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Lot 23

Domestic and commercial hobs and grills included when incorporated in cookers

Task 6: Technical Analysis BAT

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In association with

ERA TECHNOLOGY

ERA Technology Ltd

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6. TASK 6 – TECHNICAL ANALYSIS OF BEST AVAILABLE TECHNOLOGY (BAT)

This document is the Task 6 report of the DG ENER Lot 23 Ecodesign preparatory study on domestic and commercial hobs and grills. Task 6 comprises a technical analysis of the best currently available technology and technologies expected to be introduced at product level within 2-3 years. Research into the best existing products and components available on the EU-market and outside the EU are assessed.

6.1. STATE-OF-THE-ART IN APPLIED RESEARCH FOR THE PRODUCT (PROTOTYPE LEVEL)

As described in Task 4, hobs contain one or more electric hotplates and / or gas burners. New standards are being developed that will measure the energy consumption of domestic gas and electric built-in and free-standing hobs to give results that are irrespective of the number of hotplates and burners and this is based on a standard methodology and a calculation formula. These standards are not applicable to portable hobs or commercial hobs. Work on European grill standards are less well advanced although standard methods exist in Japan, in the USA for Energy Star and by at least one manufacturer. Standard tests always have limitations as it is necessary to use one standard method for all products on the market which is as close as possible to real cooking processes. However real cooking is very varied, especially with hobs and grills and these standard methods inevitably cannot compensate for the variety of cooking processes that are carried out. For example, hob energy consumption measurements use standard diameter pots whereas a wide variety of sizes will be used for cooking. Grilling food is even more complex as food is not only increased in temperature but caramelisation (browning) and sometimes also exposure to smoke are required. Although hob manufacturers main research efforts is into standby energy consumption reduction, research into methods of improving eco-design in the next 2 – 3 years could also be carried out on improvements to limit the sources of heat losses (without creating toxic gas emission from gas burners) and this can be assessed using the standard energy consumption measurement methods. These will not however assess the flexibility of each design, i.e. whether the efficiency is as high for all cooking processes or only for a limited range. The following describes the main sources of heat loss and research into novel eco-designs to reduce these losses.

6.1.1. HOBS

The energy efficiency of gas and electric hobs is dependent on two main factors:

- Transfer of heat to the cooking vessel and heat losses.

- Ability to accurately control heat output so that no more than is required is provided

Heat transfer to cooking pots is mainly user dependent as the cooking pot diameter, pot material and the use of a lid all affect heat losses as shown below.

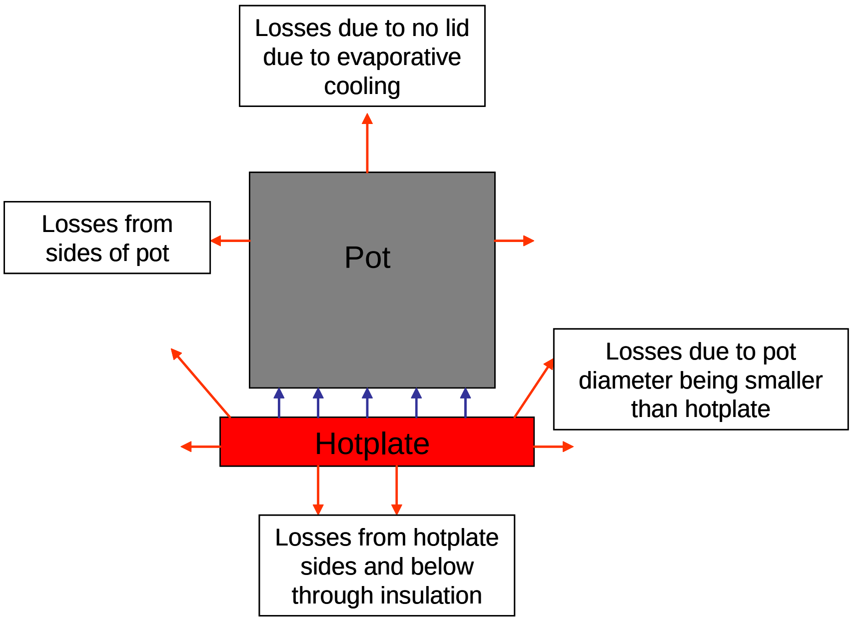

Figure 6-1 - Heat transfer (blue arrows) and possible heat losses (red arrows) from hotplate to cooking pot

For gas hobs, there is also the additional loss of heat in combustion gases that flow away from the pot. Ecodesign of hobs cannot easily control user behaviour such as choice of pots and use of lids but heat transfer efficiency and heat losses from the sides and below the hotplate can be improved by novel ecodesign. It is not possible to reduce heat losses from the hotplate area outside the area covered by pots that have diameters smaller than the diameters of the hotplate except for a few types of hotplate.

- **Gas** – All domestic gas hobs have uncovered burners but losses from gas are the most difficult to control as any heat not transferred to the pot is lost in the flue gases that flow around the sides of the pot. In fact pot design and size has a very significant impact on energy consumption. Losses from the sides and below the burner are relatively small however as heat transfer is mainly due to convection and radiation from the flames and hot combustion gases to the pot material. Pot materials are often not ideal as bright surfaces reflect infrared radiation and are poor heat absorbers whereas dark surfaces are more effective at adsorbing heat but also emit heat from the dark sides of pots. Distance between flame and pot is important (as shown in Task 4) but cannot be too small as this increases toxic carbon monoxide formation. Some commercial hobs are covered, either with metal plates or by glass ceramic and in these cases, good insulation below and to the sides of the burners are important. Covered gas burners are however less energy efficient than uncovered gas burners. One source of heat loss is the amount of excess air passing through the burner which can be minimised by burner design and is discussed in section 6.2.1.

- **Solid plate electric** – Heat transfer is via conduction and occurs only where contact occurs. Therefore if either or both the pot and hotplate are not flat, conduction will occur at only a few small areas and heat may be lost from the remaining hotplate area by convection. Heat losses from sides and below the hotplate should be prevented by thermal insulation and so losses can be reduced by improvements to this insulation (described below). Energy consumption is proportional to the mass of the hotplate although this is significant as a percentage of total consumption only with short cooking times.
- **Radiant electric** – Heat transfer is mainly by radiation from the radiant elements to the glass ceramic and then conduction to the pot / hotplate. Contact between the glass ceramic and potis important although the glass ceramic will not distort and remains flat and so would make better contact to the pot base than a distorted solid plate. Infrared radiation is emitted in all directions from the radiant element but only that which reaches the glass ceramic below the pot is utilised and so internal reflection of radiation is important And so the proportion reaching the glass ceramic below the pot is improved by using reflective surfaces below the hotplate. The sheet of glass ceramic material keeps the internal reflective surfaces clean. The glass ceramic has a low thermal conductivity and so little heat is lost by conduction away from the area above the radiant heaters and beneath the pot but the glass ceramic is transparent to a high proportion of the available infrared heat radiation so some pot heating from infrared radiation must also occur. The glass ceramic beneath the pot does become hot and acts as a reservoir of heat which causes a time lag in the response to adjustment of the hob's controls but this is faster than with solid plate hotplates.
- **Induction (electric)** – Induction heating is different to other methods as heat transfer does not occur. Power is consumed only when a susceptible metal (magnetic steel) is close to the RF inductor coil (which is in the cooker hotplate). Therefore if the pot is much smaller than the inductor coil, there are no heat losses from the sides. Also, if the pot is removed, power consumption drops to the "no-load consumption" level. Losses will occur after a period of use as the pot becomes hot and it will loose heat. The glass ceramic hob top will also become hot by conduction from the hot pot and this is also a source of lost heat. However there is little scope for improvement in energy efficiency of this type of hotplate as most energy losses are heat from the RF circuitry which according to CECED has very little scope for improvement. There are very few manufacturers of induction hob power supplies (only a few hob manufacturers design their own) and CECED report that there is only a small range in electrical energy efficiency due to small differences in technology.

