boiling is reached but power is not switched off and "over-fill" which is the heating of more water than needed. Over-fill is the same for all hob types but all other variables differ. The total energy consumed to boil 1000 litres per year is calculated and includes the theoretical minimum of 105KWh/1000 litres.

Table 4-17: Primary energy consumption for boiling water

Cooking Method	Total primary energy consumed KWh	Energy efficiency
Induction	699	15%
Electric	792	13%
Gas	461	23%

Gas has the highest primary energy efficiency because there are no generating losses but gas has the highest heat loss at 255 KWh compared to only 57 KWh for induction and 114 KWh for electric.

4. Research carried out in 1995 on a test method to determine energy consumption of electric hobs determined the following energy efficiency for heat up[21]:

- Electric sold plate 59.4%
- Electric radiant 57.2%
- Electric induction 80.2%

In these tests radiant performed less well than solid plate although this work was from 1995 and modern radiant hobs could be more efficient.

Oko-Institute[22] has calculated annual energy consumption based on tests by Stiftung Warentest Institute:

- Electric sold plate 260 kWh/year

[20] « Quooker Energy Analysis » report by VHK March 2010, downloaded from: http://www.vhk.nl/downloads/Energy%20analysis%20Quooker%20main%20final%20april%202010.pdf

[21] http://library.wur.nl/WebQuery/titelplus/lang/879030

[22] Private communication

- Electric radiant 225 kWh/year
- Electric induction 175 kWh/year

These morte modern results show that radiant is superiuor to solid plate and the best performing is induction.

5. Cooktek is a supplier of commercial induction hobs and claims on their website[23] the following cooking efficiencies:

Table 4-18: Efficiency of Cooking Methods

Cooking Method	Efficiency
Induction	90%
Radiant	5865
Gas	55%

No details of how these figures were obtained are given but the figures in Table 4-18 appear to be for the heat up stage only. 90% efficiency for induction seems too high and gas is a primary fuel so is not directly comparable

6. A paper entitled "Energy Efficiency Strategy for Spain: Description of current framework and a complementary view point[24]" energy consumption figures for different hob technologies were considered from a study by S.A. Balay. This demonstrated the efficiency of the different technologies to heat 2 litres of water from 20 to 90°C with systems of the same power capacity and the results are shown in Table 4-19. As with the Cooktek results above, these tests considered heat up only and so will be different to real cooking. The origin of the electricity used by each system was also considered and the life cycle efficiency in terms of CO_2 emissions were calculated.

Table 4-19: Comparison of the performance of different technologies to heat 2 litres of water from 20 to 90°C[3]

Technology	Time required (hrs)	Energy Consumption (Wh)	Cost (€)	Life cycle efficiency (kg CO_2)*
Electric Plate	0.217	35.33	0.53	0.15
Vitro-ceramic	0.165	26.86	0.40	0.14
Induction	0.117	19.05	0.28	0.10
Natural Gas	0.078	12.70	0.06	0.02

* From published data multiplied by 10 as energy consumption figures included in this paper are too low by a factor of 10[25].

[23] Cooktek website http://www.cooktek.com/benefits-0
[24] http://teide.cps.unizar.es:8080/pub/publicir.nsf/codigos/0434/$FILE/cp0434.pdf
[25] Kindly indicated by stakeholder and by comparison with VHK results

These results show that gas hobs consume less energy than electric although in these tests this was mainly due to the surprisingly much shorter heating time required (this is also affected by the pot design, load, etc. so may be an artefact of the method used). As expected, induction heating is the most efficient electric option. This also required a shorter time to reach 90°C than either of the other electric cooking methods. Gas cooking was clearly the cheapest from this study, mainly due to the lower consumer energy price of gas /kWh in comparison with the price of electricity / kWh but gas cooking also emitted far less CO_2 in these tests overall than electric cooking.

