

Preparatory Studies for Ecodesign Requirements of EuPs (III)

ENER Lot 20 – Local Room Heating Products
Task 4: Technical analysis of existing products

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AUTHORS	Mr. Shailendra Mudgal, BIO Intelligence Service Dr. Adrian Tan, BIO Intelligence Service Mr. Sandeep Pahal, BIO Intelligence Service Mr. Alvaro de Prado Trigo, BIO Intelligence Service	
KEY CONTACTS	Shailendra Mudgal + 33 (0) 1 53 90 11 80 sm@biois.com	Adrian Tan + 33 (0) 1 53 90 11 80 adrian.tan@biois.com
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Task 4: Technical analysis of existing products

This chapter presents the technical analysis of local room heaters covered in the scope of the ENER Lot 20 study. The technical analysis of product categories described in this chapter uses the product definitions presented earlier in the Task 1 report of this study as its basis. Analysis of the environmental impacts of a product requires the examination of its complete life-cycle, starting with the amount of raw materials used during the manufacturing phase and ending with the disposal efforts required at its end-of-life stage. The aim of this task is to examine the technical characteristics of the different product categories covered in this study, which is necessary to form a basis for identifying and defining the base cases that will be further developed in Task 5 of this study.

This task is therefore divided into the following subtasks according to the different life-cycle stages of the local room heaters:

- production phase;
- distribution phase;
- use phase of the product;
- use phase of the system; and,
- end-of-life phase

The main source of information presented in this chapter is the response of stakeholders (mainly manufacturers and industry associations) to a questionnaire designed specifically for this task. Additional information was retrieved from literature review (e.g. standards and directives concerning heating systems, technical journals, public information sources and information available from manufacturers' websites and product brochures).

4.1 Technical basics and thermodynamics

As per the definition stated in Task 1, local room heating products are “decentralised space heating stand-alone devices that convert electricity, gaseous or liquid fuels directly into heat”. Local room heaters can be operated with a variety of fuels (e.g. electricity, gas, oil and kerosene). However, their heat production principle can be classified into the following two fundamental types:

- Heat production from electricity; and
- Heat production by combustion of gaseous and liquid fuels.

Additionally, local room heating products can be categorised by the manner in which they transfer the generated heat to the heated space, i.e. by convection and/or by radiation. These technical aspects are explained in more detail in the following sections.

4.1.1 Heat production from electricity

Heat production from electricity is achieved by the transformation of electric energy into thermal energy. This process is also known as "Resistive Heating", "Ohmic Heating" or "Joule Heating", as the passage of an electric current through an electric resistor releases heat. The amount of heat dissipated by a resistor is mathematically described as:

$$Q = I^2 \cdot R \cdot t$$

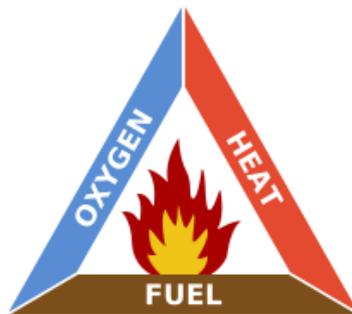
Where, "Q" is the heat generated by a constant current "I" flowing through a conductor of electrical resistance "R", for a time "t".

In other words, the formula states that the rate of heat dissipation in a resistive conductor is proportional to the square of the current passing through it and to its resistance. Metals resistance value can vary depending on the material, applied to electric heaters this means that highly resistive conductors are used. The principle of resistive heating is used in every electrically driven heating device, both convection and radiation based heaters. Depending on the principle of heat transfer, different resistive conductors and techniques are used which are explained in detail in the corresponding product sections.

4.1.2 Heat production through combustion

The second fundamental principle of heat generation is the process of combustion. Combustion (or burning) is the sequence of an exothermic chemical reaction between a fuel and an oxidant accompanied by the production of heat.

Figure 4-1: Combustion triangle¹



A simple example for this process is the oxidation of methane (CH₄) with pure oxygen (O₂):



In this case, methane is the fuel and oxygen is the oxidiser of the reaction. The result is carbon dioxide (CO₂) and water (H₂O), accompanied by the production of energy. This energy is either

¹ Image source: www.cablesystems.co.uk/fire-triangle.php

transferred to the surroundings, or it remains in the combustion products (e.g. flue gases) in the form of elevated internal energy (temperature).

Fuels are evaluated based on the amount of heat generated per unit mass through complete combustion of the fuel. This value is also known as the calorific value.

Generally the chemical reaction of combustion only happens in the gas phase of a fuel, which means that liquid and solid fuels do not burn directly, but the vapours of the combustible compounds do. The fuels for combustion can be classified into three categories with different technological characteristics.

4.1.2.1 Gaseous fuels

Gaseous fuels like natural gas can be combusted directly. This is possible because all relevant combustible compounds for the process are in gas-phase already. The gas gets mixed with the adequate amount of oxidant and is ignited by an ignition source. Because there is no need to transfer the fuel to a different phase state, the combustion of gaseous fuels can be obtained with comparatively low effort.

In the scope of this study, liquefied gases (like LPG and propane) are also considered as gaseous fuels, as they are only liquid in their storage form. LPG has a higher calorific value (94 MJ/m³ equivalent to 26.1 kWh/m³) than natural gas (methane) (38 MJ/m³ equivalent to 10.6 kWh/m³), which means that LPG cannot simply be substituted for natural gas. In order to allow the use of the same burner controls and to provide for similar combustion characteristics, LPG can be mixed with air to produce a Synthetic Natural Gas (SNG) that can be easily substituted.

4.1.2.2 Liquid fuels

Liquid fuels include fuel oil, paraffin/kerosene and (bio)ethanol fuels. Fuel oil or heating oil is commonly delivered by tank truck to residential, commercial and municipal buildings and stored in above-ground storage tanks located in the basements, garages, or outside adjacent to the building. It may sometimes also be stored in underground storage tanks. Paraffin/kerosene and ethanol fuels are however available in bottles and canisters which allow for easy storage. They are therefore usually used in transportable heating appliances, in locations without access to piped natural gas or as a back-up fuel supply.

4.1.2.3 Solid fuels

As the combustion of solid fuels is not relevant for the heaters considered in ENER Lot 20 study, they will not be further elaborated in this context. For more detailed information on solid fuels used for space heating, please refer to the DG TREN Lot 15 preparatory study on "Solid fuel small combustion installations".²

² www.ecosolidfuel.org/

4.1.2.4 **Requirements for a complete combustion**

There are several requirements that must be fulfilled for a complete combustion process. The main factors influencing the combustion process are (also referred to as “the three Ts of combustion”):

- **Temperature:** higher combustion temperatures accelerate the reaction speed and the degree of burn of the combustion process.
- **Turbulence:** to enhance the contact of the fuel with the oxidiser, the reactants have to be mixed properly. This can be achieved through higher turbulence in the reaction zone.
- **Time:** the fuel-oxidant mix has to stay in the reaction zone for a sufficient time so that there is enough time for the complete combustion process to take place.

Although there are many different principles to generate heat through combustion, the fundamental working principles always remain the same. A more detailed description of the respective functional principles is presented in the corresponding product sections of this task.

4.1.3 **Heat transfer**

4.1.3.1 **Convective heat transfer**

Convective heat transfer is the technical term used for transportation of heat within a fluid (i.e. liquids and gases). Free (or natural) convection occurs when the fluid motion is caused by buoyancy forces that result from density variations due to a temperature difference in the fluid. Forced convection is when the fluid is forced to flow over the surface by external means - such as fans, stirrers, and pumps - creating an artificially induced convection current. Physically, the mechanism of convection heat transfer is a combination of conductivity and fluid flow. Convective heat transfer depends on many factors including fluid properties, flow velocity, geometric configuration, and any fluid phase change that may occur as a result of heat transfer. Both methods, natural and forced convection, are used in heating technology depending on the functional design of the heater.

The rate of heat transfer between a heated surface and the transporting fluid is given by:

$$\dot{Q} = h \cdot A \cdot \Delta T$$

Where, “ Q ” is the transferred energy, “ h ” is the heat transfer coefficient, “ A ” is the surface area of the heated surface, and “ ΔT ” is the temperature difference between the heating surface and the flowing fluid.

4.1.3.2 **Heat transfer by radiation**

Thermal radiation is electromagnetic radiation emitted by any object due to the thermal energy possessed by it, which in turn depends on its absolute temperature. In other words, all objects with temperatures higher than absolute zero emit thermal radiation. Additionally, radiation does

not require the presence of matter to propagate, which means that it is transferred even in vacuum. This is also one of the biggest advantages for the heating technologies based on radiation, as thermal radiation is not affected by any kind of draught or wind.

Following the definition, every local room heater – even a convection heater – emits some thermal radiation. Similarly, a radiant heater also partially transfers some heat by convection. Nevertheless, the classification of a heater into convector or radiator depends on the design and the ratio of heat transmitted.

The fundamental physics behind thermal radiation are described in Planck's radiation law and can be transformed into the Stefan-Boltzmann law. This law describes the power emitted by an idealised black body as follows:

$$P = \sigma \cdot A \cdot T^4$$

with

$$\sigma = 5.670400(40) \times 10^{-8} \text{ W} \cdot \text{m}^{-2} \cdot \text{K}^{-4}$$

Where, "P" is the energy radiated in Joules [J], "σ" is the Stefan-Boltzmann constant, "A" is the surface area of the radiation emitting body in square meters [m²], "T" is the absolute temperature of the radiation emitting body in Kelvin [K].

As mentioned earlier, this formula describes the radiation emission behaviour of black bodies, which are idealised objects that absorb all incoming radiation. In reality, all bodies reflect a part of the incoming radiation. Therefore, the equation is complemented with a specific value, the emissivity factor "ε":

$$P = \varepsilon \cdot \sigma \cdot A \cdot T^4$$

The emissivity factor can take a value between 0 and 1, depending on the level of radiation emission of the body. It is influenced by many factors, e.g. the type of material used, surface conditions, corrosion, paint residue. For example, a polished metal surface has a very low emissivity factor, thus it reflects a large amount of radiation.

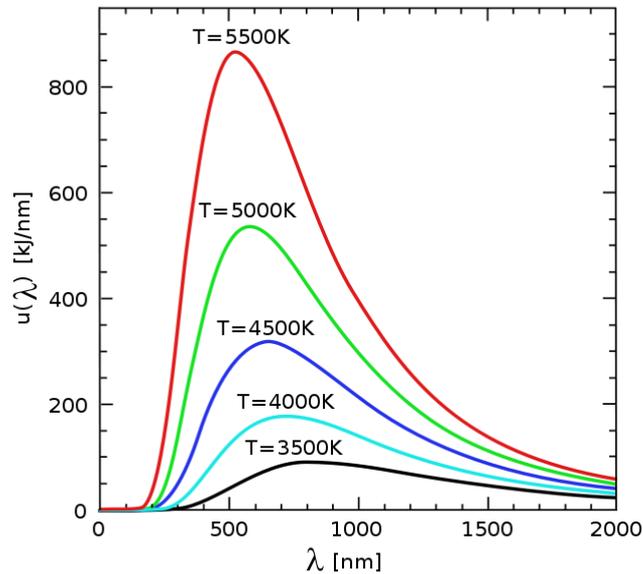
All different kinds of radiation, such as visible light, infrared light, ultraviolet light, roentgen radiation, consist of a spectrum of electromagnetic waves. The complete radiation spectrum can be categorised according to the wavelength of the emitted radiation. For example, the visible part of the electromagnetic spectrum is between 0.38 μm and 0.78 μm. Thermal radiation, which is relevant for local room heating products, has a wavelength of between 0.76 μm and 360 μm, which is mainly the infrared part of the spectrum.

Wien's displacement law states that for a particular temperature of a material there exists a wavelength at which the majority of radiation is emitted by it. This wavelength is known as the peak wavelength. Additionally, Wien demonstrated that the amount of emitted radiation increases with rising temperatures, while the wavelength (peak wavelength) of the emitted radiation decreases.

In other words, the higher the temperature of a body, the shorter the wavelength of the majority of radiation (peak wavelength) emitted by it. According to this principle, radiant heaters are

designed to reach lower combustion temperatures, in order to emit thermal radiation of higher wavelengths (infrared spectrum).

Figure 4-2 : Black body thermal emission intensity as a function of wavelength for various absolute temperatures.



4.2 Main components

This section provides a broad overview of the main components used in local room heating products. These components are designed to suit the different techniques used for heat generation and heat emission.

4.2.1 Heat generation unit

The heat generation unit represents the centrepiece of every local room heating product. Since “heat” is thermal energy, the word “generation” is not quite correct, as energy cannot be generated or lost. Nevertheless, in this context it means that heat generation units are responsible for transforming energy that is contained in the fuel into thermal energy.

Concerning the products of ENER Lot 20 study, there are two possible types of heat generating units: electric heat generators (resistive conductors) and burners. These basic principles of heat generation are used in a wide variety of techniques.