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Heat controller accuracy is also important for all types of hob because there are unnecessary heat losses if too much heat is applied. Control is also important to prevent losses occurring due to the hotplate or burner applying heat without being in use as sometimes occurs in commercial kitchens and can also occur in domestic situations if the user forgets to switch off after use. All hotplates and burners operate within a range of energy output. Some have continuous control and others have a number set output levels. Continuous control will be better if fine control is possible and controls with many set levels are better than those with only a few. Controller accuracy is also important so that once a level is set, heat output is constant and does not vary.

One of the main difficulties with domestic hobs is being able to heat up rapidly and simmer both large and small pots with only a limited number of hotplates or burners. Hobs with four hotplates /burners are common and are sold in EU with various size options but commonly are:

- One large for fast heating large pots and also used for frying.
- One or two medium size which should be suitable for simmering as well as faster heating
- One or two small size which consume least energy and are designed for simmering

It is therefore often impossible to simmer four small pots or rapidly heat four large pots. The solution to this problem is to provide a very wide range of heat output for each hotplate / burner but some designs are not able to provide this.

- **Gas** – minimum heat output is limited by flame size and should comply with the "Resistance to draught" test within the EN30-1 standard., if this becomes too small they can blow out and so the heat output range of standard gas burners is limited. Flame supervision devices are used for safety to turn off gas if they detect that the flame has blown out. However, they will also switch off gas if the flame is too small. Dual and triple ring burners are available for some models but most of these are single gas controls and are designed only for high heat output (as wok burners). However in a few burner designs, it is possible to control each ring separately so as to obtain much wider output control for one burner but these are very uncommon in the EU. This design also enables large and small pots to be used on one burner by selecting only the inner ring for small pots and using all rings for large pots.
- **Solid plate electric** – heat output is controlled by the current passing through the resistance coil and is transferred by thermal conduction to the pot where there is physical contact. Although heat input can be controlled over a wide range, response times are slow because the solid plate has a high thermal mass and heat conduction to the pot is usually restricted to a small area due to poor flatness of both the pot base and plate surface.

- **Radiant electric** – infrared radiation emission relies on a high temperature of the radiating elements and so it is not possible to reduce the heat output over a wide range by reducing the current supplied alone. Heat output is controlled however by switching power on and off as required to achieve the desired heat output. Response times are faster than solid plate because the heat capacity of the glass ceramic is less than sold plate.
- **Induction electric** – heat output is easy to control as the power to the induction coil can be regulated over a wide range by the control circuitry. Simmering is straightforward and response times are fast.

6.1.2. GRILLS

Heat losses from gas and electric grills are similar to those from hobs except that heat transfer is from the grill to the food without passing through a cooking vessel. There are two types of grill, contact which transfers heat mainly by conduction to the food and radiant which transfers heat mainly by radiation although convection also occurs.

- **Contact grills**

The diagram below illustrates where heat may be lost from single sides and double sided contact grills.

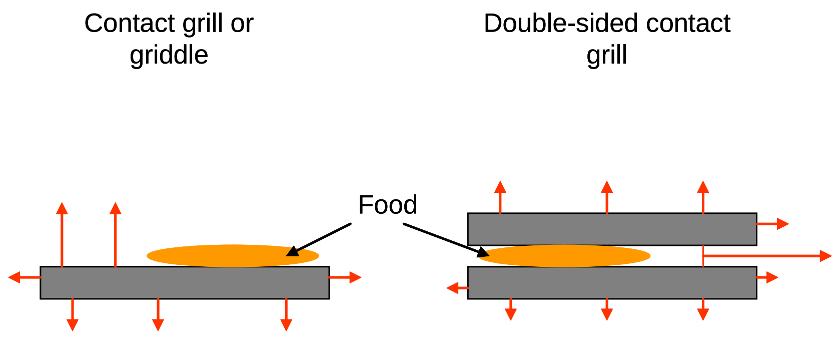

Figure 6-2 - Illustration of heat losses from contact grills – red arrows

Domestic contact grills are mostly electric but gas contact griddles and grills are used commercially and so heat losses from hot flue gases also occur and this depends on the effectiveness of heat transfer between these hot gases and the grill surfaces and the amount of excess burner air.

Heat losses from the sides and below the grill / griddle surfaces are prevented by the use of thermal insulation and so can be improved by using more effective insulation materials. Insulation technology is discussed below. Heat losses will occur from areas of the grill that are not covered by food and this can be limited by providing heat controls for more than one area of the grill or by special coatings such as the one produced by Electrolux. Electrolux markets a commercial contact grill with a special coating that limits heat loss by radiation (Ecotop) and so heat transfer occurs mainly by conduction where the grill touches food. Electrolux claims that this coating can save up to 60% in energy costs[1].

Commercial contact grills are made with thick steel plates as food contact surfaces. These require a lot of heat to reach their operating temperature but this is needed for two reasons; i) to prevent distortion due to differential thermal expansion between hot and less hot areas and ii) so that the temperature does not drop significantly when food is placed on the hot surface. These grills will consume a lot of energy during heat up due to their high thermal mass but as they are left on for long periods (e.g. 8 – 12 hours), this will be a relatively small proportion of the total daily energy consumption which will be due mainly to heating of food and heat losses from the hot upper grill surface and there will also be smaller losses through insulation. This is quite different to domestic contact grills which are not left on for long periods and so energy for heat up is a more significant proportion of total consumption. Separate heat zones are uncommon with contact grills as heat will be conducted along the metal surface. Some contact grills have more than one separate heating plate so that only those that are needed are heated.

- **Radiant grills**

Heat losses from non-contact grills are similar as shown below.

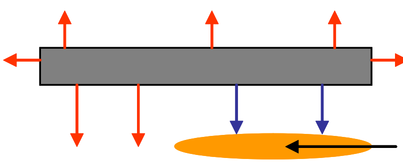

Figure 6-3 - Heat transfer to food (blue arrows) and heat losses (red arrows) for a radiant grill (or commercial salamander grill)

There will also be heat losses from hot combustion gases with gas grills. There are several types of non-contact grill. Domestic grills usually have either gas or electric heat sources above the food being cooked and these are referred to as “radiant grills”. This arrangement is also used in commercial grills which may be gas or electric but are called “salamander grills” in EU (broilers in USA). Commercial radiant grills are different designs to domestic and are essentially the same as radiant hobs with electric radiating heaters below a glass ceramic sheet on which food is placed (i.e. no pan). Domestic radiant and commercial salamander grills will have heat losses from external surfaces, i.e. the sides and above heat source which are covered by thermal insulation but heat

[1] http://www.electrolux-professional.com/index.asp?o=n&c=n&a=&n=3703

lost to areas below the grill with no food as shown in Figure 6-3 (red downward arrows) cannot be prevented except by providing controls for multiple heated areas. Home owners will use controls to heat only areas of grills that are needed if available but in commercial restaurant and hotel kitchens it is common for all zones to be on at full power continuously irrespective of need. The efficiency of heat transfer by radiation relies on a sufficiently high temperature to generate infrared radiation as at lower temperatures, heat transfer is by convection which with the arrangement in Figure 6-3 will not be particularly effective as hot air will flow away from the food (sideways then up, but not down). Barbecue grills (or outdoor grills) cook food on supports with the heat source below the food. Natural gas, LPG, electricity and charcoal are used in this type of grill.

