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**Lot 4: Industrial and Laboratory Furnaces and Ovens – Tasks 1 – 3**

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## Executive Summary

Industrial and laboratory furnaces and ovens include a very wide variety of equipment. These range from small laboratory ovens that consume less than 1 KWh to cement kilns that on average produce 586,000 tonnes of cement annually and blast furnaces that can produce 3.5 million tonnes of iron per year. Industrial furnaces and ovens consume very large amounts of energy most of which in the EU is derived from fossil fuels. The EU cement and steel industries each generate about 2% of the EU's carbon dioxide emissions.

Most furnaces and ovens are used by industry and professionals and there are many different types many of which are non-standard or custom designed. Users include manufacturers of metals, metal parts, glass, ceramics and cement, research and analytical laboratories, schools and colleges (e.g. pottery), hospitals (sterilisers and incubators) and a small number of home users for jewellery and pottery. Furnaces and ovens are used to heat materials inside a heated cavity, although some provide other functions such as cooling. Heated cavities vary in dimensions enormously and include four main design type; cubes, vertical and horizontal tubes and long tunnels with conveyers to carry the parts through the furnace or oven.

**Task 1** considers the definition and classification of furnaces and ovens that will be reviewed for this eco-design study.

Various aspects have been examined including function, design features, uses and user requirements. The definition of an oven or furnace unit has also been considered as this is important especially for large industrial furnaces and ovens that are often used as integral parts of more complex production processes. A simple definition could be **"Equipment with a primary function to heat materials inside an enclosed compartment"**. In some processes the excess heat exhausted from a furnace may be reused either to preheat burner air or materials (this improves energy efficiency) or it may be used elsewhere for building heating, electricity generation or to preheat materials for a different thermal process. Re-use of energy within a furnace unit is an integral part the furnace and so would be included in energy efficiency calculations whereas reuse elsewhere outside the furnace unit may not be considered for efficiency calculations but is no less valid.

There are many European, national and other standards that affect industrial and laboratory furnaces and ovens but very few are concerned with energy consumption or energy efficiency. Notably, ISO is developing a new standard that is a detailed and comprehensive method for calculation of energy consumption and energy efficiency for any thermal process.

There is a lot of legislation that affects furnaces and ovens. This includes safety legislation and legislation that controls emissions to air, water and land. The largest types of furnace and oven are covered in the EU by the Integrated Pollution Prevention and Control (IPPC) directive (this is currently being reviewed) and by the EU greenhouse gas emissions trading scheme (GHG ETS). IPPC effectively controls emissions of hazardous substances but is not very effective in maximising energy efficiency.

The main eco-design impacts of furnaces and ovens are energy consumption, with the associated CO2 emissions, and the use and potential emissions of hazardous substances. Hazardous substances are already regulated by a variety of directives and EU regulations and so the main opportunity for eco-design benefits lie with energy efficiency improvements. A preliminary estimate has been made of the potential for energy efficiency improvements within this sector. There are a lot of publications that describe energy efficiency improvements achievable with currently available technologies, some being very significant. It is also clear from discussion with stakeholders that users of furnaces and ovens do not always install the most energy efficient design as these are often more expensive than simpler designs with payback times that can be longer than are acceptable in the context of the user's business model (often limited to 3 years maximum payback period by EU users). There are therefore opportunities for energy savings when comparing furnaces that are supplied to EU users with those that could be supplied. The difference is less significant for the largest furnaces as energy consumption is very large and very expensive so users tend to install the most energy efficient designs although there can be some cost limitations. The difference is more significant as a percentage of energy consumed for mid-range furnaces that are often used by SMEs with limited capital availability although this can also be an issue with larger enterprises. Energy efficiency is not considered as a high priority by users of laboratory ovens and furnaces and information on efficiency and consumption of these models is very limited as many manufacturers do not measure the energy efficiency of their products.

An initial estimate of potential energy savings from using the best available technology compared to standard designs has been made and this could be as much 100TWh /year although this is based on very limited data and so could be an over-estimate. Much larger energy savings (many hundreds of TWh/y) would eventually be achieved by replacement of the large number of old, inefficient furnaces in the EU by modern efficient designs.