4.2.1.1 *Electric heat generator (resistive conductor)*

Electric heat generators are electric resistors that transform electric energy into radiation and thermal energy. When an electric current is passed through a resistive conductor its surface temperature rises and it starts emitting thermal energy and visible light (glowing). Depending on the temperature of the resistive conductor, the wavelength of the emitted radiation will vary. Most of the electric heaters use one of the following heat generation techniques:

► **Heating wires**

Heating wires are resistive conductors that can be produced in straight or coiled wires, or ribbons. They are usually made of either iron-chromium-aluminium (FeCrAl) or nickel-chrome (NiCr) or Cupronickel (CuNi) alloys. These types of heating wires can be found in common household products such as toasters or hair dryers, as well as in residential fan heaters or electric floor heating systems.

Heating wires for electric floor heating systems are usually embedded into heating cables. These heating cables can be designed in many different ways.

► **Etched foil heating elements**

Etched foil heating elements are generally made from the same resistive conducting materials as heating wires, with the only difference being that in this case they are etched into a conducting foil and therefore can be manufactured very efficiently while using little space. These elements are commonly found in precision heating applications such as medical diagnostics and are of less relevance for this study.

► **Tubular heating elements**

In these kind of electrical heating elements, a resistive heating wire (mostly a coil of nickel-chrome wire) is embedded in an insulating binder like magnesium oxide (MgO), sealed inside a tube usually made of stainless steel or aluminium. The tubes can be a straight rod or curved, and are often used in items such as electric ovens as well as in immersion heaters for electric radiator heaters. If a current is passed through the heating wire, it warms the surrounding binder and therewith the surrounding tube.

► **Heat lamps / halogen heating tubes**

Heat lamps and halogen heaters consist of a metallic filament (most often tungsten filaments) which is enveloped in a glass bulb or highly temperature-resistant quartz tube. At first sight they may look like ordinary incandescent bulbs or halogen lamps with the difference that heat lamps are specially designed to radiate mostly infrared instead of visible light. Heat lamps and halogen heating tubes are usually used in glowing radiant heating devices.

► **PTC ceramic heating elements**

Unlike traditional heating elements that use resistive wires to generate heat, PTC ceramic heating elements are special ceramic plates that act as a resistive element themselves, meaning that they generate heat in case an electric current is passed through them. This special ceramic material is named for its Positive Thermal Coefficient (PTC) of resistance, which means that the resistance remains low at lower material temperatures and increases with higher material temperatures. At a certain temperature the electric resistance of the ceramic suddenly increases significantly, diminishing the current flow to a very low value. Therefore, the PTC ceramic material itself acts as a self-limiting device. PTC ceramic heating elements are used in household applications like hair-driers and in some space heaters.

4.2.1.2 **Burners**

By definition, combustion (or burning) is an exothermic chemical reaction between a fuel and an oxidant accompanied by the production of heat. In other words, burners are heat generation devices that produce heat by burning gaseous, solid or liquid fuels. Burner design is extremely diverse since a great number of burner manufacturers have developed their own patented burner technologies.

4.2.1.2.1 *Classification by the type of fuel*

According to the type of fuel and combustion technology used, the burners relevant for this study can be classified into the following categories:

▶ **Oil burners**

Generally, the supplied oil is pre-processed inside the burner, mixed with supply air and then ignited and burned safely. Based on the fuel preparation, oil burners can be classified into:

▷ Vaporising burners

Vaporising burners contain a shell or pot-like vessel in which the oil is continuously heated. At a certain temperature level the oil will start vaporising. Mixed with combustion air, the oil vapours form a combustible gas that is ignited and burned above the pot-like vessel. Vaporising burners are mostly used in oil ovens, older kitchen stoves and tiled stoves. A basic form of a vaporising burner is also used in ethanol fireplaces.

▷ Atomising burners

As the name indicates, atomising burners atomise the supplied oil into very small oil droplets (size 40 to 200 μm) that are subsequently mixed with combustion air. By atomising the oil, the surface area is increased, which simplifies the gasification process necessary for combustion. The atomised gas/air mixture is sprayed into the combustion chamber and is ignited subsequently.

Atomisation can be achieved with different techniques such as pressure atomisation, injection atomisation, rotary atomisation, air atomisation and ultrasonic atomisation. Today, pressure atomising burners are the most commonly used oil burner technology and are available in numerous capacity ranges. Generally, atomising burners contain a fan for combustion air supply. Pressure atomising burners use preheated oil, which is subjected to high pressure by a fuel pump. The high-pressure oil is fed into an oil nozzle, where it is atomised due to the high pressure.

▶ **Gas burners**

Compared to oil burners, gas burners have the advantage that the fuel does not need to be vaporised before combustion, since it is already in the gaseous phase. Additionally, natural gas usually is supplied with a pressure level high enough for mixing with combustion air.

Gas burners are classified according to the type of gas/air mixture and the functioning principle into the following subcategories:

▷ Diffusion burners (fan burners)

Air and gas are mixed directly after leaving the flame holder. As the flame holder causes a pressure loss, a combustion air fan is always necessary. The combustion takes place concurrently with the mixing. Therefore, these kinds of burners can be used for all available types of gas compositions. Because of the great flexibility of use, diffusion burners are very widespread on the gas burner market.

▷ Premix burners (fan assisted)

These burners create a mixture of combustible gas and air. The air required for combustion is drawn in by a fan and then supplied to a mixing device. The gas is atomised by a gas nozzle into the mixing device. The resulting turbulent air stream ensures the mixing of combustion air and gas. The mixture is then led to the burner surface, usually a perforated steel plate, woven-fibre of metal or a perforated ceramic material (see Figure 4-3). Each hole in the burner surface serves as a flame holder. The geometry of the holes together with the pressure of the gas/air mixture determines the shape and the size of each individual flame. Three kinds of flames can be distinguished:

- free flame - the flame hovers over the burner surface;
- radiation burner - the flame rests at the burner surface; and
- flameless burner - the combustion takes place inside the flame holders.

Figure 4-3: Different premix burner surfaces³



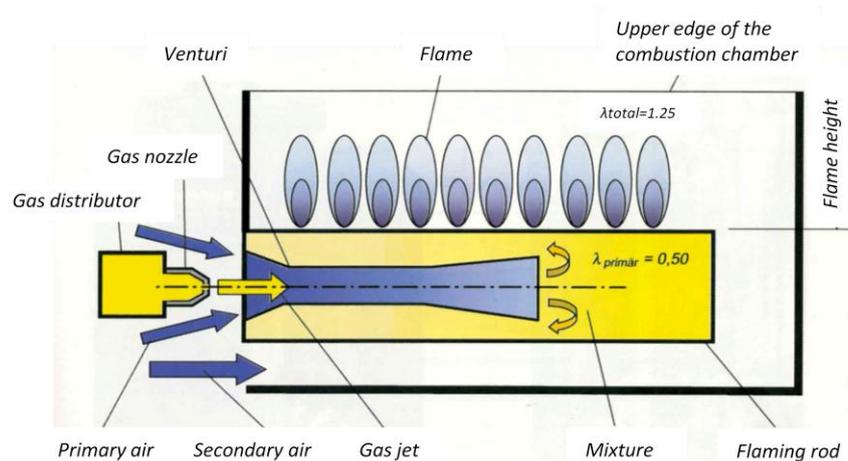
▷ Atmospheric burners (fanless injector burners)

Atmospheric burners can also be classified as premix burners as the mixing of gas and supply air takes place before combustion. In contrast to premix burners, this mixing is achieved without additional combustion air fans. The gas is atomised by a gas nozzle into a combustion rod under common gas supply pressure. This combustion rod is usually a round, oval or cylindrical metal pipe, with an integrated venturi nozzle and perforations on the top side (Figure 4-4). As the gas is

³ Buderus Heiztechnik (2002) Handbuch für Heizungstechnik. 34. Auflage.

sprayed into the venturi nozzle, primary air is drawn in by the impulsive force of the gas stream. Subsequently, due to the venturi nozzle, the gas mixes with the primary air and enters the combustion rod. The premixed gas/air mixture streams through the perforations on the top of the rod and gets ignited. The secondary combustion air is drawn in by the flame automatically. Some appliances with atmospheric burners contain an additional flue draught fan, which supports the mixing with secondary air.

Figure 4-4 : Atmospheric gas burner ⁴



► Burner capacity control

The different ways of adjusting burner capacity are covered in section 4.2.4- Heater controls (actuators).

4.2.1.2.2 Classification by the type of heat transfer

Burners in so-called hydronic or indirect fired heating systems achieve to transfer heat to a secondary medium, e.g. water or warm air, that is distributed to the heated space. Burners of such heaters therefore can be considered as separate components with individual improvement potential.

In case of direct-fired (decentralised) heating systems, the burner and heat exchanger are identical (e.g. radiant luminous heaters) or are within the same construction (e.g. radiant tube heaters and warm air heaters) with direct interaction. Burners of these heaters therefore cannot be considered as separate components.

4.2.2 Exhaust gas system (flue)

A flue is a duct, pipe or chimney for evacuating exhaust gases from combustion processes to the outdoors. They usually operate by buoyancy, also known as the stack effect, or the combustion products may be 'induced' via an additional blower. Buoyancy occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences. The result is

⁴ Buderus Heiztechnik; Handbuch für Heizungstechnik; 34. Auflage; 2002

either a positive or negative buoyancy force. A greater thermal difference and height of the structure results in a greater buoyancy force, and thus in a greater stack effect.

Combustion air supply and evacuation of flue gases (out of the heated space) can be classified into 3 types (as per the national and European installation guidelines in force):

- **Type A** – combustion air taken from the room, flue gases evacuated indirectly together with air of the room (according EN 13410). This is also known as unvented or vent-free as the combustion air is drawn from within the heated space and the flue gases are emitted into it as well. Therefore, the use of unvented heaters can pose a health risk, especially when used in poorly ventilated spaces.
- **Type B** – combustion air taken from the room, flue gases evacuated directly by pipe system with roof or wall terminal.
- **Type C** – combustion air taken from outside by air pipe, flue gases evacuated directly by pipe system with roof or wall terminal.

Installation types B and C can further be classified into a number of subcategories.

▶ **Type B venting systems**

- ▷ Natural draught / gravity venting

Natural draught appliances take the combustion air from within the heated space and vent the combustion products to the outside. The venting is solely caused by the buoyancy of the hot flue gases and without the help of any additional fans or draught inducers.

- ▷ Induced draught / power venting

Induced draught venting resembles natural draught venting, with the only difference being that an additional fan known as “draught inducer or booster fan” causes the venting. The fan is placed in the exhaust gas pipe, which draws out the combustion gases and expels them outside.

▶ **Type C venting systems**

- ▷ Direct vent / Separated combustion

Direct vent appliances draw combustion air from outside the heated space and release the combustion products to the outdoors as well. In most cases this is achieved with concentric flue gas pipes.

As combustion, products contain carbon monoxide and other dangerous compounds, proper draught, and introduction of replacement air is imperative. Building codes and other standards regulate the materials, design and installation of exhaust gas systems.

4.2.3 **Motors**

Electric motors are used for driving the fans in warm air industrial unit heaters, air curtains and electric fan heaters. Depending on the motor technology, the electricity consumption can be very different. The classic division of electric motors is according to the power type they are designed to run on. Thus, there exist Alternating Current (AC) and Direct Current (DC) motor types. Every

motor consists of both a rotor (the part that rotates), and a stator (the fixed part of the motor) that generally includes the motor's housing assembly and windings. Concerning fans used in warm air industrial unit heaters, air curtains and electric fan heaters, there are usually three types of motors used;

- The **Permanent Split Capacitor (PSC)** motor is a single-phase AC motor traditionally used in fans. A PSC motor's rotor spins due to changing the magnetic poles on the magnet mounted to the rotor. Standard PSC motors are single speed motors with an additional speed controller. This speed controller is an inefficient way of varying the supply voltage of the motor in order to regulate the rotating velocity. As PSC motors are less cost intensive than BPM motors, they are still used in many standard applications.
- The **Brushless Permanent Magnet (BPM)**⁵ motor design differs from that of PSC motors. BPM motors are brushless DC motors that use a built-in inverter.⁶ This means, that an AC current is connected to the motor and transformed into a DC current. Additionally the BPM has a permanently poled magnet (permanent magnet) mounted on the rotor and electronically varies the polarity of stator magnetic fields, causing a rotating magnetic field to be generated. Compared to PSC motors, BPM motors maintain their efficiency regardless of rotation speed, which means that there are no slip losses occurring. The ECM's efficiency can be as high as 82%, which is a 20% greater efficiency at full load and 30% better efficiency at part load conditions than a PSC motor.⁷ Besides this, there are many additional advantages like constant airflow, radial ramp-up to set point flow rate at start-up, a longer motor life and less motor noise.
- A **shaded-pole motor** is a type of AC single-phase induction motor. It is a small squirrel-cage motor in which the auxiliary winding is composed of a copper ring surrounding a portion of each pole. Currents induced in this coil by the magnetic field delay the phase of magnetic flux for that pole (a shaded pole) enough to provide a rotating magnetic field. These motors have only one winding, no capacitor nor starting switch, thus making them economical and reliable.