7. Trials have been carried out at FRPERC[26] to measure the efficiency of electric, induction and gas hobs when heating a known amount of water to 90ºC (i.e. heat up only, simmering not considered). The test is based on EN50304:2009 EN60350:2009, which is for electric hotplates only and so the results with gas may not be reliable. An uncoated stainless steel saucepan with a nominal diameter of 18 cm is filled with 1.5 litres of water. This diameter is not ideal for all hob diameters which are in Table 4-20 and so is a source of error.

Table 4-20: Hobs used in FRPERC study on hob efficiency

Type of hob	Diameter of cooking zone (cm)
Electric induction	22
Electric ring	16
Electric ceramic	20
Gas flame	10

The water is heated from 15 ± 2°C to 90°C, the time and energy consumption are then measured. The efficiency is calculated according to the following formula:

$$n = \frac{4.187 \times 75 \times m}{W_m \times 3600} \times 100$$

where:

n = efficiency(%)
W_m = measured energy consumption (kWh)
75 = temperature rise (ºC)
m = mass of water (kg)
3600 = conversion from seconds to hours (sec/h)

The conversion factor for natural gas from cubic meters to kWh were as stated on the UK Energy Saving Trust website (1 m^3 of natural gas = 11.06 kWh). The impact of greenhouse gas (GHG) emissions was also calculated to provide additional information. Emission factors of 0.523 kg CO_2/kWh and 0.185 kg CO_2/kWh for electricity and gas

[26] Food Refrigeration and Process Engineering Research Centre, Bristol University – closed 2009.

respectively were used. These are earlier UK figures according to DEFRA and the current EU average kg CO_2/kWh is significantly lower. Even so, these figures are suitable for comparison of the different hob types.

Data from this trial showed that, in terms of kWh of energy used, the induction hob had the highest efficiency (77 %) and the gas hob had the lowest (31 % which is lower than specified by EN 30-2-1) but this is misleading as gas is a primary fuel and is not directly comparable with electricity. However, in terms of mass of CO_2 produced to heat the water, the gas hob produced the least as in

Table 4-21: Measured energy efficiency of hob types and calculated CO_2 emissions

Design type	Electrical energy efficiency (except for gas)	Calculated CO_2 emission (kgCO_2/1.5 l water)
Induction	77%	0.09
Solid plate (electric ring)	65%	0.11
Radiant (Electric ceramic)	57%	0.12
Gas	31% (primary energy)	0.08

The gas heating efficiency figure in Table 4-21 of 31% is considerably lower than the 52% minimum efficiency required by EN 30-2-1: this inconsistency may be explained by the fact that the test procedure was not the same as the one specified in this standard. The CO_2 emissions results were calculated using different values for kg CO_2 /kWh electricity generated than the other studies reported here. The results of the studies reported here are summarised in the table below.

Table 4-22: Summary of data from published hotplate / burner heat-up trials of relative weights of CO_2 emitted by each hob type

Hob type	VHK study KWh primary energy	Spanish study (Balay) (kg CO_2)	FRPRC (kg CO_2 /1.5l water)
Gas	461	0.02	0.08 (should be lower)
Induction	699	0.1	0.09
Radiant	-	0.14	-
Solid plate	792	0.15	0.12

The data in Table 4-22 implies that gas hobs are the most carbon efficient. This would however change if the proportion of electricity generated by fossil fuels in EU decreases significantly. Large changes will be needed to meet the EU's target 80% reduction of global warming gas emissions by 2050 and if these are successful so that the majority of electricity is generated from sources other than fossil fuels, then all electric hobs would be much more carbon efficient than gas. However new hobs sold in the next five years will be in use until 2025 until which time fossil fuels are likely to be the predominant energy source for electricity generation.

Gas is also the most primary energy efficient as there are no generating losses. Gas cooking appears however to give the greatest heat losses as shown by the VHK study. This is because heat transfer from combustion gases cannot be 100% efficient and so loss of heat in hot gases occurs.