- **Grill Energy consumption**

Heat consumption by grills depends on heat output control accuracy and the variability in output power. Some grills on the EU market are either on or off with no heat control possible. Some have continuous control but most have a number of present levels, although usually only a small number with domestic grills. Commercial grills may have more preset levels but these are often used at full power continuously.

Heat radiation sources used for radiant hobs and radiant grills are usually hot metal surfaces such as glowing hot metal wires that emit infrared radiation in all directions. Much of this radiation travels in directions away from the food and so as a result would be lost heat energy. Reflective surfaces behind the heat source will reduce heat losses as long as they remain clean. Polished metals such as aluminium are very effective and will reflect as much as 99% of infrared energy but when contaminated with food, etc., the dirt is very effective at adsorbing the heat and so the reflective properties decline if the surface does not remain clean. In radiant hobs, the reflectors are protected from dirt by sealing the heating components under a sheet of glass ceramic but this is not used over domestic radiant grills or commercial salamanders because the glass-ceramic adsorbs some of the heat energy which is not transferred to the food. Technology to maintain clean reflective surfaces does not yet exist for grills. Novel coatings on window glass are available but these rely on ultraviolet light from sunlight to degrade organic contamination before it can be washed off by rain[2].

- **Outdoor barbecue grills**

Research by outdoor grill manufacturers has shown that energy consumption can be improved very significantly by changes to the equipment design so that energy consumption can be reduced by as much as 50% for gas outdoor grills. The most important design features for minimising energy consumption are:

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[2] Pilkington's website for self cleaning window glass http://www.pilkingtonselfcleaningglass.co.uk/how-it-works/

- Lids and lid design – as heating is from below and hot air rises, the use of a lid will retain heat around the food. As water vapour is produced, a vent is needed to prevent and this is sized to retain as much heat as possible but avoid carbon monoxide formation or excessive steam build-up. Grills with lids could be considered ovens as they are enclosed chambers that cook food. The design of the lid is also important and research has shown that these should have two metal layers with an air gap between these. The size of the air gap is an important variable for minimising heat losses and the use of reflective metal (e.g. aluminised or stainless steel) for the lid reduces radiative heat losses although most manufacturers of outdoor grills use black porcelain coated steel which is an excellent heat emitter. One manufacturer has investigated the use of thermal insulation within the lid air gap but found that this gave only a very small reduction in energy consumption compared to an optimised air gap.
- Design of "fire box" that contains the gas burners – research has shown for gas outdoor grills that the enclosure of the gas burners needs to have two or three layers of metal with optimised air gaps to minimise heat losses similarly to the lid design. Research also showed that thermal insulation gives relatively small improvements
- Combustion air control – Gas requires a stoichiometric amount of oxygen for complete combustion. Any additional air causes a loss of heat as this air dilutes and cools the combustion gases. Usually a small excess of oxygen is necessary to avoid carbon monoxide but this can be minimised by the burner design. Efficient combustion with minimum excess air requires good mixing of the gas and air and this is less effective with large flames that are produced by large size ports in the burner. Many small ports producing many small flames gives more efficient mixing so that there is less secondary air to cool the combustion gases. This is also discussed in section 6.2.1.
- Cooking zones – users can reduce energy consumption by heating only the grill area needed and this is possible if many separate independently controlled heat zones are available. It is common for outdoor gas grills to have 3 – 6 separate gas burners but usually these are not separated inside the fire box so that heat flows from the zone in use to the other zones and no heat saving is made. The use of double wall baffles with suitable air gaps prevents sideways heat losses so that energy consumption is reduced.

Several of these design innovations will be applicable to other types of grills and indicate that significant reductions in energy consumption will be achievable.

6.2. STATE-OF-THE-ART AT COMPONENT LEVEL (PROTOTYPE, TEST AND FIELD TRIAL LEVEL)

Research into the ecodesign of hobs and grills has focussed on gas burner and electric hotplate design and heat control. Research into hob and grill components is described here.

Most research is carried out by manufacturers and not published except as patents but a few independent studies are available although they are now several years old. According to hob manufacturers, however, hobs and grills on the market in 2010 have similar energy efficiency as ~15 years ago. The US Department of Energy has investigated new technology for domestic and commercial cooking and this includes domestic hobs and commercial hobs and griddles. The table below summarises their main findings[3] .

Table 6-1 - Summary of results from US Department of Energy assessment of cooking equipment technology.

Application	Technology	Conclusions
Domestic gas burners	Catalytic burners	Flameless combustion generates infrared heat. Lower NOx emissions but not commercialised
	Electronic ignition	Replaces gas pilot lights and mostly high voltage spark used in EU which has very low energy consumption. New ceramic hot surface igniters introduced for gas flames cycled on and off to control simmering.
	Insulation	US study concluded that this is used only for safety, has no effect on energy efficiency
	Radiant gas burners	Tests showed that infrared-jet burners are 16% more efficient but not yet commercialised. A "silicon carbide fibre" burner showed in tests to be ~15% more efficient than conventional burners. However there are technical problems with this technology and so it has not been commercialised. Ceramics are brittle and easily damaged and so this is viable only with covered burners tend to be less energy

[3] US DoE report on appliances in buildings, from http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/home_appliances_tsd/chapter_3.pdf

		efficient. Another limitation is the very poor energy output range so simmering is very difficult to achieve.
	Reduced excess air at burner	Concept that should improve efficiency but no designs available. Need to ensure carbon monoxide is not generated.
	Reflective surfaces	Aim is to reflect radiated heat but most heat transfer from gas flames is by convection so this has a negligible effect.
	Sealed burners	Test results show an improved energy efficiency but the extent is unclear
	Thermostatically-controlled burners	Not new technology which relied on user attaching external sensors to pans correctly which was not popular with users. Safety sensors to detect over-boiling are used in Japan but not in the EU. A new design available in EU is described in section 6.2.1.4
Domestic solid plate	Electronic controls	Danish research found significant energy saving when cooking European recipes. Relies on temperature controllers that prevent overshooting the maximum temperature however these are not used with solid plate hotplates in the EU.
	Improved contact conductance	Improved element flatness improves energy efficiency as long as the pot base is also flat, however they are often not flat so no benefit is achieved.
	Insulation	Insulation is used for safety reasons but US DoE have no data on whether it improves energy efficiency
	Low-standby-loss electronic controls	Cooking appliances are in scope of the EU standby regulation but the solid plate hotplate itself is either on or off so consumes no energy in standby. Improvements possible only if ancillary functions such as clocks are used.
	Reflective surfaces	Improvements of only 1% attained.
Domestic hobs with "smooth surfaces"	Electronic controls	The same benefits as are achieved with solid plate hotplates would be expected (except for induction hobs)

	Halogen elements	Uses infrared lamps or various designs. Limited data available but indications that efficiencies superior to solid plate are achieved
	Induction elements	Clear advantages and tests showed that an absolute energy efficiency of 84% is achievable.
Commercial radiant grills (broilers) and contact grills (griddles)	DoE found from limited data that over-fired gas grills (salamanders) were less energy efficient than electric although electricity generating losses may mean that gas has a better primary energy efficiency. DoE found however that contact grill energy efficiency was significantly higher than the equivalent radiant grill.	