The Commission Regulation (EC) No 640/2009 of 22 July 2009, established efficiency requirements for electric motors equipped with variable speed drives and motors integrated into other products – apart from motors completely integrated into a product (for example gear, pump, fan or compressor) of which the energy performance cannot be tested independently from the product. The regulation is therefore not applicable to products or components covered in ENER Lot 20, as motors are small and single-phase (for use in fans).

⁵ BPM motors are also known as Electronically Commutated Motors (ECM) which is registered trademark of General Electric.

⁶ Nailor Industries Inc.; The ECM Motor Story; www.nailor.com/pdf/ecm_1.pdf

⁷ ASHRAE Transactions; Use of electronically commutated motors (ECMs) in air terminal units; 2007; www.pwaengineering.com/articles/?article=9

4.2.4 Heater controls (actuators)

4.2.4.1 *Fuel-fired heaters*

The heating capacity of fuel-fired local room heaters can be controlled by modulating the heat output of the burner, which depends on the burner technology and the burner controls.

Single-staged burners offer only two operating stages (off and on – running at full load) and are therefore controlled by two-step controllers. Two step-controllers are unsteady control elements, with two output variables: on (100%) and off (0%). A two-step controller represents the most simple control device, and regulates the burner operation by continuously shutting the burner on and off, according to the heating demand. This intermittent operation of the burner can lead to a high number of switching cycles and is therefore not very efficient. More advanced two-step controllers regularly calculate the duration of the “on” and “off” periods in proportion to the set-point temperatures and regulate the amount of time the burner fires instead of doing temperature-event based on/off cycling. This so-called chrono-proportional PI control method can increase the efficiency of burners.

Two-staged burners offer three operating stages (off, stage 1 and stage 2). Stage 1 covers the base load and stage 2 covers maximum load. Two-step controllers as described earlier also control two staged burners. Usually a pair of two-step controllers is used, with differently set desired values for stage 1 and stage 2. For example, controller 1 is set to start stage 1 of the burner (base-load) if the room temperature falls below 18°C and controller 2 is set to start stage 2 (full-load) if the temperature falls below 15°C.

The third available type are modulating burners, which can be operated anywhere in between their minimal/maximal load range and can control the heat output without intermittently switching the burner on and off. Usually this is achieved with the help of steady, three-term PID (Proportional–Integral–Derivative) controllers. These types of controllers calculate an “error” value as the difference between the measured value and the desired set point. The controller attempts to minimise the error by adjusting the process control inputs. Therefore, PID controllers are usually the best controller elements for most heater controls. Modulating burners offer the highest efficiencies, as they adapt the heating capacity to the actual heating demand. The disadvantage of modulating burners is that the construction is more complex and therefore they are more expensive than single or two-staged burners.

► **Timer switch**

Timer switches may be available in fuel-fired local room heating products and are similar to ordinary power switches. As the name already implies, timer switches are set to a certain time interval (usually 1 to 60 minutes). During this interval the heat generator is operating. After the interval is expired, either the device shuts off or heat output decreases to a minimal state (set-back). Furthermore, there are 24-hour time switches, which offer the opportunity to set a programme for on and off times for the whole day.

4.2.4.2 **Electric heaters**

Due to the basic principles of resistive heating, electric heating elements are easier to control than burner-fired room heaters, especially because turning the appliances on and off does not affect the efficiency. The heating capacity of electric heater elements is therefore usually controlled by modulating the time of alimentionation of the heating element. However, a change of power may be possible. Multiplying the power by two would increase the speed at which the room can be heated, and thus halving the heating time. The energy consumed to provide the same quantity of heat would thus not be affected. The heating capacity of electric heater can be controlled with the following devices.

▶ **Power switch**

The most basic temperature control is the power switch of the device. The power switch offers a two-staged control of the heater (off and on – running at full load). Although most local room heating products have a more complex temperature control, some appliances, especially portable electric heaters, have no other temperature control device except for the power switch.

In case of heat requirement, the device is turned on, and as the heated space reaches the desired temperature, it is turned off. Automation, timed shut-off or temperature adjustment is not possible with the power switch.

▶ **Power stage switch**

Power stage switches are widespread control systems for local room heaters. With this type of control device, the heat output can be set for at least two or more different stages. These switches are usually used for electric room heaters, as the delivered electric supply voltage can adjust the heat output. The simplest way for power adjustment is by switching the resistance of the heating element(s) on and off. The effective voltage for the heating element is influenced by pulse width modulation or phase angle modulation.

▶ **Automated capacity control**

Some local room heaters contain automated capacity controls, which allow them to adapt the heat output according to the actual heat demand. This can be achieved with the help of integrated steady control elements, like PID controllers, as mentioned earlier in section 4.2.4.1.

▶ **Timer switch**

Timer switches as described in section 4.2.4.1 are also commonly used in electric heaters.

4.2.5 **Room temperature controls (sensors)**

Room temperature controls are part of most local room heating product as they can control the transferred heat output and therewith the temperature in the heated space. There is a wide variety of room temperature control systems as described hereunder.

4.2.5.1 Thermostats

Thermostats measure the actual air temperature with a temperature sensor, and then compare this measured value with a desired value given by the user. The heating output is then adjusted according to the difference between the desired and actual state.

Temperature controls with thermostats can be built as a simple rotary switch on the device itself or as a separate unit that is installed on the wall (for fixed heaters). These control types are often combined with timers to allow a timed shut off.

4.2.5.2 Radiant sensor (Black bulb sensor)

For the measurement of thermal comfort temperature inside a room, it is necessary to take into account both the ambient air temperature in the heated space and the radiant temperature. Black bulb sensors are specially designed for radiant heating systems and measure the room air temperature and the radiant temperature at the same time. The ambient air temperature is measured with a thermostat and the radiant temperature is measured with the help of a black bulb sensor.

4.2.5.3 Remote control

Local room heating products can be equipped with remote controls. In its simplest form, only the heat output can be set individually by remote control. Switching the device on and off is done manually. More comfortable remote control solutions allow the complete control of the device. In some cases, a temperature sensor is built into the remote control, so it can act as a room thermostat. In addition, a manual mode and timer functions are usually adjustable, allowing a time-defined special operation (e.g. reduced operations during the day or night).

4.2.6 Safety devices

4.2.6.1 Thermal cut-out

Thermal cut-outs are mostly bimetallic contacts placed inside the power circuit of the heater that shut off the device in case of an excessive temperature increase caused, for example, by heat accumulation. Heat accumulation can occur if the heater is covered or blocked by objects like towels or curtains and poses a major fire hazard. To avoid overheating in electric underfloor heating systems, a ground thermostat has to be installed.

In case the overheat cut-off is triggered, the appliance may not restart automatically after cool-down and must therefore be restarted manually. This kind of safety device is often found in fan heaters and convector heaters.

4.2.6.2 Flame supervision device (FSD)

A flame supervision device has to be installed in every combustible fuel-using local room heating product. Its function is to shut off the fuel supply in case the flame is extinguished, in order to

prevent a dangerous build up of gas within the appliance, its chimney or the room. When the FSD shuts off the fuel supply, it usually has to be manually reset. There are many types of FSDs that use different technologies, such as thermoelectric FSDs, flame rectification FSDs and optical FSDs.

► Thermoelectric FSD

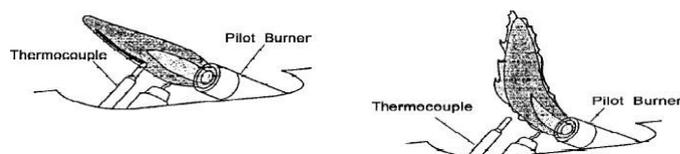
► Thermocouple

A typical thermoelectric flame supervision device contains a thermoelectric safety valve and a thermocouple tip, which is connected to the safety valve over a wire. The thermocouple tip is heated directly by the flame and creates an electric current, which flows down the wire to the valve. Inside the valve, the electric current passes through a coil that generates a magnetic field to hold open the spring-loaded gas safety valve. If the flame goes out, the thermocouple cools, the magnetism created by electricity is cut off and the valve closes, thus stopping gas flow to the burner.

► Oxygen depletion sensor (ODS)

For gas/oil based heaters (both flued and flueless) that generate heat by combustion using the necessary combustion air from the room they are used in, it is very important to ensure that there is always enough oxygen available. This can be achieved with the help of ODSs which are pilot assemblies containing a pilot burner, a separate ignition device and a thermocouple. The assembly is adjusted in such a way that under normal operating conditions the pilot flame touches the thermocouple. If the oxygen in the available combustion air runs out, the flame pattern changes so that the pilot flame will not touch the thermocouple anymore. Subsequently the measured temperature drops and the gas supply is shut off. This simple safety assembly is used in most gas-fired local room heating products.

Figure 4-5: Oxygen depletion sensor⁸



► Flame rectification / ionisation FSD

Flame rectification FSDs detect flame failure by conducting electric current through the flame. Flames contain freely moving charged particles called ions, which allow the flame to conduct an electric current. A circuit board passes a current through the flame using two electrodes. If the flame is extinguished, the circuit board will detect that current flow has stopped. It may then try to reignite the flame at the burner. If this does not work after a specified time (e.g. 30 seconds), the circuit board can shut down the appliance completely so that it will have to be manually reset.⁹

⁸ Picture property of Nanjing PRO-COM Electric Appliance Co.,Ltd., www.usaprocom.com/manuals.php

⁹ www.radmidlands.co.uk/ControlsDom.pdf

► **Optical FSD**

► Infrared FSD

An infrared FSD monitors the infrared radiation emitted by a flame. An infrared-sensitive diode receives the emitted radiation and converts it into an electric signal. If the flame is extinguished, the signal changes and the safety valve is shut off.

► Ultraviolet (UV) FSD

Ultraviolet FSDs use a UV-sensitive cell to monitor the flame. When exposed to UV radiation emitted by a flame, the UV cell converts it to an electric signal. UV FSDs work like infrared FSDs, but monitor a different part of the electromagnetic spectrum.

► Tilt switch / tip-over switch

Since heaters that are inadvertently active in any position other than the properly installed position can cause a major fire hazard, transportable local room heating devices may be equipped with so-called tip-over switches. Tip-over switches are sensitive to changes in the angle of the unit relative to horizontal. There are different types, but all share the property of a level component; when a certain angle is reached, the component either loses contact or creates contact, depending on the type of switch. This either opens and breaks the circuit to shut off the power, or closes to actively shut off the power.

The operating angle varies, but is typically between 35 and 60 degrees +/- 5-10 degrees. If the heater leans beyond the operating angle, the unit shuts down. A slight leaning angle will not shut off the unit¹⁰.

4.3 Common products and technologies

4.3.1 Residential room heaters

4.3.1.1 *Electric room heaters*

Electric room heaters constitute a big market share of local room heating products, as their technical working principles are simple and versatile. Electric room heaters can be divided into numerous categories, according to the principle of heat generation, the installation type (installed or portable), the principle of heat transfer (convection or radiation), and many more. As the name implies, they all use electricity as a “fuel” to generate heat.

Most electric room heaters may be either permanently fixed (or built-in) appliances or movable portable units. Compared to fuel-fired appliances, they do not need any kind of flue system as no combustion takes place. Fixed appliances are installed on a wall, while portable units are independent in their location of operation as long as they can be plugged in.

¹⁰ hubpages.com/hub/safety-devices-in-space-heaters-the-tipover-switch

At first consideration, the energy efficiency of electric room heating devices is nearly 100% since the electrical energy is almost completely transformed into heat. However, the efficiency of the electricity grid's power generation has to be taken into account. Efficiency of electric room heaters in terms of primary energy consumption is far lower than 100%, typically even lower than the efficiency of any fuel-fired room heaters.

In most EU countries, coal is still used as the major source for generation of electricity. The efficiency of electricity generation of conventional coal power plants in the EU is about 30%. Additionally, the combustion of coal produces more CO₂ than other energy sources. Table 4-1 presents the different energy sources and the amount of electricity they generate in the EU.

Table 4-1 : Electricity generation in the European Union, 2008¹¹

Energy source	Generated electric energy [GWh]	% of total
Coal	940,260	27.9
Nuclear power	937,236	27.8
Gas	786,472	23.3
Hydro	358,672	10.6
Wind	118,734	3.5
Oil	105,107	3.1
Biomass	78,802	2.3
Waste	31,677	0.9
Solar photovoltaic	7,433	0.2
Geothermal	5,732	0.2
Other sources	2,418	0.1
Tide	513	0.0
Solar thermal	16	0.0
Total	3,373,072	100

The efficiency of electric heaters therefore depends on the energy mix of Member States, the efficiency of the conversion processes and the transmission losses.

In order to estimate the primary energy consumption of electric heaters in this study, the electricity consumed by these heaters will be multiplied by a primary energy conversion factor of 2.5 (as for all Ecodesign preparatory studies). It should be highlighted that this is only an

¹¹ International Energy Agency (IEA); Electricity/Heat in European Union - 27 in 2008
www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=30

estimate, which is not representative for each Member State but for the average EU-27. Moreover, the value of 2.5 may be revised in case of a shift of the energy mix towards lower carbon energy.