## Task 2 considers the furnace and oven market.

This market is very diverse but data on sales of furnaces and ovens is not published. Prodcum Eurostat data is not useful as this does not provide data for numbers of most types of furnace and oven that are placed on the EU market. The only comprehensive source of freely available published data is from the IPPC directive's guidance on best available techniques (BREFs). For some types of furnace, these give data on EU energy consumption and an indication of the energy consumption of different types of furnace. There is also some information on EU stocks but this is very limited. As a result, it will be important to obtain accurate data from industry and so a questionnaire has been provided to both manufacturers and users of furnaces and ovens which aims to obtain this data.

The largest furnaces and ovens are usually custom designed. These may be designed by furnace manufacturers, furnace design consultants or by the user themselves. Construction may be by a furnace manufacturer, specialist installer or by the user. Smaller furnaces and ovens are more often standard models but adapted standard designs or custom designs are also supplied in the EU. These are usually designed and constructed by a furnace or oven manufacture. Many of the smaller models are supplied by distributors. Furnace and oven manufacturers are mostly SMEs in the EU although

there are some large multinational group companies with subsidiaries that specialise in ovens and furnaces.

Purchase and operating cost data is being obtained and more is required from stakeholders. Purchase prices vary enormously ranging from over €1 billion for a blast furnace to ~€500 for a small laboratory oven. Users incur costs from energy use as well as maintenance and, for some furnaces, regular refurbishment is also needed.

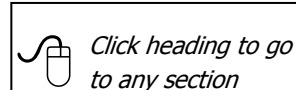
**Task 3** investigates the technical requirements of users of furnaces and ovens from provision of information, requirements in use to disposal.

The information supplied by manufacturers to users depends on the type of furnace / oven with rather more information being available including energy consumption predictions for the largest furnaces and ovens whereas more limited information concentrating on available functions and specifications is provided for laboratory ovens and furnaces.

The requirements of users vary considerably depending on the business sector and the type of furnace or oven. Variables that are important to users include size, throughput, maximum temperature, temperature uniformity and control, price and running costs.

Most furnaces and ovens have very long useful lives with some coke ovens used by the steel industry being over 100 years old although 20 – 30 years life is more typical for most types of industrial furnace and oven. At end of life some materials such as steel are recycled whereas insulation material is land-filled.

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## 0. Introduction

The Eco-design of Energy using Products (EuP) Directive 2005/32/EC was adopted as a framework directive to set up the procedures required to assess energy using products and adopt implementing measures if needed to achieve eco-design improvements, in particular reductions in energy consumption which will be needed to achieve the EU's targets for reducing emissions of global warming gases (GHG). This directive was replaced in 2009 with the Eco-design of Energy related Products Directive (2009/125/EC) which has similar aims but a broader scope.

The Eco-design Directive by itself does not provide binding requirements for specific products, but provides the framework and defines conditions and criteria for introducing directly binding requirements (implementing measures). A product category shall be covered by an implementing measure when it:

- represents a significant volume of sales in the EU market (indicatively, >200,000 units a year),
- has a significant environmental impact, and
- presents a significant potential for improvement.

The "Study for preparing the first Working Plan of the Eco-design Directive" carried out for the European Commission by EPTA Ltd. in 2007<sup>1</sup> showed that industrial and laboratory ovens and furnaces were the fourth largest category for emissions of greenhouse gases and the sixth largest user of energy. These products consume significant quantities of energy, mostly derived from fossil fuels although this includes a relatively small number of very large furnaces in the EU. IPCC estimate that industry produces 19.4% of global greenhouse gas emissions, second only to electricity generation at 25.9% globally<sup>2</sup> and a significant proportion of energy used by industry will be from furnaces and ovens.

Furnaces and ovens include a very wide range of products mostly used by industry although a small number of furnaces are used in households for hobbies such as pottery and jewellery. Ovens and furnaces range from laboratory products with a capacity of less than 5 litres to blast furnaces which can produce over 1 million tonnes of steel annually. Some laboratory instruments contain small heated chambers which are integral parts of these products although they could be referred to as either ovens or furnaces. Energy efficiency is not generally considered when buying small laboratory ovens but industry is becoming increasingly conscious of the energy efficiency of their processes due to the very high cost of energy. Significant reductions in energy consumption are widely reported as being achievable but the capital cost of new plant is significant and so new technology is not adopted

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<sup>1</sup> EPTA study for preparing the first Working Plan of the Ecodesign Directive, Report for tender No: ENTR/06/026, [http://ec.europa.eu/enterprise/policies/sustainable-business/files/workingplan\\_finalreport\\_en.pdf](http://ec.europa.eu/enterprise/policies/sustainable-business/files/workingplan_finalreport_en.pdf).