Preliminary trials by CECED with electric hotplates based on measurement of energy carried out to develop an energy consumption measurement test standard have been carried out. This involves heating water to 90°C followed by 20 minutes simmering at 90°C which is supposed to represent typical EU cooking. The measurements are for hobs and so separate tests are carried out with each hotplate using standard sizes of pan and amounts of water that match hotplate diameter. The test results are for energy consumed per kg of water and are independent of number of hotplates and their size. Unfortunately, there is very little published data on actual EU cooking processes with hobs so it is not possible to be certain what simmer time would be realistic. CECED's tests with 16 electric hobs found that the energy consumption varied within a range of ~15% (i.e. ±7.5% of the average) for all three types of electric hob including solid plate and induction[27]. In CECED's tests, the simmer stage consumes about 30% of the total energy consumed but this depends on the type of hotplate.

- Solid plate – consumed most energy during heat up but the retained heat reduces the heat input needed for simmering and so this accounted for less than 30%
- Radiant – consumed less energy during heat up than solid plate but more than induction. Some heat is retained by the glass ceramic so that simmering accounts for about 30% of total energy consumption
- Induction – the hob does not adsorb or retain heat and so this type consumed least energy during heat up but more than 30% for simmering although overall consumed least energy by ~10 - 15%.

Clearly the percentage of the total energy consumption used during simmering will increase with simmering time but CECED also measured this for 30 and for 40 minutes but this made very little difference to their results overall. Therefore, if average EU simmering time were more than 20 minutes, increasing the test time would make little difference to the tests accuracy.

Average cooking processes will be different to commercial cooking and there are likely to be large difference between EU States. However, no reliable published data is available but a realistic hob energy consumption test should reflect actual EU average cooking processes. One issue is that users do not necessarily use the correct pot size on each hotplate. There are no heat losses if the pot is larger but uncovered areas of solid plate and radiant hotplates will lose energy whereas induction hotplates are less

[27] Unpublished results provided by CECED.

affected. It is difficult however to see how this can be considered in an energy consumption test.

A test conditions for gas is being developed but is less well advanced. The test will be different, for example, the electric hob testing standard uses steel pots whereas the gas test standard uses aluminium. The control of heat output from gas burners can be adjusted very quickly with no delay unlike solid plate but it is difficult to provide a very wide energy output range.Sustainable low heat output from large burners could be better achieved with novel multiple ring burners which would be independently controllable. . As with the test for electric hobs, standard pan sizes would be used for the gas tests and these would be chosen to ensure that simmering is possible on standard burner designs even though a wide variety of pan sizes will be used.

4.4.2. Grills

Very little published data on the energy consumption or energy efficiency of grills could be found. There is some data from the US EPA testing of commercial griddles sold in USA and some Japanese tests[28]. These are described below. Swiss research from 1993 found that electric grills have an average efficiency of 20% and gas grills an average efficiency of 15%[29]. There is a lack of published data for grills because grill designs vary considerably and there are no standard energy consumption test methods available except for the ASTM commercial griddle test standards and a Japanese standard for the Top Runner program. One manufacturer has also provided test data for domestic outdoor grills.

The energy consumption of grills will be affected by their design and the way that they are used. Design variables that may affect energy consumption include:

- Control of hot area to match size of food – some grills can be controlled to allow the user to heat only part of the available grill area. Various options are on the market although each grill design has relatively few area options, often just two with domestic products. Clearly by being able to use only half of the grill area will reduce energy consumption by half.
- Control of heat input – this is standard for gas grills but is not always available with electric radiant grills. Some have no control whereas others have either a limited number of power levels or continuous control. Heat input control of commercial contact grills is more common.
- Sensors are used in some toasters to switch off the heat when the toast is cooked.

[28] "Final Report by the Subcommittee on Gas and Oil Powered Equipment Judgement Criteria Energy Efficiency Standards Subcommittee The Advisory Committee for Natural Resources and Energy", 6 May 2006 (Japan).