► **Fixed electric convector heaters**

Fixed electric convector heaters are permanently installed room heaters that convert electrical energy into heat and distribute it to the heated space by convection. The heat is generated by passing an electric current through a resistive conductor, which can be a metal wire or a ceramic heating element (PTC heating element – positive temperature coefficient heating element).

The generated heat is usually distributed to the heated space by natural convection, which means that air circulates due to differences in density caused by generated temperature gradients and without the help of fans. The advantage of natural convection heaters is that they are almost noiseless, since they contain no moving parts such as fans. The biggest drawback is that natural convection takes some time to evenly distribute the heat within the space. Fixed electric convector heaters are available in power ranges from 400 W to 3000 W.

► **Fan heaters**

Fan heaters work like electric convector heaters apart from the major difference that fan heaters contain a fan to boost the amount of air passing over the heating element (forced convection). The result is that the room is heated more quickly because more warm air is emitted, making fan heaters a favourable choice for short-term use.

Typical residential fan heaters are compact units with power capacities of 500 W up to 3000 W and are designed to heat small areas. Additionally, there are bigger industrial fan heaters available. These appliances can reach heating capacities up to 12 kW. Fan heaters may be portable or fixed to a wall.

The main disadvantage of forced convection heaters and fan heaters is that the resulting airflow can cause an air draught and lower the comfort level in the room.

► **Electric radiators**

There are two main types of electric radiators: oil-filled radiators and glass/cast iron/aluminium facade radiators. They provide continuous and homogenous heat that resembles the sensation of central heating (hydronic) radiators. The product range contains column-style or panel-style devices with a heating capacity of between 500 W and 3000 W.

Glass/cast iron/aluminium facade radiators are similar to radiant panel heaters but they have their heating element extruded in glass, cast iron or aluminium. These heaters respond rapidly to any temperature change, provide steady, gentle and homogenous heat, and have low surface temperature.

Oil-filled heaters use an immersed electric heat element to heat up a particular thermal oil or fluid, which is sealed in a radiator body. Due to the convective flow of the oil inside the radiator, the unit's outer casing is evenly heated and subsequently emits the heat to the heated space in the form of thermal radiation and natural convection, in the same manner as a conventional (hydronic) radiator. Most units contain a room thermostat and temperature-controlled safety shut-off devices.

As it takes some time to initially heat the oil, these devices are usually not suitable for short-term use. The main application purpose is for long-term operation, since oil-filled heaters have a significant thermal inertia. Because of the high density of the contained oil, most electric radiators are heavy and cumbersome.

As a result of their weight, portable electric radiators are usually equipped with wheels and handholds so they can be transported more easily. Other units are specially designed for fixed installation and do not contain such additional components. Modern “oil-free” devices use a specific thermal fluid for heat transfer. The advantage of these fluids is that the start-up time can be reduced significantly and the weight of the device is lower.

► Radiant panel heaters

Radiant panel heaters are fixed room heating devices that emit heat to the indoor space by radiation and convection. For the purpose of heat generation, a resistive heating element is integrated into a radiation panel usually made of natural stone, ceramic or metal. By passing an electric current through the heating element, the surrounding radiant panel is heated up to approximately 100°C.

Due to this simple working principle, electric radiant panel heaters are often combined with decorative elements. They can be installed on the ceiling or wall while different portable systems are also available as heat-emitting panels in the form of mirrors, or even pictures for the living area.

► Glowing radiant heaters

Glowing radiant heaters can be built as portable units or as permanent installations usually in residential buildings. Heating elements of radiant heaters typically contain a resistive conductor for heat generation that is embedded into a temperature-resistant tube made of steel or quartz glass. These tubes are filled either with isolating material (e.g. magnesium oxide), or with inert gases like xenon. As the conductor warms up, it starts glowing, and so does the surrounding tube. Depending on the surface temperature of the heating tube, the wavelength of common electric glowing radiant heaters is around 3 µm which implies that the biggest part of radiation is emitted in the infrared part of the spectrum. The heating capacity for these types of heaters is around 500 W to 3000 W.

► Storage heaters

Electric storage heaters are decentralised room heating devices, which store electrically generated heat during the night and release it during the day. The heat storage process is achieved by heat-storing bricks (i.e. magnetite, magnesite, ceramic or clay bricks), which are installed in the storage core of the heater. These bricks are heated by embedded electric heating elements or cartridges. The heater distributes the stored heat to the heated space, by drawing air in either by natural convection, or by an internal fan, and leading it through the storage core, where it takes up the thermal energy stored in the bricks. The heated air is then released back into the room. Due to the heavy weight of the heat storage components, electric storage heaters are usually fixed to walls or floors. Electric storage heaters are ideally charged with lower-priced, base load (off-peak tariff) electricity, to approximately 500°C to 700°C with a 4 to 5 hour charging time, commonly during the night. There are dynamic and static storage heaters available on the

market. Dynamic heaters are equipped with fans to allow forced convection for the heat transfer, while static storage heaters make use of natural convection only. Dynamic storage heaters also have better controls for both charging and discharging heat.

An internal steel plate jacket and a layer of heat insulation consisting of mineral wool or microporous insulation material with a thickness of 20 to 50 mm usually surround the the storage core with the embedded heating elements. The casing usually consists of painted sheet steel. Some storage heaters also contain a direct heating element to maintain heat supply in the case of a sudden outdoor temperature drop.

Storage heaters contain different load control mechanisms to adjust the load times and duration. Older devices usually have a simple time switch, where the load times can be adjusted according to the electricity supplier's base load times. Recent storage heaters have automatically controlled loads, which adjust the load duration according to the outside temperature conditions.

► **Electric thin film and cable heating systems**

Electric thin film and cable heating systems are radiant floor heating systems that generate heat by passing an electric current through a resistive wire coated with an electricity insulating material. These so-called heating cables may be installed directly on the floor or are woven into self-adhesive heating mats that are applied to the floor. Another kind of heating cables, used in electric floor heating systems, are self-regulating heating cables. These cables consist of two parallel wires embedded in a semi-conductive self-regulating matrix with a Positive Temperature Coefficient (PTC), meaning that the resistance and thereby the amount of generated heat generated varies with the temperature of the PTC material. At a certain temperature point, the electric resistance of the material suddenly increases significantly, diminishing the current flow and the heat generated. In order to prevent heat losses to the ground or unheated areas below, electric cable heating systems can be equipped with a reflecting layer that reflects a major part of the radiant heat into the required direction.

As electric thin film and cable heating systems provide heat without significantly raising the floor level, they are predominantly used in stocked buildings. As the floor coating above electric floor heating systems influences the heat transfer and other thermal characteristics, it has to be considered particularly. A thin floor coating enables quick response times, while a more massive coating can improve the thermal storage effect. Electric thin film and cable heating systems are very durable and have lower purchase costs, compared to hydronic floor heating systems.

► **Electric fireplaces**

Electric fireplaces are room heating devices that mimic a conventional solid fuel fireplace. Therefore, they combine the process of heat generation with the visual effects and atmosphere of a real fireplace. This visual impression can be achieved by the combination of special coloured lights and water vapour to simulate flames, even the cracking noises of wood can be simulated by a sound module. Usually the heating-mode of electric fireplaces can be switched on or off, independent from the visual fire impression. The biggest advantage of such devices is that no combustion takes place and therefore no flue gas or ash is produced. However the heating power is limited (mostly 500 W to 2000 W), which means that the heating is not sufficient for larger rooms. Electric fireplaces are usually fixed to a wall or into a conventional fireplace.

4-3.1.2 **Gas heaters**

▶ **Flued gas heaters**

Flued gas heaters generate heat by combustion of natural gas or liquefied gas (e.g. LPG) and are available in both, open combustion and closed combustion types. Flued gas heaters are connected to a flue system, with the purpose to transport all formed flue gases to the outside of the building. Heating capacity of flued gas heaters varies from 2 kW to 20 kW.

Open combustion flued gas heaters take the air necessary for combustion directly from the room they are installed in. To do so, the combustion chamber is not sealed to the room, so that the combustion air can directly enter the combustion chamber.

In contrast to this, closed combustion flued gas heaters (or balanced heaters) are room-sealed devices, in which the combustion chamber is sealed to the room in order to prevent flue gases from entering the heated space. The necessary combustion air is drawn in from the outside. The flue gas is led to the outside of the building. This can be achieved with the help of double-walled flue pipes, where the outer pipe contains combustion air and the inner pipe contains the flue gas.

▶ **Flued gas fires**

Flued gas fires are available as floor and wall-mounted devices and thus can be built into conventional fireplaces. Usually they are designed as “closed fireplaces”, so that the combustion takes place behind fireproof glass windows. In such closed combustion fireplaces, the combustion air is drawn in from the outside while the flue gases are transported to the outside as well. As a result, no flue gas can enter the heated space. Open fireplaces can be found in mostly in modified conventional fireplaces. Open fireplaces take the combustion air from the heated space and transport the flue gases to the outside of the building. This is achieved by connecting the fireplaces to a specific flue gas system. Usually the flame tube of gas fireplaces is built into a fireproof imitation of wood logs, so that it visually simulates a real wood fire. In order to use gas fireplaces, a steady connection to a gas supply network is preferred. Nevertheless some types can additionally be operated with liquefied gas; i.e. propane, which is available in transportable bottles. The heating capacity of gas fireplaces can fall within a range from 2 to 20 kW.

▶ **Flueless gas heaters**

Flueless gas heaters are heaters that burn gas and have no flue or chimney to transfer the combustion products to the outside. Instead, the products are released directly into the heated space. As they do not have a flue, these heaters can be easily installed to any gas connection point and can also be built as portable space heaters with bottled fuel supply. Also, as a result of the missing flue system, flueless gas heaters are usually cheaper to purchase than flued gas heaters. The stated features make flueless gas heaters an attractive heating option for many consumers. The main disadvantage of these appliances is the release of combustion products into the room, which could contribute to poor indoor air quality.¹²

¹² Commonwealth of Australia; The health effect of unflued gas heater use in Australia; 2007

4.3.1.3 **Liquid fuel room heaters**

▶ **Liquid fireplaces / gel fireplaces**

Liquid fireplaces feature a fuel container holding a combustible liquid i.e. ethanol – hence the name of ethanol fireplace – usually made of stainless steel, with a capacity of 1 to 5 litres. The container has an opening for the flame and oxygen transport for the combustion process. Some burner models offer the opportunity to adjust the flame height with the help of a simple slide mechanism. The fire in the ethanol fireplace is extinguished using a flap or a similar tool that stops the combustion air supply and consequently extinguishes the fire. The oxygen for combustion is taken from within the surrounding heated space.

From a technical point of view, gel fireplaces do not differ from liquid fireplaces with the exception that the used ethanol is gel-like and consequently easier to handle.

Both liquid and gel fireplaces most commonly use bioethanol as fuel. Bioethanol is the term for an ethyl alcohol (ethanol) of biological origin. It is generally obtained through fermentation and further processing of glucose from plant residues like sugar beets, corn or potatoes. The fireplaces can easily be refilled by the product users and are manually ignited with the help of a long match or a fireplace lighter. Due to the simplicity of use and their compact design, gel fireplaces are often used for decorative purposes. They are available as fixed fireplace inserts and portable devices with a heat output from approximately 400 W to 3000 W.

▶ **Paraffin/Kerosene heaters**

Kerosene heaters usually are unflued, kerosene-fuelled, space heating devices which are mainly used for supplemental or emergency heating, especially in the US and Japan. They play a minor role in the European market and are even restricted in some Member States.

Within a kerosene heater, a wick is used to lift kerosene from a fuel tank into a burner assembly. As the wick is ignited, the flame vaporises the liquid kerosene in the wick. The emerging kerosene vapour is mixed with surrounding air and is burned. The combustion can be controlled by rising and lowering the wick in the wick holder. Kerosene heaters are usually equipped with automatic ignition systems and are available with a heating capacity range between 3 and 7 kW.

There are two types of kerosene heaters: convection style (round) and radiant style (square), depending on the type of heat transfer they use. The most common complaint with kerosene heaters is the typical kerosene odour. Kerosene heaters used to be very widespread as residential portable heaters, but nowadays many people are switching to propane, being a cleaner fuel than kerosene.¹³ Nevertheless, kerosene heaters may be still used in some Member States, due to financial issues and lack of alternative fuel supplies.

¹³ www.bestpropaneheatersforhomes.net/

4.3.2 Non-residential heaters

4.3.2.1 *Non-residential radiant heaters*

► Radiant tube heaters

All radiant heating devices work according to the same physical laws and principles of heat transfer by radiation. Thermal radiation does not become effective until it hits a person or an object. After a short time, the heating effect is noticeable even when ambient temperatures are low.