CECED has provided information on BAT (currently available best products on EU market) and BNAT (new technology being developed) of domestic hobs. The information from CECED is provided in the table below.

Table 6-2 - CECED options for BAT and BNAT of domestic hobs

Type of hob	Technology	Impact	BAT or BNAT
Gas	Optimised mass of the pan support	Would have only a minor impact as supports must comply with safety requirements	BNAT
	Burner design	Burner outlet shape allows smaller flames but at higher cost (1 - 3% energy saving).	BAT
	Electronic controls	Allows lower temperature for simmering, minor energy impact (1 - 3% saving)	BAT
Solid plate	Siliconite (SiC) radiant	SiC has a very high thermal conductivity but this is no benefit if the pot does not also have this. High implementation cost and unresolved technical issues	BNAT
	Reduction in mass	~1% reduction possible	BNAT

		but no R&D because this is a declining market	
Radiant	Electronic controls	More accurate controls with many levels could save up to 3% of energy. Already available on best products	BAT
Induction	Switch from solid plate or radiant to induction	Significant annual energy saving possible (10 - 15%) due to the technology switch from solid plate electric hobs	BAT
	Optimisation of controls and standby energy consumption	Smaller improvement possible	BAT
All types	Pot sensors	Used on a few models that have electronic controls. Used to avoid wasting energy when no pot present	BAT
	Automatic cooking	Electronic control of cooking temperature to avoid over-heating. Would prevent poor control by user but not credited by EN standard.	BAT Option for hobs with electronic control

Heat losses from hobs occur for four main reasons:

- Using too small pot and no lid – user behaviour may be influenced by cooking sensors or energy consumption indication
- Cooking for longer than necessary – user behaviour may be influenced by cooking sensors or cooking programs with automatic switch off.
- Inadequate control of heat output – electronic controls and superior gas burner designs
- Poor insulation behind and to sides – relevant mainly for solid plate and radiant

Hobs with integral cooking sensors are sold in only very small numbers and are considerably more expensive than standard hobs. However, manufacturers estimate that these can potentially save 30% of energy or more when used. It is not currently possible however to give credit for this function with the proposed standard hob energy consumption measurement method that is currently being developed.

Losses occur with solid plate and to a lesser extent with radiant due to the delay in reducing heat output after the controls are altered. This is due to the thermal mass of the materials. All types of electric hotplate can have wide heat output ranges if analogue variable controls are used although some have a number of settings available with the controller and so control accuracy depends on the number of levels. In general, most types of electric hob are able to simmer most pot sizes although it is not safe and energy efficient to use pots with diameters less than solid plate or radiant hotplate diameters. Standard gas hobs have limited power output ranges with typically a turn-down ratio of 8:1. Simmering with pots that are smaller than the burner is designed can be difficult or impossible although several novel designs have been developed that have wider heat output and as these can simmer under a wider range of conditions, these will reduce overall energy consumption. However the standard hob energy consumption measurement method that is currently being developed cannot easily give credit for these design benefits. These novel designs are described below.

6.2.1. Hobs

6.2.1.1 Gas hob burner design

There are several advanced commercial and domestic gas burner designs on the market and there are also patents describing novel designs which have not been commercialised.

- **Domestic sector**

The majority of gas burners in hobs sold in the EU are of one similar design which has a ring of gas flames that are controlled with a single gas valve controller. Gas and air are premixed and combustion requires secondary air to completely burn the hydrocarbons to CO_2 and water vapour. The best designs have improved control of the orifice size that enable very small flames to be produced that are less affected by draughts and so comply with the draught requirements of EN 30-1. This gives a wider range of heat output so that simmering can more easily be controlled. Some burners have two or three rings of flames. Wok burners are of this type and are intended for higher heat output and all of the rings are controlled together. As mentioned in Task 4 however, the most controllable gas burners (widest range of heat output) are dual and triple ring burners where each ring can be controlled separately. This is available in the EU for both domestic and commercial burners but is extremely uncommon. Several patented designed have been published[4].

One US hob manufacturer (Dacor) achieves a very wide range of energy output by fans that control the flow of gas and can achieve lower flow rates and energy output as low as 100 Wh. This technology is not available in the EU as it does not comply with European safety requirements. In the EU, gas burners have flame supervision device which would normally turn off gas when very low heat output occurs. In the EU all products are obliged to incorporate a thermocouple to detect the flame and turn the gas flow off whenever the flame is too small. This technology is therefore not transferable to the EU market without significant design modifications.

Another hob manufacturer (BSH Home Appliances) cycles the gas flame on and off which can give heat energy as low as 60 Wh (e.g. cycles with gas on 10 seconds followed by gas off for 50 seconds). These designs are available in the EU but are very uncommon and are not marketed in all EU States.

Gas burners need to be designed to ensure that the gas / air ratio is close to stoichiometric for complete combustion of the gas without forming carbon monoxide. If there is too much secondary air, this cools the flame and dilutes the hot combustion gases so that heat transfer to the pot is less efficient. Much of the heat will be lost as warm gas flowing around the sides of the pot. Control of gas / air ratio is well understood by the industrial furnace industry where 15% excess air is regarded as optimum for minimising energy efficiency and that as the amount of excess air increases, gas consumption needs to increase to compensate. Gas hobs need to have variable heat output and this creates makes burner design more difficult as the gas and air flow both need to be controlled to maintain an optimum energy efficiency. An example for an industrial furnace shows that by reducing excess air from 20% to 5%, gives a reduction in gas consumption of at least 10%[5] although savings at lower temperature may be lower.

- **Commercial sector**

Commercial hob design is different to domestic. In general these are larger but there are also novel designs

- Duoflam[6] - These are atmospheric gas burners that are designed for highly efficient operation utilising the impingement principle. This is intended to give improved heat transfer to the cooking pot and entails the introduction of secondary air above the gas orifice. These burners also develop a very high flame temperature with low gas pressures, thus providing large volumes of heat in confined spaces. The manufacturer states that they operate with a

[4] Two examples are: "Gas burner", US Patent Application US 2007/0218414 A1, "Improved gas burner", WO 2009/053125 A1

[5] Energy efficient design and operation of fuel-fired furnaces by Bob Tucker 2008, from http://vesma.com/tutorial/furnaces.htm

[6] Flamaire gas burner manufacturer's website: http://www.cateringburners.co.uk/duoflam.htm

permanent pilot facility, require no adjustment and have a turndown of 90% with absolute safety.