[29] N. Jungbluth "Life-cycle assessment for stoves and ovens", UNS Working paper No. 16, August 1997. http://www.esu-services.ch/cms/fileadmin/download/jungbluth-1997-WP16-LCA-cooking.pdf

- Thermal insulation to prevent heat losses from grill surfaces away from the side where the food is placed, e.g. beneath contact grills and above horizontal radiant grills. The insulation will be used to ensure that external surfaces are safe to touch but not usually to minimize energy consumption because there are no standards or legal requirements on energy consumption of grills in the EU.

- **Japan Top Runner Scheme**

In Japan, the "Top Runner standard" measures the energy consumption of household appliances including grills and publicises the best performing products. Standard methods for measurement of energy consumption from grills have been developed[28]. The method measures the energy used to raise the temperature of a standard metal block placed below the grill by 100°C. There is also a standard that specifies "Energy Consumption Efficiency" (in Wh) for single-sided and double-sided grills.

Single-sided grill	25.1V + 16.4 Wh
Double sided grill	12.5V + 101 Wh

where V = Internal volume. This is measured by multiplying the grill area by the height from the bottom surface of the grill pan to the top of the inlet.

Double sided grills are less common in the EU, these have heater elements located on both sides of the food so avoid the need to turn it over. Double sided grills are not sold in the EU except as toasters and Panini grills (sandwich makers) and Japanese grills may be different. The Japanese Top Runner measurement method determines the energy required to raise the temperature of the test load whereas grilling food also requires ongoing cooking and also often darkening (caramelising) of food.

Tests on all grills sold in Japan in 2002 were compared and found that there was a potential for energy efficiency improvements of 27 % although the range of grills on the Japanese market is different to those in the EU. Test results showed that for the more common grill sizes, the energy consumption of models varied considerably. For example, for Japanese single-sided grills with volumes of 4 litres, energy consumption ranged from 280 Wh to 430 Wh using the standard test showing that considerable energy consumption reductions would be achievable by eliminating the worst performing models from the market. Corresponding data for grills on the EU market does not exist as there is no corresponding EU energy consumption measurement standard.

The Top Runner report states that heat losses occur because of inadequate insulation and leaks which allow hot air to escape and efficiency improvements may also be possible by increasing the amount of radiant heat from heater elements (this is applicable only for radiant, non-contact grills).

Energy Star for commercial griddles

Most commercial grills (or griddles) are contact grills and an Energy Star standard has been developed for these products. Two tests methods, ASTM F1275 and F1605, are used to measure energy efficiency and normalised idle energy rate which is stated by EPA to be equivalent to standby mode. US EPA claim that Energy Star griddles consume on average 10% less energy so that each griddle can potentially save 2270 kWh per year[30]. EPA states that the Energy Star standard specifies the minimum energy efficiency and idle energy rate and only the best ~25% (27% of electric and 23% of gas) commercial griddles sold in USA meet this standard. EPA tests of commercial griddles shows the variation in energy efficiency of products on the market and demonstrates that there is potential for eco-design to reduce overall energy consumption in use. This is summarised in Table 4-23.

Table 4-23: Requirements and test results for Energy Star standard for commercial griddles (units are as given in respective publications)

Results of tests	Electric griddles		Gas griddles	
	Energy efficiency range	Normalized idle energy rate range (watts/ft^2)	Energy efficiency range	Energy efficiency range (Btu/h ft^2)
Minimum required by standard	70%	355 (320 from 1 Jan 2011)	38%	2650
Available griddles that meet energy star standard	72 – 77%	210 - 342	41 – 51%	1538 - 2562
All tested by EPA	65 – 76% (one was 46%)	210 - 410	29 – 47%	1800 - 3600

These results show that there is considerable variation in energy efficiency of US commercial griddles although few if any of these are sold in the EU. There is no equivalent Energy Star standard for domestic grills. The EU commercial catering industry believes that the US griddle Energy Star requirements are not very demanding and that EU products are on average more energy efficient than US products[31]. Furthermore, EU griddles do not have any type of standby mode, they are either on or off.

The important design features for energy efficiency of grills will depend on whether they are radiant or contact.