Gas radiant tube heaters (radiant tubes) are devices that are mainly used for heating industrial and commercial buildings. A radiant tube heating system consists of a combustor for heat generation, linear or U-shaped steel tubes for heat transfer, a radiance reflector above the tubes and a fan for supporting the flow of the resulting flame and the hot flue gas through the tubes. Radiant tube systems are installed on the ceiling and walls of large halls or commercial buildings with a recommended minimum installation height of approximately 3 metres. The combustor, which is mounted on one end of the steel tube, produces a long flame with a length of up to 5 metres that reaches far inside the tubes. A fan propagates the flame. The fan can be installed as a pressure fan ahead of the combustor or as a suction fan sitting at the end of emitting tube. Therefore, the tube is heated by the long flame to temperatures of 300°C to 600°C. In this relatively low temperature range, the steel tubes do not emit visible light (glowing); the wavelength of the emitted radiation is about 5 µm. With the help of the radiance reflectors above the steel tubes, the thermal radiation can be redirected to the ground in the heated space.

The produced flue gas has to be lead to the outside of the building because it contains noxious residues like carbon dioxide and carbon monoxide. The heat output capacity can range from 10 to 70 kW to up to a few hundred kW depending on the dimensions of the radiant tube system.

For smaller heated spaces, radiant heaters are also manufactured as compact devices with radiant tubes, reflector, insulation, gas burner and exhaust fan forming a unit. The capacity is normally between 5 and 120 kW. These devices can also be transportable, when fired with LPG.

In many Member States it is common to extract the flue gases of radiant tube heaters by a flue pipe. In some Member States such as France and the UK, it is also usual to use indirect evacuation systems (according to EN 13410), where flue gases are let out from the heater in the upper area of the room and evacuated by room ventilation. For radiant tube heaters, the supply of combustion air and the evacuation of flue gases out of the room can be installed according to the three flue classification types (described earlier in section 4.2.2.)

► Luminous radiant heaters

Luminous radiant heaters are mainly used in industrial buildings and warehouses, as well as in gymnasiums or stadiums. Similar to radiant tubes, they are installed on the ceiling and walls of heated spaces with a recommended minimum installation height of 4 metres. The gas nozzle atomises the combustion gas into the venturi nozzle. This injection causes the air needed for combustion to be automatically sucked in and mixed with the gas according to the Bunsen burner principle. One major advantage of this technique is that no additional fan is needed, causing luminous radiant heaters to work almost noiselessly. The gas-oxygen mixture is led

through the burner plate, which has several small holes (diameter approximately 1 mm) and is ignited. The combustion process takes place in these holes, so that no direct flame can be seen. Because of this process, the surface of the ceramic plate is heated up to 950°C and starts glowing “luminously”. The wavelength of the emitted radiation is about 2.5 µm. As the combustion of luminous radiant heaters is very “clean,” there is no need for a direct flue gas system. In most cases the flue gas is discharged to the outside by ventilation of the heated space.

► **Radiant cassettes**

Radiant cassettes are a type of electric radiant panel heaters that are installed on ceilings. They use embedded electric heating elements to generate heat and distribute the heat by emitting thermal radiation to the surroundings. The surface temperatures of radiant cassettes can reach close to 100°C.

The main advantage of radiant cassettes is that they provide noise and draught-free heating for large non-residential buildings with ceiling heights up to 3 metres. Therefore, they are mostly used in public buildings, such as schools and community centres. The heating output of radiant cassettes varies from 1 kW to 4 kW.

4.3.2.2 Warm air unit heaters

Warm air unit heaters are compact heating appliances that are often used for heating of non-residential buildings like garages, factories, workshops, and warehouses.

These heaters contain gas or oil burners, or use resistive electric heating to generate heat. They can be designed as unflued or flued appliances. The generated heat is transferred to the heated space by convection using an axial fan. Typical capacity ranges for these heaters are from 10 to 1000 kW depending on the type of heat generator used. Warm air unit heaters can be direct- or indirect-fired.

► **Direct-fired warm air unit heaters**

In direct-fired warm air unit heaters, the heat generation by combustion takes place directly in the air stream circulating in the heated space. Due to the direct contact of the flue gases with the ventilation air, all combustion residues are released to the supply air that diminishes its quality. Therefore, it is necessary to keep the heated space well ventilated. Direct-fired appliances may only be fired with natural gas or LPG, as the flue gas emissions of other fuels (e.g. oil) are considerably higher and may pose health risks.

The biggest advantage of direct-fired systems is that, compared to indirect-fired systems, a very high thermal efficiency is reached (up to 100% net calorific value) while there are no requirements for costly and maintenance intensive heat exchangers.

► **Indirect-fired warm air unit heaters**

With indirect-fired warm air unit heaters, the fuel is burned and the hot flue gas is passed through a heat exchanger that is installed inside the ventilation airflow. A fan draws in the surrounding air and passes it over the heat exchanger. The heat is transferred from the flue gas to the ventilation air. After passing the heat exchanger, the hot flue gas is extracted to the outside either by natural or induced draught.

4-3-2.3 *Air curtains*

Air curtains are usually found in commercial buildings, where they are installed over openings to the exterior or between two differently conditioned spaces. The most common configuration of air curtains is a down facing installation, blowing a forced air stream across the surface of the opening to the floor, creating an air barrier.

Air curtains can serve many purposes. They can be intended to help keep flying insects out by creating forceful turbulence or to prevent outside air entering by reducing infiltration through the opening. They can also be used to avoid cold draughts by mixing in warm air heated by the air curtain. The fan must be powerful enough to generate a jet of air that can reach the floor.

4.4 Production phase

In order to calculate the environmental impacts and costs of materials and production processes, 'bill of materials' (BoM) of typical local room heating products were gathered from manufacturers. BoMs list all the types and quantities of materials and components used to produce one product unit. Detailed BoMs of selective Lot 20 heaters are presented in Annex 1.

4.5 Distribution phase

Local heaters for residential applications are typically packed in cardboard boxes to ensure maximum protection of the product. The packaging of heaters for non-residential applications also usually contains a high proportion of wood. The plastic share of packaging usually does not exceed 3%. Occasionally, some products are packaged in boxes entirely made of plastic.

Depending on the type and model of the product, the weight of the packaged product is between 1.5 and 615 kg (1.5 kg to 130 kg for heaters used in residential applications and 90 kg to 615 kg for heaters used in non-residential applications). Portable heaters are usually among the lightest appliances. The heaviest products are typically storage heaters and open combustion fires for residential heating applications, and warm air unit heaters for non-residential applications.

The volume of a packaged product varies from 0.03 to 0.40 m³ for residential heaters whereas non-residential heaters are considerably larger; the biggest appliance described by stakeholders is 12 m³. This is to be expected, as the heaviest appliance is typically also the largest in volume.

The data obtained from manufacturers is summarised in

Table 4-2.

Table 4-2: Summary of distribution data (volume and weight of packaged product)

Appliance type		Weight [kg]			Volume [m ³]		
		Mean	Min	Max	Mean	Min	Max
Residential	Open combustion flued gas heater	22	22	22	0.15	0.15	0.15
	Open combustion flued gas fire	40	17	79	0.21	0.12	0.34
	Flueless gas heater	19	27	11	0.13	0.10	0.16
	Convector electric fixed	16	1	69	0.05	0.01	0.02
	Electric portable fan heaters	5	3	6	0.04	0.03	0.05
	Static electric storage heater	119	106	132	0.17	0.14	0.19
	Electric underfloor heaters	1.7	0.5	3.6	0.03	0.01	0.04
Non-residential	Warm air unit heater	90	35	400	0.3	0.2	3.5
	Radiant luminous heaters	20	8	40	0.2	0.05	0.4
	Radiant tube heater	90	45	250	1.0	0.5	3.6
	Air curtain	100	100	100			

4.6 Use phase (product)

4.6.1 Energy consumption

The energy consumption of Local Room Heating Products (LRHPs) is determined by two major factors - heat demand and system efficiency:

4.6.1.1 Heat demand

The heat demand is mainly influenced by climate conditions, the building environment and personal preferences of consumers. In case of cold temperatures, consumers of LRHPs try to match the heat demand directly by switching on the LRHP or indirectly by raising the desired temperature value of the thermostat.

The climatic conditions and building insulation determine the amount of heat loss to the environment. The heat loss of buildings increases with the temperature difference between the outside temperature and room temperature. The climatic conditions of the Member State are analysed in Task 3 - Consumer behaviour and local infrastructure.

The building shell affects the fuel consumption of LRHPs as every construction component of a building (e.g. walls, windows and doors) has its own heat transfer coefficient. The higher this

coefficient is, the more heat can pass through the building element. As a result, the heat loss and thus the heat demand are higher.

Another issue that has a major influence on the fuel consumption of local room heating products is internal heat gains. Internal heat gain is the heat contribution to a heated space (room or a building) of direct sunlight, people, lighting and other equipment present inside the heated space. The higher the internal heat gains, the less energy heating systems need to provide during heating season to heat the space (room or building), resulting in reduced fuel consumption. In contrast to this, high internal heat gains may lead to overheating in summer, which raises the cooling energy demand and will increase fuel consumption.

4.6.1.2 *System efficiency*

System efficiency, or the amount of energy that is taken out of the fuel, depends on many product aspects and system factors. Therefore the product and system efficiency is analysed in more detail in section 4.7- Use phase (system).

4.6.2 Electricity consumption

The electricity consumption of local room heating products is influenced by many factors such as the components and operational procedures. The main electricity consuming components are:

- electric heating elements;
- electric motors (convection fans);
- burners (fans and control devices)
- ignition systems; and
- controls (thermostats).

AFYCET estimated the electricity consumption of fixed electric heaters as shown in Table 4-3.

Table 4-3: Estimated electricity consumption of fixed electric heaters¹⁴

Electricity consumption		
Operation Mode	Consumption [kWh]	Typical proportion of time in a mode in year [%]
On mode	1.430	13%
Standby mode	0.001	28%
Off mode	0	59%

¹⁴ AFYCET, Association of Manufacturers and Traders of Fixed Electrical Heaters

4.6.3 Emissions of pollutants

Combustion processes, as they occur in local room heating products, are accompanied by the production and emission of different pollutants. These pollutants have various characteristics concerning environmental impacts and toxicity. For these reasons it is of great importance to analyse the emission of pollutants from local room heating products and their corresponding environmental impacts.

The amount of pollutants produced depends on the characteristics of the fuel used and the type and quality of the combustion process. The combustion of natural gas generally emits lower quantities of greenhouse gases and other pollutants per unit of energy production than other fossil fuels (see Figure 4-6). Firstly, it is easier to achieve complete combustion of natural gas, as no gasification or pre-processing is necessary before combustion, and also because it can be easily mixed with combustion air. Complete combustion is a primary requirement to avoid high amounts of emitted pollutants. Secondly, natural gas contains fewer impurities than other fossil fuels such as oil.¹⁵ The figure below illustrates emissions by fuel type. The following section gives an overview of pollutants and their environmental impacts.

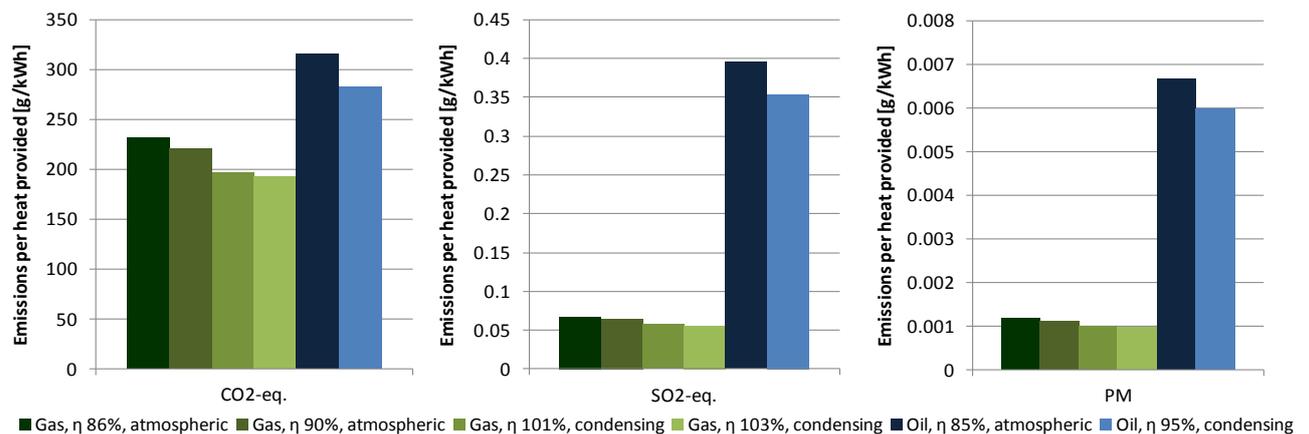


Figure 4-6: Comparison of emitted pollutants of gas and oil¹⁶

4.6.3.1 Pollutants

► CO₂ - Carbon Dioxide

Carbon dioxide is a greenhouse gas. In a properly calibrated heating appliance, nearly all of the carbon content of the fuel (over 99% in both natural gas and oil) is converted to CO₂ during the combustion process. Due to incomplete combustion, carbon content of the fuel, which is not converted to CO₂ results in methane (CH₄), carbon monoxide (CO), and/or VOC emissions.¹⁷ Thus, the amount of CO₂ emitted depends on the quantity of carbon contained in the fuel. As demonstrated in Figure 4-6, natural gas contains the lowest amount of fuel carbon, followed by oil and coal.