- Electrolux commercial "flower flame" gas burner - is a design of burner that generates a flame that has a size that can be adapted to a wide variety of pot sizes without the excessive heat losses that would normally occur when a small diameter pot is placed on a large gas burner. This burner design can be used with pots with an unusually wide range of sizes from 10 – 40 cm diameter.
- Electrolux patent W097/47927 (issued 18/12/2007 for C. Eskildsen and P. Östlund) described a different type of design for a gas hob. In this design individual flames can be controlled via individual pipes to each burner orifice and the required space for this is provided by directing the flames from the outside and towards the centre of the cooking vessel. The orifices are positioned in the sides of channels which provide the air supply and exhaust of burnt gases. The channels are formed in what is otherwise the larger flat top of the hob.
- Flameless combustion **-** Flameless combustion is used in industrial gas furnace burners as this gives more uniform heating and can have better energy efficiency. This is not currently used in hobs or grills although there has been research into flameless burners for hobs[7].
- Research has been carried out into catalytic combustion of gas / air mixtures which are claimed to be more energy efficient[8] but this does not appear to be used yet in gas hobs placed on the EU market.

6.2.1.2 ELECTRIC HOTPLATES

Of the three main types of electric hotplate, induction is the most energy efficient. During heat up this is very significant (see Task 4) but if simmering is also considered, then they are on average, about 15% better than radiant or solid plate types. They also have the advantage that power consumption is low when no pot is present, even if they are switched on at full power as is common in commercial restaurant and hotel kitchens.

6.2.1.3 GLASS CERAMIC HOBS

Radiant and induction hobs are covered by sheets of glass ceramic. This is used as it is easy to clean and has a low thermal conductivity to prevent conductive heat losses

[7] J-C. Pivot, "Catalytic combustion structure in an induced air catalytic burner", UK Patent GB 2347362, September 2000.

[8] "Autonomous Urban Development, draft final report" April 2001, EC Contract 99-286, www.york.ac.uk/inst/chp/hsa/papers/rudlin.pdf

from cooking pots. It has a very low or zero thermal expansion coefficient and so no stresses are imposed between hot and cool areas and also important for radiant hobs is that they transmit a high proportion of infrared energy from the radiant elements to the pot base. The best glass ceramics have thermal conductivity coefficients of ~1.5 W/mK and transmit up to 90% of the infrared energy between 500 and 2500 nm (near infrared) but a lower proportion at longer wavelengths (medium infrared). Most of the heat energy from radiant elements is in the near infrared range but there is also some medium range infrared (2500 – 5000nm) where transmissivity is lower. Stakeholders believe that there is no scope for improving the performance of the glass ceramic materials used on hobs.

6.2.1.4 HEAT CONTROLLERS AND SENSORS FOR HOBS

- **Domestic hobs**

Hob energy consumption is minimised by avoiding heat losses due to

- Heating without a lid where one could be used (i.e. not for frying, etc)
- Reducing power later than necessary
- Setting the power setting too high
- Cooking for longer than necessary

Tests by one manufacturers (BSH) found that not using a lid, reducing power too late and setting power levels too high each typically wastes 10% more energy than needed, i.e. 30%. Cooking for longer than necessary wastes an additional 10% every 10 minutes[9]. Automatic temperature controllers that adjust power levels automatically avoid too high power setting and also encourage users to use lids as this removes the need to see the contents of the pan. Timers and buzzers either alert users to the need to switch off or do this automatically. There are currently several automated sensor systems sold in the EU. The BSH design[10] that combines these features having an infrared sensor that measures temperature and a timer / buzzer alerts users to the end of cooking. Research into infrared sensors with thermopile detectors that are integral to the hob was published in 2003[11]. This type of cooking sensor can give a reduction in energy use by modifying user behaviour but will not be demonstrated by the currently proposed standard hob energy consumption measurement methods. Although the overall energy saving could be <30%, this is applicable only for heating water based food and is not applicable to frying although frying sensors are also available. It also depends on how well the cook normally controls energy consumption without the

[9] Information provided by BSH
[10] Bosch Cooking Sensor Plus
[11] U. Has, J. Schieferdecker and D. Wassilew "Infrared sensors to control temperature of pots on consumer hobs", DIAS Infrared GmbH – publication No. 3, 2003.

sensor and so 30% is a maximum figure although 10 – 20% is not unrealistic. The actual saving depends on normal user behaviour and so will vary considerable although it is not known how much energy this type of sensor could save if it were to be widely used in the EU. Other automated cooking sensors include Siemens (infrared cooking sensor and a frying sensor), Bosch (also supply a frying sensor) and Whirlpool (boil detection sensor).

BSH and MSX (who have developed another type of cooking sensor) claim that their cooking sensor technologies save about 30% energy compared to cooking with average manual control... BSH and other brands of cooking sensors (but not yet MSX) are available integrated into hobs sold in the EU. The MSX sensors operate in a different way to others on the EU market using a combination of sound and temperature and sometimes also pressure with algorithms to control heat input. When water (and water-based liquids such as milk) nears boiling, the formation of steam bubbles creates sound that is detected by the sensor within the hob. Additional sensors placed on pot lids or handles that are connected wirelessly to the hob sensor control unit give more accurate control. Cooking sensor systems are designed to be integrated into the electronic control circuitry and sio can be used with gas and all types of electric hobs (both domestic and commercial). Independent tests of the MSX sensors have been carried out by VDE in 2009[12]. VDE used a non-standard MSX in-house test method because several hob manufacturers have said that the standard method currently being developed by CENELEC for hobs is not able to show a the benefit for any type of heat input control sensors that are currently on the EU market in a realistic and repeatable way when compared to manual control. VDE's tests showed that the sensor could reduce energy consumption by over 50% although the true figure depends on how precisely the user of the hob is able to control it manually.

- **Commercial hob controllers**

Gas hobs tend to be left on continuously in commercial kitchens but pot sensors are available from several manufacturers which automatically switch off the flame when the pot is removed and automatically switch it back on again when replaced. Electrolux's product is Ecoflam and flame re-ignition is with a gas pilot light and Rosinox has a design where the metal of the pot makes a circuit which causes the burner to ignite[13]. Rosinox accept that the sensor can become contaminated and so they are designed to be easily removed and cleaned. Ego Elektro Geraetebau have patented a pot sensor control system that reignites the flame when the pot is replaced but at a lower power level for a short period of time before returning to the original power level. This is designed to prevent burns to users[14].

[12] VDE report download from MSX website http://msxtech.com/independent-testing/
[13] Manufacturer's website www.rosinox.com/actualities/actu.asp?a=28
[14] "Method for controlling a cooking point of a gas oven and device", M. Baier, US Patent US201039987

6.2.2. Grills

- **Grill design – domestic and commercial**

As described in section 6.1.2. there are many types of grill. These are relatively simple in their design in that there is a heat source that relies on radiation or conduction to transfer heat to the food. The sides of the heat source away from the food are insulated for safety reasons and this may also improve energy efficiency. Some heat losses will occur through insulation but most is from surfaces not in contact with food as described in section 6.1.2. Heat losses from commercial contact grills are prevented by using bright chromium plated steel which is poor radiator of heat and special coatings are also used. Simple ways of minimising heat losses are by having a wide range of temperature control and by separate control of many small heated areas of the grill. Domestic grills usually have only limited heat output settings and only one or two heat zones but commercial grills can have better control and more heat zones although this varies considerably. Unfortunately in commercial restaurant and hotel kitchens, due to the urgency in delivering cooked food, chefs tend to leave all grill zones on full power continuously to avoid the delay in heat-up, even though in some products, this is not very long. For example, Rollergrill have recently introduced a salamander grill that heats up to 400°C in 9 seconds and have several models that reach cooking temperature within 20 seconds[15]. Grill energy consumption is largely dependent on the overall design although component design is also important.