Radiant – heat transfer is by infrared radiation from the grill to the food. Infrared radiation travels in straight lines like visible light and the heating effect occurs when it is absorbed by food. Dark food absorbs more effectively than pale but the grill

[30] US Energy Star website www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

[31] Information from CESA.

manufacturer has no influence over this. Insulation behind a radiant grill will be beneficial for two reasons.

- Less energy is needed to maintain the high temperature of the radiating elements. This is valid for glowing electrical resistance wires and for gas heated elements
- Insulation is needed to minimise heat conduction to the external surface so that surface temperature is within safe limits.

Heat reflectors behind the radiating elements would help but will soon become dirty and ineffective. Cleaning would be very difficult.

Contact – heat transfer is by conduction and so food colour is not relevant. Insulation behind the heat source is important to reduce losses of heat by conduction to external surfaces from where it is lost by convection. It is likely that insulation will have a more significant impact on contact grill performance than radiant grill performance but for short cooking times, if a larger amount of insulation were used in contact grills, this may increase energy consumption as it absorbs heat. Therefore any grill energy consumption test must realistically reflect real cooking. This will be different for domestic and commercial catering.

- **Domestic outdoor grills**

Outdoor grill energy efficiency has been studied by at least one manufacturer using in-house testing based on measurement of total energy used and heat flux measurement. Different energy consumption measurement methods (developed by Charbroil) were used for gas and charcoal grills.

The manufacturer of domestic outdoor grills has provided test data based on their own in-house tests for gas grills and for charcoal grills. These tests measure efficiency based on total energy input (from weight of gas burned) and heat flux measurements. Results showed:

- **Gas grills efficiency varied between 15 – 40%**
- **Charcoal grills efficiency varied between 40 – 70%**

These figures indicate that there is significant potential for improvement in energy efficiency and reduction of CO2 emissions. Charbroil compared their in-house gas grill test with the tests used for Energy Star and although the numbers generated were different, the ranking of grills was the same.

- **Standby and low energy modes and power management**

Electric hobs and grills are regulated by EU Regulation 1275/2008 and so must have an off-mode, standby-mode or equivalent mode that consumes $\leq$1 watt (or $\leq$2 watts with a display) until 2013 when these limits halve. Normal use is to cook food and then switch them off except for some commercial hobs and grills used in restaurants, hotels, etc. which are often left on continuously during a working period. Automatic power management is very rarely fitted to grills and hobs except as a safety feature in some gas hobs. These automatically turn the gas off after a certain period of time with no changes to the controls.

4.5. USE PHASE (SYSTEM)

Hobs and grills are usually used inside buildings and the heat generated influences the temperature of their surroundings and can affect local energy use. Situations where this can occur include:

- In cool climates where buildings are heated (with thermostatic temperature control). Heat from the hob or grill offsets and reduces the amount of heat energy required to maintain the required ambient temperature.
- In warm climates, the heat generated by the hob or grill may raise the local temperature so that ventilation by fans or cooling by air-conditioning is required.
- In commercial kitchens, much more heat can be generated than in domestic kitchens so that air conditioning may be needed for staff comfort, even in cool climates although if excessive extraction is used, the kitchen may be quite cold in cool climates requiring additional heating.

The overall impact of heating buildings by a hob or grill in cool climates depends on the type of fuel / energy source used for building heating and for the hob or grill. If the building heating and the hob or grill both use natural gas as the energy source, the quantity of energy used and global warming gas emissions evolved (mainly CO_2) is, in principle, the same whether heat is from the building's heating or from cooking. Similarly, there would be little difference if the building heating and the hob / grill are both electrically powered. However, if the building is heated by natural gas, oil or coal and the hob / grill is electrically powered, there is a significant difference. The energy consumed to heat the building (using gas, oil or coal) will be less than the energy consumed to generate and transmit the electricity to operate the electric cooking appliance and provide an equal quantity of heat energy. This is mainly because of the inefficiencies and losses from electricity generation and transmission which overall is about 35%. Building heating efficiency using natural gas boilers tends to be 75 – 90% (highest with modern domestic condensing boilers). The relative CO_2 emissions are more varied as electricity is generated from a variety of fuels in EU. Published figures vary between 0.45kg CO_2/kWh[32] (for Europe) and 0.39 kg CO_2/kWh (2007)[33] (estimate for EU). Most of the electrical energy supplied to an electric oven is converted into heat which is eventually lost to the interior of the building (unless removed by fans or