¹⁵ Environmental impacts of different types of central heating boilers taken from EcoReport (VHK, 2005)

¹⁶ Environmental impacts of different types of central heating boilers taken from EcoReport (VHK, 2005)

¹⁷ Office of Air Quality Planning And Standards, Office of Air And Radiation, U.S. Environmental Protection Agency; Compilation Of Air Pollutant Emission Factors, Chapter 1.3 to 1.5; January 1995; www.epa.gov/ttnchie1/ap42/

▶ **NO_x - Nitric Oxides**

NO_x is a generic term for mono-nitrogen oxides NO and NO₂ (nitric oxide and nitric dioxide). Both gases participate in ozone layer depletion while NO is also responsible for acid rain.

NO_x is a by-product of combustion because of partial oxidation of nitrogen contained in the fuel. The maximum amount of nitric oxides are emitted as NO (>90%) and the smaller amounts as NO₂ (<10%). The emissions of NO_x increase with increasing nitrogen contents in the fuel, excess air ratio, and higher combustion temperature. Heavy oils contain between 0.1% and 0.8% nitrogen, and fuel oils between 0.005% and 0.07%. Natural gas contains no organically bound nitrogen¹⁸.

▶ **CO - Carbon Monoxide**

Carbon monoxide is a highly toxic gas and it promotes the formation of ground-level ozone, which has negative impacts on the environment. Carbon monoxide is found in combustion of all carbonaceous fuels, as an intermediate product of the combustion process and in particular as a result of understoichiometric combustion¹⁹. The level of emission of CO is influenced by the excess air ratio, the combustion temperature and residence times of combustion products in the combustion zone¹⁸.

▶ **PM - Particulate Matter**

Particulate matter can be described as the amount of fine particle emissions in flue gas. It consists of carbon, smoke, soot, stack solid or fly ash. The amount of particulate matter released mainly depends on two factors: combustion quality and fuel composition. For these reasons, the main measures to prevent high PM emissions are optimal design of the combustion process to achieve complete combustion and increased fuel quality¹⁸. PM emissions cause severe impacts on environment, most notably an increase of global warming, in addition to causing adverse effects on public health.

▶ **SO₂ - Sulphur Dioxide**

Sulphur dioxide is a major air pollutant and has significant impacts on health and the environment. It is mainly formed through the combustion of sulphur-containing fossil fuels. The quantity of emitted sulphur dioxide directly depends on the sulphur content of the burned fuel, while the sulphur content itself varies locally.

▶ **NM VOC - Non-Methane Volatile Organic Compounds**

NM VOC is a generic term for a large variety of chemically different compounds, such as benzene, ethanol, formaldehyde, cyclohexane, chloroethene and acetone. As is the case for CO, emissions of NM VOC result from inferior combustion temperatures, insufficient residence time in combustion zone, and/or insufficient oxygen availability during the combustion process.

¹⁸ Kubica, Paradiz, Dilara; Small combustion installations: Techniques, emissions and measures for emission reduction; European Commission; 2007

¹⁹ Understoichiometric combustion signifies that there is less oxygen available for combustion than potentially should be available to ensure complete combustion.

► HM - Heavy Metals

Most of the heavy metals considered (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn) are released as compounds associated with and/or adsorbed on particles (e.g. sulphides, chlorides or organic compounds). Hg and Se are at least present only in the vapour phase. Less volatile elements tend to condensate onto the surface of smaller particles in the exhaust gases. Therefore, the emission of heavy metals strongly depends on their concentrations within a given fuel. Coal and its derivatives normally contain heavy metal concentrations that are several orders of magnitude higher than oil (most exceptionally for Ni and V in heavy oils) and natural gas (about 2-5 µg/m³).

► PAH - Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons are potent atmospheric pollutants that consist of fused aromatic rings and do not contain heteroatoms or carry substituents²⁰. PAHs occur in oil, coal and tar deposits, and are produced as by-products of fuel burning (whether fossil fuel or biomass). Emissions of all polycyclic aromatic hydrocarbons result from incomplete (intermediate) conversion of fuels. As for CO and NMVOCs, emissions of PAH depend on the quality of the combustion process, especially on combustion temperatures (low temperatures increase their emission), the residence time in the combustion zone and the availability of oxygen²¹. As a pollutant they are of concern because some compounds have been identified as carcinogenic, mutagenic (may induce mutation of the human genome), and teratogenic (may cause disturbance of the growth and development of an embryo or foetus).

► PCDD/F - PolyChlorinated Dibenzodioxins and -Furans

PCDD/F are commonly referred to as dioxins and furans for simplicity because every PCDD molecule contains a dioxin and every PCDF molecule contains a furan skeletal structure. Emissions of dioxins and furans are highly dependent on the conditions under which combustion and exhaust gas cooling is carried out. Carbon, chlorine, a catalyst and oxygen excess are necessary for the formation of PCDD/F⁶. Members of the PCDD/F family are known teratogens, mutagens, and confirmed human carcinogens.

4.6.3.2 *Pollutant emissions factors*

Pollutant emissions factor is a representative value that attempts to relate the quantity of a pollutant released into the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per tonne of coal burned). Such factors facilitate the estimation of emissions from various sources of air pollution.

²⁰ Fetzer; The Chemistry and Analysis of the Large Polycyclic Aromatic Hydrocarbons. Polycyclic Aromatic Compounds; 2000

²¹ Kubica, Paradiz, Dilara; Small combustion installations: Techniques, emissions and measures for emission reduction; European Commission; 2007

4.6.4 Energy efficiency ratings

As there are several different methods for measuring the energy efficiency of heating products, the following section gives an overview of the relevant efficiency ratings for local room heating products.

4.6.4.1 Thermal efficiency

Thermal efficiency (η_{th}) is a performance measure (in %) of devices that use thermal energy, such as local room heaters. In general, thermal efficiency is the ratio between the useful output of a device and the input, in energy terms. Accordingly, when considering heating appliances, thermal efficiency is the ratio of the heat output divided by the heat-content of the consumed fuel:

$$\eta_{th} = \frac{Q_{out}}{Q_{in}}$$

Thermal efficiency always necessitates restating the used heating value. Net thermal efficiency indicates that the net heating value (lower heating value) was used for efficiency calculation while gross thermal efficiency is based on the higher heating value.

All electric resistance heaters have a thermal efficiency of 100%. However, most electricity is produced from oil, gas, or coal generators that convert only about 30% of the fuel's energy into electricity.²² When researching the overall efficiency of electric heating products, this fact must be taken into account.

4.6.4.2 Radiant factor

Radiant factor (0.0 ...1.0) measures the share of nominal heat input converted into radiant heat. The method for determining the radiant factor of luminous radiant heaters is described in EN 416-2:2006, "Single-burner gas-fired overhead radiant tube heaters for non-domestic use - Part 2: Rational use of energy". Tube radiant heaters are described in EN 419-2:2006, "Non-domestic gas-fired overhead luminous radiant heaters - Part 2: Rational use of energy".

²² www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12520

4.6.4.3 **AFUE (Annual fuel utilisation efficiency)**

The annual fuel utilisation efficiency (AFUE) is a US measure of thermal efficiency for combustion equipment such as furnaces, boilers, and water heaters expressed as a percentage. The AFUE differs from true 'thermal efficiency' in that it is not a steady-state, peak measure of conversion efficiency, but instead attempts to represent the actual, season-long, average efficiency of a piece of equipment, including the operating transients²³. The method for determining the AFUE for residential furnaces is the subject of ASHRAE Standard 103.

4.6.4.4 **Air curtain efficiency**

Air curtains reduce the heat loss by reducing the natural convection of warm air through open doors as much as possible. The ISO 27327 standard defines the efficiency of an air curtain as the percentage reduction of the heat loss through the door opening in comparison to a situation without an air curtain.

$$\eta = \left(1 - \frac{Q_{out,with\ air\ curtain}}{Q_{out,without\ air\ curtain}} \right) \times 100\%$$

Where, Q_{out} represents the outflow of warm air through the open door

An air curtain with a discharge velocity of 0 m/s has an efficiency of 0% (as it is same as the situation without an air curtain). An air curtain with too low discharge velocity will only lose its heat to the outside space and therefore the heat loss to the outside will be larger than in a situation without air curtain, creating a negative efficiency. At a certain critical discharge velocity the air curtain will be strong enough to reach the floor and to avoid outward bending. As the heat from the air curtain is now going to the inside space, the curtain will save a fair amount of energy and become highly efficient. An air curtain with too high discharge velocity will be less efficient because of the resulting impact of the air stream on the floor. Induction along a high speed air stream also increases losses to the outside.

4.6.5 **Energy losses**

4.6.5.1 **Incomplete combustion**

The flue gases of all fuel-fired local room heaters may contain combustible substances like CO and hydrocarbons because of incomplete combustion. Such substances are not completely burned during combustion, meaning that not all-useful energy is taken out of the fuel. In order to achieve complete combustion it is necessary to adjust the burner with the correct fuel-air ratio or to operate it with an air excess²⁴. This issue does not affect electric room heaters.

²³ ASHRAE, Inc.; ASHRAE Handbook, Systems and Equipment, 2004

²⁴ ELVHIS and EUROAIR commented that incomplete combustion does not occur with gas-fired decentralised heaters in non-domestic premises as long as technical guidelines and manuals of manufacturers are observed.

4.6.5.2 *Flue gas losses*

Efficiency reduction due to flue gas losses means that heat is carried away in chimney gases due to high flue gas temperatures. The basic causes for high flue gas temperatures are insufficient heat transfer surfaces (insufficient heat exchanger size) and the fouling of heat exchangers. As a result, too little heat is transferred from the flue gas to the supply air and is lost through the chimney. To keep the flue gas losses as low as possible it is desirable to take as much heat as possible out of the flue gas, without causing condensation and cold end corrosion in the flue gas route. The calculation method to estimate the flue gas losses for indirect flue gas evacuation (Type A) are described in EN 13410 and EN 15316-4-8. For direct flue evacuation (Types B and C) condensing and non-condensing heating systems needs to be differentiated.

For local room heaters using combustion to generate heat, auxiliary energy is completely transferred into heat inside the heated space, thus, there are no heat losses for auxiliary energy, e.g. fans.

4.6.5.3 *Purge losses*

Every local room heater that generates heat by combustion has to complete a specific cycle of safety operations before and after the actual firing interval is conducted. This cycle contains a pre and post-purge of the heater. In the pre-purge phase, the burner fan operates to force air through the heater's flue gas route, to flush out any combustible residues that may have accumulated. The post-purge performs a similar function. During the purge, heat is removed from the boiler as the purged air is heated. Due to this, it is desirable to avoid short cycling of the heater that is usually a result of over sizing. One of the ways to reduce purge losses is to use capacity-modulating burners, as they adjust the heating output to the actual heat demand, and thereby avoid short cycling. Most modulating burners can only modify the heating capacity in a specific range. This range is expressed by the turndown ratio, which is the ratio of the burner's maximum capacity to its minimum capacity. If the turndown ratio is too low, it may still result in short cycling of the burner, as the burner cannot adjust its output below the minimum range.

4.6.5.4 *Pilot flame*

Traditional appliances often have a continuously burning pilot light, which serves as a small ignition flame for the gas burner and can consume a significant amount of fuel. The heat produced by the burning pilot light is released inside the heated space and therefore should not be considered a heat loss while the heater is in operation. However, when the heater is not operating in particular during the off-heating season (summer) the energy consumed by the burning pilot flame should be considered as an energy loss.

4.7 Use phase (system)

4.7.1 Overview

Several factors can have an influence on the efficiency of local room heating products. Besides the product-related issues (see section 4.6.5), there are other system-related factors. These system factors are not a direct part of the product itself, but are associated with the energy consumption and efficiency of the product. For these reasons it is necessary to investigate these system influences further.

As the products of this study are decentralised local heating products, they are usually not integrated into a heat distribution system. A local room heater usually joins the role of heat generator and heat distributor.

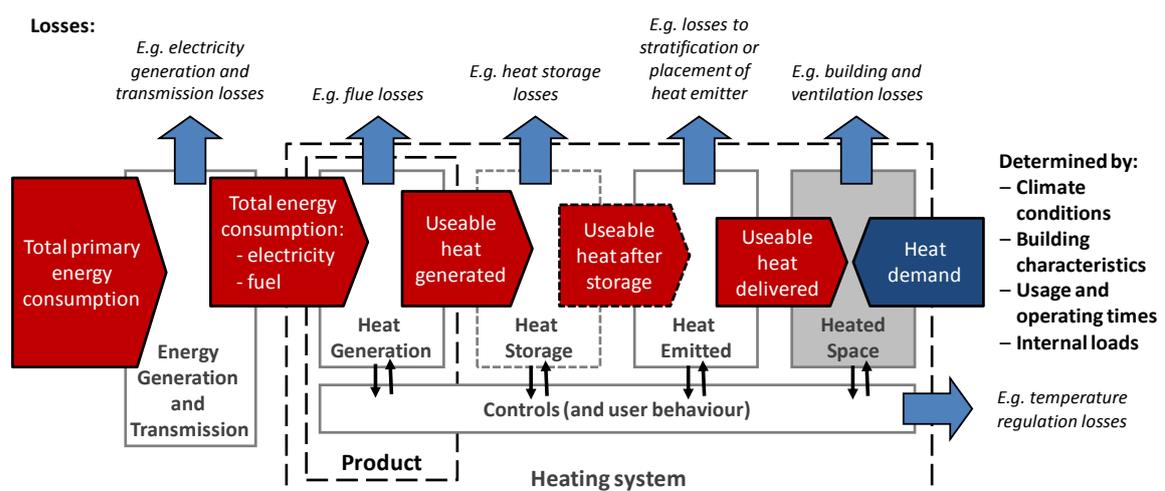
4.7.2 Product/System boundaries

The following section defines the product and system boundaries of the treated local room heating products.