As described in section 6.1.2. gas burner design for outdoor grills can be improved to reduce energy consumption by changing the port size to improve gas / air mixing and this reduces heat losses from heating secondary air. Optimisation of the gas / air ratio is important for all types of gas burner, for grills and also for hobs. Obtaining consistent gas / air mixing with hob burners is more straightforward as the burners are round so the inlet to port distances are all the same. With hobs there are several innovations published for example using venturies for efficient gas /air mixing. Grill burners tend to be fairly simple designs often with only one air inlet but multiple gas ports. This can cause variation in the gas / air ratio for individual ports resulting in reduced efficiency. As it is essential to prevent carbon monoxide formation, all ports must have sufficient air and so if the gas / air ratio varies, then some will have too much secondary air causing heat losses. Separate correctly sized air inlets for each gas port should give better and more accurate mixing but there is no data available on how significant the energy saving would be.

Reduced flame and combustion gas temperature due to excess secondary air causes lower energy efficiency because heat transfer is less efficient. Radiant grills transfer heat by a combination of radiation and convection. Radiant grills above food will mainly be by radiation as hot gas tends to flow upwards but convection heating is more important where the heat source is below the food such as in outdoor barbecue grills.

[15] Manufacturer's website: www.rollergrill.co.uk e.g. model SEM 600VC

Research by Charbroil has found that most gas outdoor grills transfer heat as 50% radiation and 50% convection. Research has shown that by altering the ratio to 75% radiation and 25% convection, less heat is needed to grill food (reduced from ~12 KW to ~10 KW). This ratio can be manipulated by burner design for gas but also by electric radiant heaters of grills. Radiant heat may be more efficient for grilling food than convection as heat transfer is linear to the food. With convection, hot gases are able to flow away from the food and be lost. Radiation is most effective with dark surfaces and so will become more efficient for grilling once some browning has occurred and convection heating may be needed top achieve this in the early stages of grilling.

6.2.3. Hobs and Grills

6.2.3.1 Thermal insulation for hobs and grills

The benefit of thermal insulation for hobs and grills is mainly for safety to prevent external surfaces from becoming too hot. As heat transfer is from the hotplate / burner to the food is directional, i.e. mainly by conduction or by radiation this heat is not affected by insulation around the other sides of the heat source. However in some applications, retaining the heat within the heat source will improve energy efficiency. Solid plate electric hotplates and contact grills become hot from the heat source (electric resistance heating or gas burners) and this heat is transferred to the food or cooking pot. Any heat lost is not available for cooking and so thermal insulation is important for these cooking processes and so will affect energy efficiency. Insulation is also beneficial for radiant heat sources as these rely on achieving and maintaining a high temperature and so less energy is required if heat is not lost from the sides away from the food. Thermal insulation prevents heat losses by having a low thermal conductivity. However, insulation does adsorb heat and with shorter cooking times can adsorb a significant amount of the heat generated. The amount of heat adsorbed depends on its heat capacity which is largely dependent on its density and so low density materials are preferred. For short cooking times, a low heat capacity of the insulation is most important whereas for long cooking times, low thermal conductivity is more important. Mineral wool is the most commonly used insulation in cooking equipment as it has a relatively low heat capacity and thermal conductivity. There are however materials with superior thermal conductivity but these are more expensive and some are not effective insulation at high temperatures as they are optically transparent to infrared heat radiation. Some examples are:

Table 6-3 – Thermal conductivity of high performance insulation compared to mineral wool

Material	Thermal conductivity
Mineral wool	0.04 W/mK at 25°C (0.1 at 350°C)
Microtherm (silica-based)	0.02 W/mK at 100°C
Aspen Pyrogel	0.02 W/mK at 25°C

Increasing insulation thickness reduces heat conduction but the larger mass of insulation increases its heat capacity.

6.2.4. GAS IGNITERS FOR HOBS AND GRILLS

All domestic ovens have electric high voltage spark igniters in EU. However commercial hobs with pilot lights are very common as these are viewed as being more reliable. Some stakeholders have said that automatic electric ignition is less reliable due to the higher temperature that the electronics would experience in commercial equipment than in domestic. A search of published data revealed that at least one EU manufacturer offers automatic electronic ignition of gas burner hobs as an option although pilot lights are standard[16]. Many commercial gas oven burners use automatic high voltage ignition without pilot lights and the temperature of the electronics should be the same as for hobs. Several manufacturers produce automatic control systems. And these are commonly used in EU as gas boiler igniters but one US manufacturer states on their datasheet that these are suitable for commercial catering[17]. The datasheet states that the electronics are suitable for use at up to 80°C which should be suitable for most hobs and grills as long as the circuitry is located at a suitable location. The main reliability concern with high voltage spark igniters is dirt that can build up on the spark electrodes. This can create an ionically conducting pathway that allows the high voltage to pass without generating a spark. This can also occur in domestic hobs but these are not as heavily used and the burner area is usually cleaned regularly so that dirt build up is less of an issue. High reliability is very important to commercial hob users who have to cook food quickly on demand and gas burners failing to light would cause delays. In commercial restaurant and hotel kitchens, as mentioned previously, there is a tendency to leave gas burners on continuously so failure of spark igniters would not be a significant issue. However failure of the spark is an issue under two circumstances; i) some chefs, especially those who are also the owner and so pay energy bills do turn off gas when not in use and ii) gas hobs with pot sensors require frequent re-ignition.

[16] Available on Royal Chef Modulaire for open gas burners as an option although pilot lights are standard
[17] Fenwel Controls, Series 35-60 & 35-71 datasheet.

Sparking causes erosion of the electrodes but they are able to last the life of domestic hobs. However, due to the much heavier use, they would need to be replaced regularly in commercial hobs and grills to maintain reliability during planned maintenance.

6.3. STATE-OF-THE-ART OF BEST EXISTING PRODUCT TECHNOLOGY OUTSIDE THE EU

Hobs and grills designed for markets outside of the EU may be different to those sold in the EU. This is particularly the case with products for the US market. EU manufacturer's opinions are that equipment intended for use in the EU is on average superior in terms of energy performance to equipment intended for the US market although there is no independent testing that could confirm this. There does not however appear to be any evidence that non-EU products are superior to EU products.

In the USA, there are Energy Star standards for commercial grills. Only some US grills meet the Energy Star requirements and EU manufacturers have said that most EU grills will perform better than US grills although there is no comparative data. Japan has the Top Runner program for domestic grills which includes an energy consumption measurement method and maximum energy consumption (standard target) based on grill volume. Measurements of Japanese grills showed significant variation in performance when this was first introduced. By introduction of the standard target (a minimum energy performance specification) based on existing grill performance, an improvement in energy consumption of 27% was expected due to the Top Runner standard.

Charbroil is a US manufacturer who also sells outdoor grills in the EU and who has developed an in-house test based on heat flux sensors. Its tests with several outdoor grill designs showed very large variations in energy efficiency, with some grills consuming double the energy of others.

6.4. POTENTIAL FOR ENERGY SAVINGS

There clearly is some variation in energy consumption of hobs and grills but very little quantitative data is so far available because no EU measurement method standard yet exists. Manufacturers have provided some data (mainly for domestic products) on expected improvement potential from eco-design changes. These figures are the improvements that they are confident can be achieved and so further improvements may be possible but this is less certain. Potential energy saving is used as a marketing tool, especially for commercial equipment and several examples have been found and included in this report. Clearly, predicted energy savings used in marketing will be optimistic and is usually a comparison of the new innovation with relatively old technology and may not be the same as the improvement potential that could be obtained by modification of current representative products. Some of the claimed improvements are due to eco-design improvements and others are from features that alter user behaviour.