[32] Carbon Monitoring for Action (CARMA), www.carma.org
[33] Eurelectric calculation

air-conditioning). Published figures for the amounts of CO_2 emitted from fossil fuels used for building heating are:

Table 4-24: CO_2 emitted per kWh of chemical energy from building heating by energy source[34]

Energy source	kg CO_2 / kWh
Natural gas (EU standard)	0.184
Oil	0.265
Coal	0.30

Comparison of heat from hobs or grills with heating using heat pumps is even more complex. Heat pump heating efficiency can be > 100% and some can achieve better than 300%. This means that >3kWh of energy is released inside the building for every 1 kWh of electricity consumed. Clearly heat pump heating of buildings is more energy efficient than heating using an electric cooking appliance which cannot exceed 100% efficiency but the difference to gas appliances depends on the heat pumps actual efficiency. The comparison of heat source for buildings described above ignores the location of the kitchen and additional ventilation required to remove odours and combustion gases where gas is used. This has however been studied by the UK Market Transformation Programme (MTP).

The so-called "heat replacement effect" has been studied by MTP[35]. MTP define the heat replacement effect as "the contribution to heating made by lighting and appliances in heated living space". This research shows that heat from appliances such as electric and gas ovens is generated throughout the year but building heating may be required for only part of the year (41% in UK). This MTP study includes ovens but not hobs or grills however the data from heat emissions from ovens should be essentially the same as heat emissions from hobs or grills which are used at the same locations in buildings with the same ventilation. Also, MTP state that for electric and gas cooking (ovens), ventilation is required so that only 60% of the heat is utilised within the building. They also find that the heat from cooking is generated away from the main living area so that only 75% is transferred to the living area. MTP calculate the heat replacement factor by multiplying these three factors = 60% x 75% x 41% = 18%. MTP have also looked at commercial buildings but there is very limited data and none for cooking. This data is appropriate however only for the UK and the system impact will be different in other EU States. In France, local ventilation is compulsory which will reduce loss of heated building air.

[34] MTP report BNXS01, 2010 and D. Mackay, "Sustainable Energy without the hot air", www.withouthotair.com/

[35] MTP report BNXS05 version 9.0 updated 15th March 2010.

Where hobs and grills are used in warm climates, the heat produced may have to be removed. This may only require an open window but ventilation fans or air conditioning may be required. The energy consumed will depend on the cooking time (for ventilation fans) and the amount of heat generated (for air conditioning). Commercial kitchens often have ventilation systems that exchange room air several times per hour and so in cool climates can result in the loss of a lot of heat energy which may be replaced by the building's heating system. This type of ventilation is most common where gas appliances are used. Better designed and more focused ventilation would reduce building heat losses overall as hobs and grills cannot be redesigned to reduce these losses as gas combustion fumes and cooking smells will always need to be removed from the cooking area.

The total energy consumption from cooking is often greater than the energy used by the hob or grill alone. The total amount of energy will depend on the hob and grill design. For example, covered hobs can be designed to draw in air from outside the building and expel combustion fumes directly outside of the building so that these have little impact on the energy used for building heating or cooling. Energy efficient appliances that consume less energy will also have a smaller impact on building temperature control energy than less energy efficient appliances. Other factors will affect overall energy consumption including the availability of ventilation, household size, social situation, climate, etc.

4.6. END-OF-LIFE PHASE

Cooking appliances such as hobs and grills contain a high proportion of metals. Once collected, they are usually shredded and then the metals separated for further treatment and recovery. Hobs and grills contain very little plastic but glass-ceramic is used in large quantities and if removed from hobs it can be recycled. Hobs and grills are within scope of the EU WEEE Directive which requires mandatory recycling of all end of life equipment once it has been collected by retailers, at municipal waste sites or by recyclers. As these tend to be relatively large, a high proportion are collected and recycled. Metals recovery yields are relatively high (>90% for steel, copper, aluminium).