The term product defines the heating appliance and all contained components. The product boundary can therefore be imagined as the housing of the heating appliance including all connections to external lines.

The system boundaries extend the product boundaries to other energy-influencing parameters, such as properties of the heated space, building environment, climate conditions and controls. Figure 4-7 gives an illustration of the presumed product and system boundaries of this study.

Figure 4-7 : Product and system boundaries



4.7.3 System factors influencing energy efficiency and annual energy consumption

4.7.3.1 Building environment

Buildings account for around 40% of Europe's energy consumption and offer the greatest potential for energy efficiency improvements.²⁵ This shows that building characteristics have a major influence on the energy efficiency of heating systems. The energy efficiency is directly linked with the heat demand of a building, as it represents the amount of heat lost through the building surface. Depending on the year of construction, insulation and the other conditions, the heating demand of a building can vary strongly. For example, older buildings may have a specific heat demand that is three times higher than new buildings²⁶. This is a result of improved building methods and improved choice of materials, including masonry, windows, doors and insulation materials.

The following section gives an impression of the main influences of buildings on energy efficiency of local room heating products.

► Location of the appliance

The location of the appliance must be adequate in terms of sufficient availability of combustion air (if necessary). Lack of combustion air will inevitably lead to incomplete combustion and thereby to a decrease in combustion efficiency.

As local room heaters exclusively get used directly inside the room where the heat is needed, no jacket losses occur. All heat that is lost by the appliance to the room has a heating effect on the room.

► Transmission heat losses

Transmission heat loss is the sum of the heat lost by conduction through a building's walls, windows, roofs, doors, and floors. The higher the transmission heat loss of a building, the more heat must be provided to balance the loss and reach the desired temperatures. Transmission heat loss depends on two factors: the indoor/outdoor temperature difference and the thermal resistance of the building's envelope. The greater the difference between the indoor and outdoor temperatures, the greater the rate of heat loss. Thermal resistance affects heat loss as well; the more resistance the building material has, the lower the transmission heat loss. The resistance to heat flow of a building part is measured in terms of the heat transfer coefficient (U value) in W/m²K. A common way to reduce the transmission heat losses in stock buildings is to improve the insulation of the building.

► Outdoor air infiltration

Air that infiltrates a heated space from the outside has to be heated to keep the inside space at the desired temperature. This results in an additional consumption of energy. Outdoor air

²⁵ Intelligent Energy Europe IEE; News Review No. 4; February 2009; http://ec.europa.eu/energy/intelligent/library/doc/ienr_4_en.pdf

²⁶ www.dena.de/themen/thema-bau/

infiltration can occur due to leakages in the building envelope and can also be caused by normal using behaviour, i.e. as a result of the opening of doors and windows.

4.7.3.2 Sizing and product selection

As seen in the previous section, the sizing and the selection of the appropriate product has a major influence on the heating performance in terms of achieving required temperature. Therefore, determining the heat load of a building is necessary to correctly size heating products. As modern buildings tend to have a significantly lower heat demand, the required heating capacity is lower as well. With the help of a professional heat load calculation and product selection, over- and under-sizing can be prevented.

Generally, many local room heaters are not sized correctly according to the heat demand, as they may be selected, purchased and installed by the user. This tendency can be observed with heaters designed for primary and secondary heating in both the residential and non-residential sectors. To avoid over-sizing of these heaters it is necessary to raise users' awareness of the energy consumption of the products.

Furthermore, in order to achieve an energy-efficient heating system, it is necessary to consider the building environment. Depending on the type and use of a building, the choice of the most efficient local room heating product can vary.

4.7.3.3 Flue gas extraction system

The flue gas extraction system can influence the efficiency of local room heating products in two ways.

► Flue design

To maintain the stack effect, there are some general requirements that a flue must fulfil. As the stack effect increases with height, a flue has to keep a minimum height in order to create a sufficient draught (approximately 4 to 6 metres). Additionally, the pressure loss inside the flue must be kept as low as possible. The diameter of the flue pipe must not be too small, the material should have a low roughness, and bends in the flue should be reduced to an absolute minimum. Incorrect sizing of the flue gas extraction system may result in high pressure loss and thereby lead to a constrained flue gas flow. Additionally, installation issues may have a negative effect on the heating performance. All flues have to be installed in such a way that wind cannot directly enter the flue.

► External conditions

The external conditions (e.g. strong winds and surrounding buildings) may affect the flue gas extraction rate and thereby the combustion efficiency. It can be seen that the dimensioning of a flue is a very important system factor of flued local room heaters. The calculation and dimensioning of flue gas systems is described in the European standard EN 13384-1 and -2.

4-7-3-4 **Fuel supply**

All fuel-fired local room heaters have to be provided with a sufficient amount of fuel under constant conditions. Irregularities in fuel supply may lead to combustion issues, such as flame lifting and flame loss.

Gas-fired appliances can be permanently connected to a gas grid, or be supplied with bottled gas. As the gas pressure may influence the combustion efficiency, the gas supply lines must be sized properly. Under-sizing may result in a high-pressure loss and insufficient fuel supply.

Oil-fired appliances usually need to be permanently connected to an oil supply line and an appropriately sized oil tank. The oil supply lines must be sized correctly to avoid high-pressure losses. Liquid-fuelled transportable heaters (such as kerosene heaters and ethanol fireplaces) are usually equipped with an appropriate fuel tank that has to be manually refilled.

4-7-3-5 **Controls**

Controls of the local room heating products (including sensors and actuators) are relevant for the efficiency of heating systems. Correctly configured controls can help to provide heat only when it is needed and can minimise waste of energy caused by effects like overheating. On the other hand, incorrectly configured controls can decrease efficiency. Therefore, the control system has to be considered when assessing the efficiency of local room heating products.

4.8 End-of-life phase

Stakeholders provided interesting insights via their responses to the questionnaire survey on the end-of-life of local room heaters. Several manufacturers suggested that local room heaters are not likely candidates for significant re-use.

Many manufacturers of local room heaters pointed out that, in their opinion, although they do not have much influence over the end-of-life practices of their products, only a very small proportion of their products go to landfill or incineration. Based on stakeholder feedback, it is estimated that on average 15% (ranging from 0% up to 50%) of local room heaters in EU end up in landfills at the end of their life.

The design characteristics and the value associated with the materials used in local room heaters encourage their recycling. For example, a large majority of manufacturers pointed out that their wiring board is easy to disassemble, thus enabling easy sorting of the materials. Some manufacturers producing heaters made exclusively from plastics and metals commented that their products are assembled in such a way that disassembly and subsequent recycling is made easy. Plastics and metals used in the local room heaters are often 100% recyclable. The ENER Lot 20 products are included in the “large household appliances” product group covered by the WEEE Directive²⁷. The Eurostat provides data about the end-of-life practices of these products. The level of detail of the available statistics does not enable the waste treatment of each type of local

²⁷ Waste Electrical and Electronic Equipment Directive

room heater. The project team therefore assumed that local room heating products have a similar end-of-life as other large household appliances. According to Eurostat,²⁸ the recycling rate of large household appliances collected as WEEE was 77% in 2008 and the total recovery (including material recycling and energy recovery) was 84%. This is consistent with the estimate of manufacturers that 15% of the product goes to landfill. However, still according to Eurostat, only 37% of WEEE was collected compared to the total amount put on the market in 2008. Therefore, it is not sure that the WEEE data is representative of the end-of-life for these types of appliances. It is not clear whether this low collection rate is due to material accumulation in households or to waste that is improperly treated. The estimate for 15% landfill might be optimistic, but without better data this is a reasonable assumption.

Finally, in order to determine the data that will be use for the life cycle analysis in Task 5, the project team decided to use manufacturer inputs on landfill (15%) and to extrapolate the WEEE data on large household appliances from Eurostat to plastics.

- 15% of the overall waste stream goes to landfill
- 77% of plastics is recycled.
- 7% of plastics is used for energy recovery (incineration)

4.9 Recommendations on mandates

As presented in Task 1, energy efficiency test measurement standards at the EU level already exist for most of the appliances covered in the ENER Lot 20 study.

At present, there are standards (in place and under development) that specify methods for calculating the energy requirements of local room space heaters to determine their energy efficiency performance. These cover both air heating and overhead radiant heating systems.

Concerning electric appliances, stakeholder responses to the questionnaire survey suggests that manufacturers in the EU usually do not use any standard to determine their appliances' efficiency as it is always considered to be 100% at the time of use. They do however, use some design standards as described below:

- IEC 60675²⁹: deals with portable, stationary, fixed or built-in electric direct-acting room heaters which include panel heater, fan heater, convector heater, radiant heater and visibly glowing radiant heater
- IEC 60531: concerns electric storage heaters.
- IEC 60800³⁰: for low capacity underfloor heating systems

The European Commission has issued a horizontal Mandate to CEN and CENELEC covering all relevant activities related to standardisation in relation to the Ecodesign Directive. The Technical Committee CLC/TC 59X was thus set up to accompany the EuP activities concerning the

²⁸ Eurostat, Waste Electric and Electronic Equipment (WEEE) [env_waselee]

²⁹ Household electric direct-acting room heaters - Methods for measuring performance

³⁰ Heating cables with a rated voltage of 300/500 V for comfort heating and the prevention of ice formation

performance of household and similar electrical appliances. The working group WG 12 (“Electric room heating appliances”) aims at refining the EN 60675 standard to take care of performance and comfort of different electric room heating appliances including underfloor heating equipment. This may deal with associated aspects related to the use of the appliances and aspects such as classification, accessibility and usability of appliances, ergonomic characteristics and conditions for the information provided at the point of sale.³¹

Manufacturers of gas fired appliances mostly use the following energy efficiency test standards which specify the test methods for the rational use of energy:

- EN 613 : Independent gas-fired convection heaters
- EN 509: Decorative fuel-effect gas appliances
- BS-EN 7977: Gas-fired fixed independent space heaters, primary and secondary heating.
- EN 13278: Open fronted gas-fired independent space heaters with nominal heat input not exceeding 20 kW
- EN 416-2³²: radiant tube heaters
- EN 419-2³³: overhead luminous radiant heaters
- EN 525³⁴: gas fired warm air unit heaters
- EN 1020³⁵: gas fired warm air unit heaters
- EN 1196³⁶: gas fired warm air unit heaters

The following standards specify methods for calculating the energy requirements of local room space heating systems to determine their energy efficiency performance. These cover both air heating and overhead radiant heating systems.

- EN 13790³⁷: gives calculation methods for assessment of the annual energy use for space heating and cooling of a residential or a non-residential building
- EN 15316-2-1³⁸: include energy efficiency of local room heaters from a system perspective

Concerning non-domestic heating appliances using gas, new standards are currently being elaborated by CEN TC 180 WG 4. Technical committee TC 180 (decentralised gas heaters). Working Group WG 4 of TC 180 is elaborating and revising standards for the efficiency of warm

³¹ CENELEC, CLC/TC 59X

www.cenelec.eu/dyn/www/f?p=104:7:1189491449718425:::FSP_LANG_ID,FSP_ORG_ID:25,114#1

³² Single burner gas-fired overhead radiant tube heaters for nondomestic use – Part 2: Rational use of energy

³³ Non-domestic gas-fired overhead luminous radiant heaters – Part 2: Rational use of energy

³⁴ Non-domestic direct gas-fired forced convection air heaters for space heating not exceeding a net heat input of 300 kW

³⁵ Non-domestic forced convection gas-fired air heaters for space heating not exceeding a net heat input of 300 kW incorporating a fan to assist transportation of combustion air or combustion products

³⁶ Domestic and non-domestic gas-fired air heaters - Supplementary requirements for condensing air heaters

³⁷ Energy performance of buildings -- Calculation of energy use for space heating and cooling

³⁸ Heating systems in buildings – Method of calculation of system energy requirements and system efficiencies

air and radiant heating systems. The new and revised standards that will result from this initiative will consider relevant product features as well as the system perspective defined by EPBD standardisation (EN 15316-x-y). A similar approach for electric and liquid fuel based heating systems taking into account the building characteristics and the product-system relation would be very useful for including system parameters in the efficiency testing of products within the scope of the ENER Lot 20 preparatory study.