<sup>2</sup> Intergovernmental Panel on Climate Change, "Climate change synthesis report 2007", [http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr\\_spm.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf).

as quickly as it becomes available. Industrial furnaces tend to have very long lives, over 20 years being common, but regular refurbishment is carried out to extend the product life and this can be an opportunity to make energy efficiency improvements.

The aim of this study is to look at all eco-design aspects of these products although energy efficiency is likely to be the aspect where the largest gains are achievable. The cost of introduction of these improvements is important as this can be a barrier to adoption. It will be important to understand what barriers exist to adopting eco-design improvements in order to develop a range of options that the Commission will consider for this category of equipment.

The study comprises seven tasks:

**Task 1** defines the scope and classification of products to be included in this study. Standards and legislation will also be identified.

**Task 2** will collect economic and market data that will be used in later tasks. Market data is a useful parameter for identifying potential product types for use as Base-Cases. There are a very large variety of ovens and furnaces on the EU market and so it will be necessary to limit the number of Base-Cases to a manageable number.

**Task 3** investigates user requirements and behaviour including end of life.

**Task 4** is an assessment of selected Base-Cases and provides technical information on selected products including bill of materials and energy consumption. Standard products currently on the market need to be identified which can in later tasks be compared with best available technology (BAT) and the best not yet available technology (BNAT).

**Task 5** reviews the potential for improvement by reviewing the best available technology (BAT) and the best not yet available technology (BNAT).

**Task 6** determines the eco-design improvement potential and presents a sensitivity analysis of key parameters.

**Task 7** presents an analysis of policy options and their potential impact.

## 0.1 Scope of study - definition of furnaces and ovens

The main function of furnaces and ovens is to heat materials inside an enclosed space. However not all heated enclosures are ovens or furnaces. For example, a boiler heats water inside a container and premature babies are kept warm inside special incubators but neither would be regarded as an oven or furnace. It will therefore be essential to define what is a furnace or oven.

## 0.2 Eco-design impacts of from ovens and furnaces

Energy consumption of furnaces and ovens in use is very large and is probably the most significant environmental impact although emissions of hazardous materials during fabrication, use and end of life are also important.

Furnaces and ovens are used for a very wide variety of industrial and laboratory processes. Users are not likely to heat an empty oven or furnace (possibly except for small laboratory ovens which are left on when not being used) and industrial furnaces and ovens will almost always be used to heat materials to carry out one specific process. Raising the temperature, melting, boiling or causing chemical reactions to these materials usually consumes energy and can also cause the emission of hazardous substances, usually as gases. Some processes are exothermic such as the injection of oxygen into liquid pig iron in a basic oxygen furnace (BOF) where the carbon dissolved in the iron burns with the oxygen to produce CO<sub>2</sub> and heat. This process generates more energy than is needed to maintain the iron as a liquid and excess energy can be re-used elsewhere in the steel plant. Hazardous gases can also be emitted from gas, coal or oil burners such as carbon monoxide and nitrogen oxides and production of these gases should ideally be avoided but if unavoidable they should be trapped and disposed of safely.

It is likely that the main environmental impact of furnaces and ovens will be from energy consumption. Hazardous materials emissions can be significant but are already regulated in the EU. In order to understand the energy efficiency of an oven or furnace, it is important to differentiate the terms:

- "Energy efficiency" which is a ratio or percentage of energy consumed by the material and the total energy input
- "Energy consumption" which is the total quantity of energy consumed by the process.