6.4.1. CONSUMER HOBS

There are two ways of reducing energy consumption; i) by adoption of energy saving innovations and ii) by eliminating the least efficient products from the market. Energy saving innovations are discussed in this Task 6 report. Some will give relatively small improvements such as gas burner design and reducing thermal mass of solid plate hotplates. The use of pot presence sensors is mainly beneficial in commercial kitchens whereas cooking sensors are used for domestic cooking and could potentially give very large energy savings of up to 30% for domestic cooking sensors based on data from BSH although an average of ~10% may be a more realistic figure overall. Potentially, the saving could be more than 30% for commercial pot presence sensors. Cooking and pot sesnors could reduce energy consumption but these require users to utilise these features and they may not be convenient for every kind of food. It is also difficult to show these benefits by the standard hob energy consumption measurement methods that are being developed. Minimum energy performance standards would eliminate the least efficient products but the range of energy consumption of hobs may be too small for this to be effective. The use of energy labels that give credit for cooking sensors and pot presence sensors may be more effective as this would encourage manufacturers to develop more energy efficient designs. Available data on the range of energy consumption of new hobs on the EU market is as follows:

- **Gas**

Currently domestic and commercial open gas burners must comply with the minimum of 52 and 50% energy efficiency specified by EN30-2-1 (domestic) and EN203-2-1 (commercial) whereas several manufacturers have stated that a minimum of 60% would be achievable for open single crown burners. Some deterioration of efficiency occurs with age and multiple crown burners are reported by CECED to have a lower maximum efficiency than single crown[18]. There is no energy consumption test data available from manufacturers. This will be determined while the standard gas hob measurement method is developed but currently this is at an early stage of development. It is possible that further improvements (e.g. using some of the innovations described in this report) could be made if there were an incentive such as from energy labels as has happened with domestic electric ovens.

- **Electric**

Preliminary measurements of domestic electric hob energy consumption by CECED showed that energy consumption during the draft standard test varied in a range of

[18] This information has been provided by stakeholders but no published peer reviewed quantitative data appears to be available.

about 25%. Induction hobs typically consumed about 15% less than other types in their tests. This range is from only 16 hobs and the true variation may be larger. Further improvements may be possible if there were an incentive from energy labels although it is difficult to see how the best induction hobs can be improved by more than 1 or 2% except by using cooking sensors.

It is difficult to compare electric with gas as gas is a primary energy source unlike electricity. As described in the Task 4 report, VHK report that the primary energy efficiency of boiling water on an electric radiant hob is 13% whereas with a gas hob it is 23% (this is not the same as the EN 30-1-2 measurement method). The improvement potential for hobs could be about 10% which may be achieved from ecodesign improvements and a change from radiant and solid plate to induction for electric hobs. Larger energy reductions may be possible if users could be persuaded to use cooking sensors.

6.4.2. Consumer Grills

There is evidence from research in USA for Energy Star, Japan for Top Runner and from one manufacturer (Charbroil) that there is significant variation in energy consumption by domestic and commercial grills. No EU standard measurement methods are yet available so the true variation in performance of grills on the EU market is not known but from the available evidence, there is a very significant improvement potential. Japanese Top Runner tests showed that domestic gas grills in Japan consumed from 280 – 430 Wh in their standard test. Charbroil's test measures percent efficiency and found a range from 15 to 40% for outdoor gas grills. These results indicate that over all there may be a situation where the worst grills consume double the energy of the best and so energy labelling would reduce energy consumption by at least 20%. Charbroil has compared its in-house test method with the Japanese grill standard test method that uses a black painted block of copper and found a roughly linear correlation. The energy consumed to raise the temperature of the copper block by 100°C per unit area of grill gave a significant variation in results from ~3.5 Wh/m2 to ~ 5.9Wh/m2 (tests with 3 outdoor gas grills).

Toasters usually have pairs of slots with only one control so they use double the amount of electricity when only one of the two is used. It is possible to add a switch or a sensor to allow only one slot to be used and reduce electricity consumption by 50%. At least one brand offers this the option in the EU with a sensor[19] and at least one with a switch[20]. The actual saving depends on how often consumers use only one slot. If this is 30% of uses (no real data so this is a guess), then this would save 15% energy. Energy is also saved by wall insulation but the variation of toaster energy consumption

[19] Kenwood's website, April 2011: http://www.kenwoodworld.com/uk/Products/Kettles-Toasters-Snack-Makers/Toasters/TTM100/

[20] Dualit's website April 2011: http://www.dualit.com/products/2-slice-newgen

on the EU market is not known as no EU standard energy measurement test method exists.

6.4.3. COMMERCIAL HOBS AND GRILLS

Hobs

Reduction in energy consumption of commercial hobs could be achieved by a variety of eco-design options. Most of those suggested for domestic are also applicable to commercial:

Electric: Change from radiant / solid plate to induction – energy saving estimated at ~15% for domestic but will be higher for commercial because radiant and solid plate hobs that are used in circumstances where these are left on continuously. Induction hobs consume much less power when no pot is present and so savings are likely therefore to be much greater in restaurant and hotel kitchens where hobs are left on continuously even when not in use. The difference for institution kitchens will be closer to 15% as cooking is much more predictable so hobs tend not be left on unused. One publication suggests that savings of **50 – 86% may be achievable**[21] and this probably refers to restaurant kitchens.

Gas: Pot presence sensors – These are already available for some hobs and offer a benefit mainly for restaurants and hotels where gas burners are left on at full power continuously. The benefit depends on the reduction in time that the burner is on and so could save **30% or more**.

Electric solid plate and radiant thermal insulation – insulation surrounding the electric elements prevents heat losses in directions not towards the pot so will save energy. No data is available to show what improvement is achievable so an **estimate of 5%** is suggested.

Gas burners – EN 203-1 gives a minimum energy efficiency of 50% for open burners whereas several manufacturers have claimed that **60% is achievable**. The corresponding domestic hob standard EN 30-1-1 allows a lower minimum efficiency of 25% for covered burners, although a stakeholder has claimed that covered burners can achieve 50% efficiency. Covered burners are used for easier simmering and other lower heat input processes whereas open burners with good output control could be more energy efficient. The improvement potential for open burners by good design of burner jets and gas / mixing will potentially reduce energy consumption by ~ 10% but pot presence sensors will give a further energy reduction. Burner design of covered burners should give a similar percentage energy improvement but pot presence sensors are not available. The improvement potential will depend on how covered burners are used. For circumstances where a covered burner is in continuous use with

[21] "Making the kitchen greener" by Kevin Tyson, October 2010, from: http://www.caterersearch.com/Articles/2010/10/20/335563/making-the-kitchen-greener.htm

several pots, there is little scope for improvement whereas when used for only part of the time, usually with one pot, then under these circumstances, these will use more energy. The differences between the two types of commercial gas burner are summarised below.