4.7. RECOMMENDATIONS ON MANDATES

Although some standards for hobs and grills exist, some have limitations and there are none available for measurement of energy consumption for many types of appliance. The table below lists these existing standards and their limitations that impact on assessment of energy use.

Table 4-25: Existing EU Standards.

Number	Scope	Limitations / questions
EN 203-2-1	**Gas catering hobs** – measurement of gas to raise water temperature by 70°C. Efficiency for open burners must be >50%	Excludes covered burners – known to be less energy efficient No assessment of energy used for controlling temperature (simmering)
EN 30-2-1 & 30-2-2	**Domestic gas hobs and ovens**. Efficiency of open and covered hobs specified. Maintenance consumption of gas ovens specified – empty oven gas used to maintain specified temperature	Gas hobs limited to >1.16KW. Heating efficiency specified (as %) but not energy to maintain temperature Minimum efficiency of open burner is >52% but covered burners may be only 25% (a stakeholder claims these can achieve 50%)
EN60350	Electric **domestic** BI and standalone (range) **hobs** – Energy (Wh) consumed to raise temperature of water by 75K. Temperature of oil measured when minimum setting used	**Hobs**. Does not specify maximum consumption or efficiency. Temperature maintenance test does not assess ability to simmer water. Not applicable to **portable** hobs No **grill** energy assessment.
EN61817	**Portable electric hobs and grills**. Performance tests only. Includes test for ability to simmer (maintain 92°C (and not scorch)	Need energy consumption measurement procedures for portable hobs and grills.

- **Standards needed**

Energy consumption test methods and possibly also some efficiency / consumption limits needed for:

- Grills – all types, domestic and commercial, gas and electric
- Domestic electric hobs
- Commercial electric hobs
- Commercial covered gas hobs.
- Standards EN203-2-1 and EN30-2-1 include minimum energy efficiency requirements for commercial gas uncovered hobs and for domestic gas but no

requirements for covered commercial gas or all types of electric hobs. Also review of minimum efficiency allowed for covered hobs, which currently is much lower than uncovered hobs.

- Portable hobs – all commercial and electric domestic.

Significance

Energy labels must be based on standard energy consumption test method. They could be needed if number of appliances sold in the EU is significant and potential for improvement is large.

- Commercial hobs – No data available on sales (Prodcom codes are too broad scope) or energy efficiency. Numbers sold will be less than domestic but used much more intensively.
- Domestic portables – Prodcom data (for code 27.51.28.35) is 4 million consumed in the EU (includes portable hobs and grills)
- Grills – sales numbers very large – 10.5 million (Prodcom).

Test methods for energy consumption

- **Hobs** – test method needs to use realistic pot size and mass of contents for domestic products and for commercial products (which may be different). The sizes used must reflect the sizes of pots most often used in EU in domestic and commercial kitchens (then the hotplate / burner size designed to suit these sizes). The test for domestic hobs would include a heat up stage and a simmer stage. The length of the simmer stage should reflect real cooking processes carried out in EU. This time is uncertain and so it may be appropriate to use a slightly longer test period, perhaps >30 minutes so that the efficiency of simmering is more accurately taken into account so that the hob design that consumes least energy for all types of cooking process is shown to have the best overall performance in the test. One concern with tests that use average cooking conditions is that they may not identify the most energy efficient design for all cooking processes. For example, sensors that control temperature and special gas burner designs with much wider range of heat output may not appear better than standard designs.

  For commercial hobs, cooking times will be different but other considerations need to be taken into account. As it is common practice to leave burners on full power even when not used or for simmering (by moving pot to the edge of a covered burner) then some means of giving credit to energy efficient design should be used. For example, the energy consumed may be measured over a two hour period during which rapid heat up by 70°C, a period of 30 minutes simmering and the remaining hour not in use, this could be used as one type of assessment for commercial hobs. Commercial induction hobs and gas hobs with pot sensors and good simmer control should perform well by this test procedure.