A complicating factor is the energy source. Ovens and furnaces can be heated directly by burning flammable materials, most commonly fossil fuels such as gas, coal and oil (each emits different amounts of CO<sub>2</sub> and energy efficiency can also vary for a specific process). A proportion of the heat of combustion is utilised in the oven or furnace process but some is lost as hot ventilated combustion gases. Electric heating can be more energy efficient in that almost 100% of the electricity can in theory be converted into heat energy inside the oven or furnace. However generation of electricity is only about 35% efficient as there are generating and transmission losses. As most electricity in EU is generated from fossil fuels (with a 30 – 35% efficiency), each KWh of heat energy input to the oven or furnace from electrical heating will result in the emission of more CO<sub>2</sub> than by the same amount of heat energy derived directly from fossil fuels such as gas or oil. Electric heating is less popular for processes that consume large quantities of energy because the cost of electric heat energy is greater than the cost of heat energy from fossil fuels such as natural gas. Currently estimates for the average CO<sub>2</sub> emissions/KWh electricity generated vary in EU between 0.45kg CO<sub>2</sub>/KWh<sup>3</sup> and 0.39 kg

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<sup>3</sup> Carbon Monitoring for Action (CARMA), [www.carma.org](http://www.carma.org)

CO<sub>2</sub>/KWh (2007)<sup>4</sup> whereas natural gas emits only 0.184kg CO<sub>2</sub>/KWh of energy<sup>5</sup>. The difference in CO<sub>2</sub> emissions / KWh between electricity and gas will change as the major source of electricity generated in the EU changes from fossil fuels to renewable sources or nuclear. EU policy includes a target of at least 20% of energy should be generated from renewable sources by 2020. Although the proportion of non-fossil fuel generated electricity including nuclear energy could be larger than 20%, it is not likely to be sufficient to make the use of electric heating of ovens and furnaces preferable to fossil fuel combustion in terms of global warming gas emission by 2020<sup>6</sup>, possibly except where a low efficiency fossil fuel process (some can be only 20%) is compared with a high efficiency electrically heated process (>75% is possible).

### 0.3 Energy consumption and efficiency

The principal function of ovens and furnaces is to heat materials. However the heat energy input is used in a variety of ways such as:

- To raise temperature of materials, e.g. metal heat treatment
- To evaporate liquids such as in drying processes
- To cause chemical reactions within materials – these can be endothermic so require heat input e.g. cement production (which converts CaCO<sub>3</sub> to CaO and CO<sub>2</sub>) or exothermic so emit heat such as in iron production (Fe<sub>2</sub>O<sub>3</sub> + C = Fe + CO<sub>2</sub>) and minerals smelting such as reaction of copper sulphide with oxygen to form copper metal and sulphur dioxide
- To raise temperature of the interior - floor, roof and walls, internal insulation, any support structures and the atmosphere inside the oven or furnace
- To heat air that ventilates through oven or furnace. Heat losses are proportional to the number of air changes per hour. Air changes may be needed to remove moisture (drying) or combustion gases where fossil fuels are burned inside the chamber
- Hot combustion gas emissions where gas, oil or coal heating is used to heat the furnace or oven
- Heat lost from external surfaces of furnace or oven.

This can be shown for an electrically heated unventilated oven or furnace by<sup>7</sup>:

$$H_T = H_1 + H_2 + H_3$$

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<sup>4</sup> Eurelectric calculation.

<sup>5</sup> Market Transformation Programme report BNXS01 "Carbon dioxide emission factors for UK Energy Use" version 4.2, 2010.

<sup>6</sup> [http://ec.europa.eu/energy/strategies/index\\_en.htm](http://ec.europa.eu/energy/strategies/index_en.htm). See also World Energy Outlook 2009 Fact Sheet, October 2009, [www.worldenergyoutlook.org/docs/weo2009/fact\\_sheets\\_WEO\\_2009.pdf](http://www.worldenergyoutlook.org/docs/weo2009/fact_sheets_WEO_2009.pdf)

<sup>7</sup> "Handbook of Thermoprocessing Technologies" ed. A. von Starck, A. Muhlbauer and C. Kramer, Vulkan Verlag, 2005.

where:  $H_T$  = total energy input, i.e. the **total energy consumed**.

$H_1$  = heat supplied to heat material being processed

$H_2$  = heat supplied to interior of furnace or oven and

$H_3$  = heat lost to exterior of furnace or oven.