As the European Commission has already issued a mandate to CEN and CENELEC to provide European standards to enable the implementation of the Ecodesign Directive, no further recommendation of mandates is therefore expressed here. For a further description of all standards, please refer to Task 1.

4.10 Conclusions

This task presents the technical characteristics of various technologies existing in the EU for local room heating products. Local room heaters can be broadly categorised by their usage in residential and non-residential applications. The heaters used in non-residential building mostly serve the primary heating purpose whereas the ones used in residential buildings includes heaters used for both primary and secondary heating purposes. These heaters can further be distinguished based on their method of heat generation and the principle of heat emission. These heaters use electricity, gaseous and liquid fuels for the generation for heat. The generated heat is directly transferred to the heated space by radiation and natural or forced convection. These heaters can further also be classified based on secondary functionalities such as heat storage.

Therefore, the material requirements, components and energy consumption during the life cycle of these local room heaters are very different. These different types of heaters will be analysed separately in the following tasks.

With this aim, some inputs for each life-cycle stage are presented for the different product types in this Task 4 report. The inputs are completed with a more in-depth analysis in Task 5 in order to perform the environmental and economic impact assessment of the representative Base Cases.

Annex 1

Bill of Materials

Table o-1: Bill of Materials for open combustion flued gas heaters

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [kW]	7.00	7.00	7.00	7.00	0.00
Product weight [kg]	15.9	15.9	12.00	19.8	-
Packaging weight [kg]	2.00	2.00	2.00	2.00	0.00
Product	Content [%]				
Steel	92.5	92.5	90.00	95.00	2.50
Cast Iron	0	0	0.00	0.00	0.00
Other ferrous metals	0	0	0.00	0.00	0.00
Non-ferrous metals	3	3	2.00	4.00	1.00
Plastics	0.625	0.625	0.25	1.00	0.38
Coatings	2.5	2.5	1.00	4.00	1.50
Electronics	0.5	0.5	0.00	1.00	0.50
Other Materials	0.875	0.875	0.00	1.75	0.88
Packaging	Content [%]				
Plastics	2.5	2.5	2.00	3.00	0.71
Cardboard	84	84	70.00	98.00	19.80
Paper	1	1	0.00	2.00	1.41
Other (Wood, etc.)	12.5	12.5	0.00	25.00	17.68
* Bill of Materials received: 2					

Table o-2: Bill of Materials for open combustion flued gas fires

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [kW]	4.54	4.40	3.60	6.50	0.96
Product weight [kg]	28.15	22.47	14.46	70.00	19.01
Packaging weight [kg]	2.90	1.90	0.50	8.50	2.61
Product	Content [%]				
Steel	73.43	66.00	60.59	89.07	12.14
Cast Iron	0.00	0.00	0.00	0.00	0.00
Other ferrous metals	0.00	0.00	0.00	0.00	0.00
Non-ferrous metals	3.89	2.49	0.00	11.02	4.04
Plastics	1.04	0.29	0.14	4.00	1.46
Coatings	1.88	2.00	0.00	3.00	1.07
Electronics	0.67	0.00	0.00	4.00	1.49
Glass	3.74	2.86	0.00	10.00	4.07
Other Materials	12.68	14.15	2.14	21.15	7.18
Packaging	Content [%]				
Plastics	6.10	1.79	0.00	17.30	7.73
Cardboard	83.99	95.00	35.29	100.00	22.90
Paper	1.11	0.00	0.00	4.00	1.58
Other (Wood, etc.)	8.71	0.00	0.00	58.82	22.11
* Bill of Materials received: 7					

Table o-3: Bill of Materials for flueless gas heaters

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [kW]	2.50	2.50	2.50	2.50	0.00
Product weight [kg]	15.62	17.71	9.35	25.00	6.30
Packaging weight [kg]	1.47	1.47	1.15	1.78	0.45
Product	Content [%]				
Steel	69.10	63.80	59.40	85	9.69
Cast Iron	0.00	0.00	0.00	0.00	0.00
Other ferrous metals	0.00	0.00	0.00	0.00	0.00
Non-ferrous metals	14.41	17.22	6	18.44	2.93
Plastics	1.34	1.34	0.67	2.00	0.94
Coatings	1.27	0.03	0.00	5	2.15
Electronics	0.48	0.48	0.00	0.96	0.68
Glass	2.20	2.20	0.00	4.40	3.11
Other Materials	8.89	10.84	3	11.67	3.44
Packaging	Content [%]				
Plastics	3.30	3.30	2.25	4.35	1.49
Cardboard	48.88	48.88	0.00	97.75	69.12
Paper	0.00	0.00	0.00	0.00	0.00
Other (Wood, etc.)	47.83	47.83	0.00	95.65	67.64
* Bill of Materials received: 3					

Table o-4: Bill of Materials for electric fixed convectors

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [kW]	1.47	1.50	0.50	2.00	0.51
Product weight [kg]	13.4	10.5	4.67	29.80	9.68
Packaging weight [kg]	1.73	1.30	0.30	4	1.41
Product	Content [%]				
Steel	58.59	80.00	0.00	91.00	35.88
Cast Iron	0.53	0.00	0.00	4.15	1.37
Other ferrous metals	0.23	0.00	0.00	2.06	0.69
Non-ferrous metals	10.64	0.04	0.00	69.20	22.87
Plastics	10.05	6.42	0.00	52.38	16.16
Coatings	3.00	4.28	0.00	5	2.20
Electronics	1.86	2.00	0.00	3	1.13
Glass	0.39	0.00	0.00	3.51	1.17
Other Materials	15.98	1.50	0.00	98.57	31.69
Packaging	Content [%]				
Plastics	10.99	4.35	0.00	66.67	21.20
Cardboard	82.90	93.75	0.00	100.00	31.69
Paper	2.39	0.00	0.00	20.00	6.62
Other (Wood, etc.)	3.73	0.00	0.00	33.33	11.10
* Bill of Materials received: g					

Table 0-5: Bill of Materials for electric portable fan heaters

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [kW]	2.00	2.00	2.00	2.00	0.00
Product weight [kg]	1.75	1.43	1.3	2.36	0.42
Packaging weight [kg]	0.50	0.50	0.20	0.80	0.42
Product	Content [%]				
Steel	49.50	52.00	5.00	99.00	36.89
Cast Iron	0.00	0.00	0.00	0.00	0.00
Other ferrous metals	0.00	0.00	0.00	0.00	0.00
Non-ferrous metals	5.00	0.00	0.00	10.00	5.00
Plastics	48.00	48.00	1.00	95.00	66.47
Coatings	0.00	0.00	0.00	0.00	0.00
Electronics	2.50	0.00	0.00	5.00	2.50
Other Materials	0.00	0.00	0.00	0.00	0.00
Packaging	Content [%]				
Plastics	5.63	2.50	0.00	15	5.69
Cardboard	97.50	98.50	0.95	100.00	3.54
Paper	5.00	5.00	0.00	10.00	7.07
Other (Wood, etc.)	0.00	0.00	0.00	0.00	0.00
* Bill of Materials received: 3					

Table o-6: Bill of Materials for static electric storage heaters

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [kW]		-	2.55	-	-
Product weight [kg]	116.5	116.5	104.00	129.00	17.68
Packaging weight [kg]	2.4	2.4	1.60	3.20	1.13
Product	Content [%]				
Steel	15	15	13.00	17	2.83
Cast Iron	0	0	0.00	0.00	0
Other ferrous metals	76.5	76.5	75.00	78	2.12
Non-ferrous metals	0.65	0.65	0.00	1.30	0.92
Plastics	0.15	0.15	0.00	0.30	0.21
Coatings	0.1	0.1	0.00	0.20	0.14
Electronics	0	0	0.00	0	0
Other Materials	7.25	7.25	4	10.50	4.60
Packaging	Content [%]				
Plastics	13.5	13.5	11.00	16.00	3.54
Cardboard	64.5	64.5	42.00	87.00	31.82
Paper	2.00	2.00	2.00	2.00	0.00
Other (Wood, etc.)	20.00	0.00	0.00	40.00	28.00
* Bill of Materials received: 2					

Table o-7: Bill of Materials for electric underfloor heaters³⁹

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [W/m]	83.00	100.00	15.00	200.00	79.92
Product weight [kg/m]	0.31	0.054	0.07	0.55	0.26
Packaging weight [kg]	0.40	0.40	0.30	0.6	0.13
Product	Content [%]				
Steel	1.14	2.27	0.00	4.55	1.90
Cast Iron	0.00	0.00	0.00	0.00	0.00
Other ferrous metals	17.59	0.00	0.00	70.37	29.44
Non-ferrous metals	33.30	50.00	9.09	65.00	27.54
Plastics	41.66	40.91	35.00	50.00	4.83
Coatings	0.00	0.00	0.00	0.00	0.00
Electronics	0.00	0.00	0.00	0.00	0.00
Other Materials	2.27	4.55	0.00	9.09	3.80
Packaging	Content [%]				
Plastics	25.00	50.00	0.00	100.00	41.83
Cardboard	66.67	66.67	0.00	100.00	38.01
Paper	8.33	16.67	0.00	33.33	13.94
Other (Wood, etc.)	0.00	0.00	0.00	0.00	0.00
* Bill of Materials received: 3					

³⁹ Bill of Materials for underfloor heaters represents itself an summary of BoM for underfloor cables and mats.

Table o-8: Bill of Materials for warm air unit heaters

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Max. heating output [kW]	158.40	40.20	35.00	400.00	209.25
Product weight [kg]	273.00	131.00	88.00	600.00	284.01
Packaging weight [kg]	15.33	12.00	5.00	29.00	12.34
Product	Content [%]				
Steel	83.30	81.50	71.00	97.40	13.29
Cast Iron	0.00	0.00	0.00	0.00	0.00
Other ferrous metals	12.00	18.00	0.00	18.00	10.39
Non-ferrous metals	3.63	0.90	0.00	10.00	5.53
Plastics	0.20	0.00	0.00	0.60	0.35
Coatings	0.10	0.00	0.00	0.30	0.17
Electronics	1.10	0.80	0.50	2.00	0.79
Other Materials	0.00	0.00	0.00	0.00	0.00
Packaging	Content [%]				
Plastics	1.40	0.20	0.00	4.00	2.25
Cardboard	12.22	16.67	0.00	20.00	10.72
Paper	0.10	0.00	0.00	0.30	0.17
Other (Wood, etc.)	86.28	83.33	79.50	96.00	8.64
* Bill of Materials received: 3					

Table o-9: Bill of Materials for gas fired radiant tube heaters

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Nominal heat input [kW]	25.90	25.90	19.40	32.40	9.19
Product weight [kg]	52.33	52.33	21.66	83.00	43.37
Packaging weight [kg]	5.72	5.72	4.44	7.00	1.81
Product	Content [%]				
Steel	89.72	89.72	81.44	98.00	11.71
Cast Iron	0.75	0.75	0.00	1.50	1.06
Other ferrous metals	1.52	1.52	0.00	3.05	2.15
Non-ferrous metals	3.00	3.00	0.00	6.00	4.24
Plastics	3.05	3.05	0.00	6.09	4.31
Coatings	0.00	0.00	0.00	0.00	0.00
Electronics	1.75	1.75	0.50	3.00	1.77
Other Materials	0.21	0.21	0.00	0.42	0.29
Packaging	Content [%]				
Plastics	0.00	0.00	0.00	0.00	0.00
Cardboard	57.14	57.14	14.29	100.00	60.61
Paper	0.00	0.00	0.00	0.00	0.00
Other (Wood, etc.)	42.86	42.86	0.00	85.71	60.61
* Bill of materials received: 2					

Table o-10: Bill of Materials for gas fired radiant luminous heaters

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Nominal heat input [kW]	19.40				
Product weight [kg]	21.66				
Packaging weight [kg]	4.44				
Product	Content [%]				
Steel	0.00				
Cast Iron	0.00				
Other ferrous metals	3.0				
Non-ferrous metals	6.0				
Plastics	6.3				
Coatings	73.1				
Electronics	2.8				
Other Materials	1.7				
Packaging	Content [%]				
Plastics	0.00				
Cardboard	100				
Paper	0.00				
Other (Wood, etc.)					
* Bill of Materials received: 2					

Table o-11: Bill of Materials for air curtains

	Content				
	Mean	Median	Minimum	Maximum	Std. Deviation
Nominal heat input [kW]	24	24	24	24	0.00
Product weight [kg]	100	100	100	100	0.00
Packaging weight [kg]					
Product	Content [%]				
Steel	76.00				
Cast Iron					
Other ferrous metals					
Non-ferrous metals	14.00	14.00	14.00	14.00	0.00
Plastics	3.00	3.00	3.00	3.00	0.00
Coatings	1.00	1.00	1.00	1.00	0.00
Electronics	3.00	3.00	3.00	3.00	0.00
Other Materials	3.00	3.00	3.00	3.00	0.00
Packaging	Content [%]				
Plastics					
Cardboard					
Paper					
Other (Wood, etc.)					
* Bill of Materials received: 2					



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20-22 Villa Deshayes

75014 Paris

+ 33 (0) 1 53 90 11 80

biois.com