- **Grills** – designing a realistic test is more difficult as there are so many different designs. Also, it is not clear what test load should be used. In the US standard an aluminium block is used and the energy consumed to raise its temperature by a predetermined amount is measured. Aluminium is however completely different in heating performance to most types of food and so may not give reliable data. In Japan, a black painted block of copper is used. A wet brick similar to those used for oven energy consumption tests in EU but having dimensions suitable for the grill may be more realistic but has not been developed or tested. Any test method for grills may need to express the energy consumption as KWh/unit area and may have to use test loads of various sizes designed to cover at least 90% of the grill area unlike with the domestic oven test where one standard wet brick size is used. One outdoor grill manufacturer has developed an in-house method as discussed in section 4.2.3.1. This uses heat flux sensors instead of a dummy load and finds that the same ranking of products is obtained as with the Energy Star test methods. They also compared these tests with the Japanese method and found a linear correlation between their in-house test and the Japanese test although with only three grills. Measurements could be made as Wh/m2 so that grills of different sizes can be compared. Grilling food is more complex that raising the temperature of water or a dummy load because there are surface changes that need to occur and these affect the adsorption of infrared radiation, i.e. browned meat adsorbs infrared energy more effectively than pale surfaces. This means that the energy consumed in tests that use metal blocks will be less than would be required for similar size food but the relative performance of grills may be the same.
- If energy labels are adopted for hobs and grills, they would be based on energy consumption in a standard test. Domestic and commercial appliance test methods and so labeling schemes would be different. Different tests (and so different labeling schemes) would also be needed for gas and for electric hobs. For grills there would need to be many more schemes, e.g. electric horizontal radiant, electric contact – one side, electric contact double sides and the gas equivalents of these. If toasters are included then a separate scheme a test for these would be needed. There does not however appear to be any technical reason to differentiate between portable and other appliances.

4.8. CONCLUSIONS

This task presented a general technical analysis of the existing products on the EU-market. It detailed the technical solutions used in domestic and commercial hobs and grills and their characteristics relevant for the distribution phase. It presented an analysis of their use phase both at the product and at the system level, and of their end-of-life.

As no energy consumption test standard or labelling obligation exists in EU, it is difficult to estimate the improvement potential of hobs and grills on the EU market. Data from the USA and Japan indicate that the energy performance of these products can vary significantly and it would be reasonable to conclude that there is an improvement potential in the EU. This should be quantified in task 6.

This information gathered in this report will serve as input for defining base-cases in task 5.

The British thermal unit (BTU or Btu) is a traditional unit of energy, commonly used in USA which is equal to about **1.06 kilojoules**. It is approximately the amount of energy needed to raise the temperature of one pound of water by one degree Fahrenheit.

The standard unit of energy in the International System of Units (SI) is the joule (J), equal to one watt second (1 watt.s = 1J) or inversely, one watt is equal to 1 J/s. One kilowatt hour is 3.6 megajoules, which is the amount of energy converted if work is done at an average rate of one thousand watts for one hour.

Also note:

The kilowatt-hour (kWh) is not a unit of power, it is a unit of energy.

The kW is a unit of power = 1000 W or 1000 J/s.

Energy = power × time

If we choose to measure power in kW and time in hours, we have:

Energy (kWh) = power (kW) × time (h)

Joules and Btu are also both units of energy and therefore Btu, MJ and kWh should be directly convertible. However, there are several complicating factor when considering the relationship between gas and electricity. Electricity has to be generated and this is only about 30% efficient from fossil fuel power plant. Also, there are four recognised types of natural gas in EU and some town gas is also used. These have different chemical compositions and as a result have different energy values as well as emitting different amounts of carbon monoxide. The standard energy consumption tests use "standard gas" to avoid inconsistent results.