	Covered burner	Open burner
Main uses	Simmering and low heat processes	High heat processes but can be turned down for simmering, etc.
Flexibility	Can heat several pots simultaneously	One pot only
Pot presence sensors	Not available	Available from several manufacturers
Energy efficiency based on EN 203-1	Not specified, domestic equivalent is 25 – 35% although 50% may be achievable	50% minimum with 60% being achievable
Mode of use in restaurants / hotels	May be on full power continuously. Lower heat achieved by moving pot	May be on continuously unless pot sensor available. Can be turned down to simmer

Clearly there are differences in the way that covered and open burners are used and covered burners are more convenient for low heat input processes in commercial catering but as open burners can be fitted with pot presence sensors and have to be turned down to simmer, overall they should consume less energy.

Stop using gas pilot lights – this would save ~6KWh per day per gas hob (250W for 24 hours). The power consumption of the Honeywell S4560 automatic ignition control consumes a maximum of 10VA (10 watts electricity). This therefore consumes 0.24 KWh per day (maximum) of electricity equivalent to ~0.6KWh/day of primary energy (assumes electricity to primary ratio is 2.5). The primary energy saving by changing from pilot light to electronic ignition is **5.4KWh/day per appliance**. One stakeholder has claimed that the pilot lights of commercial gas appliances are on only when the appliance is in use, i.e. ~12 hours per day so where this is the mode of use, the energy saved would be halved at 2.7kWh/day. At present, few EU gas hobs currently use high voltage spark ignition so this option would reduce gas consumption for example, by ~7% for a 6KW gas hob that is used for 12 hours per day and the pilot on continuously. If the pilot were on only during the 12 hours of use, changing to a HV spark would save ~3.6%. Hob manufacturers have expressed concern over the long term reliability of automatic igniters.

Gas burner design – this can reduce gas consumption if this improves gas / air mixing and optimises gas / ratio. Wider ranges of power output and flame size also potentially reduce energy consumption where a wide range of pot sizes is used on each burner. Electrolux "flower flame" and independently controlled multi-ring burners are options that are used in the EU but only in small numbers at present. No potential energy saving data is available but an energy saving of at least 10% is possible where small pans are frequently used as well as large-size pans on the same burner.

Cooking sensors and improved electronic control are options for domestic hobs which could save up to 5% but these are less likely to give benefits with commercial hobs where these are used on at full power for many fairly short periods per day.

Grills

Improvement of grills is clearly possible but different design options would be used for each type. Options are:

- Salamander grills: Fast heat up – encourages users to turn off when not used and at least two manufacturers sell grills with this option in the EU. One reference indicates that the use of pan sensors with salamander grills could save up to 70% of energy[21].
- Zone isolation and separate control – available on many grills but often not used (all zones left on). It may be possible to improve effectiveness of zone separation on gas grills
- Pan sensors are available on a few salamander grills such as the "Hatco-Quicktherm" (this is a fast heat-up model reaching cooking temperature in 8 seconds). An energy saving of up to 70% is claimed to be achievable[21], presumably as it turns off when not in use.
- Thermal insulation – needed to prevent heat losses away from food, even for radiant types. Tests by outdoor gas grill manufacturer showed >50% reduction in gas consumption compared with grill with minimal insulation. Improvement in quality of insulation estimated for contact grills – 5 to 10%.
- Outdoor gas grill insulated lids (these have vents) - give 40% reduction in gas consumption compared to no lid.
- Gas grill combustion air control – measured by outdoor grill manufacturer but should be applicable to all gas grills = 11% reduction in gas consumption by optimisation of burner orifice design
- Pilot lights – as for hobs (above).
- Contact grill coatings – intended to prevent radiant heat losses from unused areas. Electrolux have a special coating ("Ecotop") that they claim reduces emissions from unused areas by up to 60%[1]. Chromium-plated surfaces are

poor infrared emitters and are claimed to reduce energy consumption by ~30% when compared to dark surfaces that are good infrared emitters

- Research by Charbroil has discovered from their research that by increasing the proportion of heat transferred by grill gas burners to food (for outdoor grills but also applicable to radiant and salamander grills), to achieve the same cooking result, from 50% to 75% (the remainder being transfer by convection) reduces the energy consumed by 17%.

Based on results of tests in the USA and Japan, there will be potential for reducing energy consumption of grills in the EU. Improved insulation is an option for some types, gas burner design, pilot light replacement and zoning of gas burners will all improve gas grills. Changing user behaviour will also reduce energy consumption, especially in restaurant and hotel kitchens where fast turnaround is important. Grills tend to be left on continuously to avoid delays while they reach operating temperature but fast heat up designs should eliminate this requirement. Inclusion of timers will also prevent misuse by automatically turning grills off after the pre-set time. One outdoor grill manufacturer has optimised their gas grills and found that by improving lid design, zoning and burner design together gave a reduction in gas consumption of ~75%[22].

6.5. CONCLUSIONS

Significant reductions in energy consumption appear to be achievable for hobs and grills by eco-design. Changing from electric to gas is a potential option but it can be inconvenient to implement as piped natural gas is not available in all parts of the EU, although using LPG bottles remains an alternative. On the other hand, there are also limits to electric supplies in some EU Member States which makes gas the only viable option. Also, gas cooking sometimes gives different results to electric cooking and so is not always directly comparable. The main environmental advantage of gas over electricity is that gas is a primary energy source and electricity has to be generated and in most EU States, this is at present predominantly from fossil fuels. . Another complicating factor is that energy consumption and CO_2 emissions are not directly related. Natural gas and LPG are fossil fuels both emitting CO_2 when used. CO_2 from electricity generation depends on the mix of energy sources. The EU is planning that CO_2 emissions per kWh electricity generated will decrease in the future but it is likely to take many years before the use of electricity for all types of hobs and grills will emit significantly less CO_2 than the use of gas. Therefore energy saving technologies for electric and for gas appliances has been considered separately in this report.

Domestic: A very significant reduction in EU energy consumption by domestic hobs and grills could be achieved by adoption of the design changes for hobs and grills that are discussed in this report. The largest energy consumption reduction for hobs will be

[22] Data kindly provided by Charbroil (a US outdoor grill manufacturer)

from a change from solid plate or radiant to induction hobs (10 – 15%) but technology for improving gas, sold plate and radiant hobs is being developed. Less research is published on grill eco-design but data available from USA, Japan and from one manufacturer indicate that there is a large variation in energy efficiency and so eco-design changes should reduce energy consumption.

User behaviour affects energy consumption but cannot be regulated by 2009/125/EC but cooking sensors can give large reductions in energy consumption of hobs (for heating liquids) if these are designed as part of the hob and used. These would not however be shown to provide lower energy consumption by proposed the draft standard hob energy consumption measurement method.

Commercial: There are many design changes possible for commercial hobs and grills and there appears to significant improvement potential in terms of energy consumption in the use phase. Some of the design options are similar to those for the domestic market but the reduction in energy consumption can in some cases be larger due to the different user behaviour. For example, changing from solid plate, radiant or gas hobs to induction hobs will give a large improvement in circumstances where the hobs are left on full power continuously because induction hobs use much less power when no pot is present. There are several design options that influence user behaviour such as pot sensors. In commercial kitchens, the cooks are usually not responsible for energy bills whereas rapid turnaround is demanded and so hobs and grills tend to be left on continuously. Design options that make this unnecessary would significantly reduce energy consumption although these may not be credited by energy consumption measurement standards.

A trend already occurring in commercial catering is for commercial hobs and other appliances are being replaced by combi-ovens as these are able to cook food using less energy than by traditional methods. One stakeholder claims that an electric combi-steamer oven can cook vegetables using 60% less energy than an electric hob.