**Energy efficiency** therefore is =  $H_1 / (H_1 + H_2 + H_3)$

$H_2$  is dependent on the insulation material as  $H_2 = m \cdot T_m \cdot C_p$ , where

$m$  = mass of insulation

$T_m$  = mean temperature of insulation

$C_p$  = specific heat of insulation.

Therefore low density insulation with low specific heat is ideal for minimising energy consumption.

$H_3$  depends on the dimensions and properties of the insulation as  $H_3 = \lambda \Delta T (A/d) t$  where:

$\lambda$  = thermal conductivity of insulation material

$\Delta T$  = temperature difference between the inside and outside of the furnace or oven

$A$  = cross-sectional area of insulated surface

$d$  = thickness of insulation

$t$  = time (process time).

Therefore  $H_3$  is lowest with:

- Low thermal conductivity insulation – select appropriate insulation material (see Table 9),
- The lowest practical process temperature – limited by process requirements
- Small oven / furnace cavity size – needs to accommodate parts or materials. A full oven or furnace is therefore more efficient than one only part full.
- Thick insulation - see Table 9,
- A short process time – e.g. use more powerful heating to shorten pre-heat time.

Many ovens and furnaces are ventilated, for example for drying materials. This heated air generally has to be replaced by fresh cold air that requires heating. Oil, gas and coal burners generate hot combustion gases and as much of this heat as possible should be transferred to the furnace / oven and the materials being processed, but inevitably some heat energy is lost in the exhaust gases.

These losses can be minimised in a variety of ways. The flow-rate of air through a drying oven should be as low as possible to minimise energy consumption although this will slow drying processes. Effective heat transfer from hot gases from flames into the oven or furnace is achieved by good design but inevitably heat is lost as hot exhaust gas emissions although this heat can sometimes be used to pre-heat burner air (recuperative and regenerative burners), heat feed materials or for heating buildings, all of which reduce overall energy consumption.

Oven and furnace designs should take into account the variables that affect energy consumption and energy efficiency but it is inevitable that some energy will be consumed to carry out the process which is unavoidable – steel production, heat treatment, melting metals, drying, etc. Energy will be consumed even if the oven / furnace energy efficiency were 100% and the only way to reduce EU energy consumption from very high energy-efficiency furnaces and ovens is by reduction in the consumption of manufactured products which is not likely to be an acceptable option. Furthermore, a large quantity of commodities and fabricated products that have been made using furnaces and ovens are imported into EU. The energy efficiency of these furnaces and ovens may be inferior to those in the EU (and cannot be regulated by the EU). Although energy efficient processes are being introduced world-wide, in some countries older less energy efficient processes are being installed. It is important therefore to encourage the consumption (in EU) of fabricated products and commodities that have been produced using energy efficient processes. This is however, outside the scope of this study, but it is important that EU manufacturers are not placed at a competitive disadvantage that results in an increase in the imports into the EU of products that have been made using lower energy efficient processes as this would increase global carbon emissions. Relocation of manufacturing to countries outside the EU has been occurring for many years although products made with very large furnaces such as ceramics, glass and cement tend to be made in EU. If new EU energy efficiency legislation causes the economics to change so that a new furnace built in EU is more expensive than a new less energy efficiency furnace built elsewhere, then users will consider the payback period (cost of additional energy efficient design minus the energy saved) and if it is more than often 3 years, then there is a risk that they would decide to relocate outside EU.

Most furnace and oven processes have energy efficiencies that are much less than 100% and so there should be scope for improvements in energy efficiency and a reduction in energy consumption and this will be studied in tasks 4, 5 and 6. The first task in this study, however, is to define furnaces and ovens.

## 1. Task 1 - Definition

Task 1 examines the scope of this preparatory study and so considers the definition of ovens and furnaces. The functions and characteristics are assessed as well as defining the boundaries for this study. Ovens and furnaces are very varied in their size, design and functions but all apply heat to materials within an enclosed space. ISO committee TC244 defines these products as heated enclosures. This simple definition could include products that are not within the scope of this study however, for example kettles used for boiling water (to make beverages) which are enclosed vessels that are internally heated. Ovens and furnaces have many different designs; most heat items in a chamber in which the interior is a gas (air or other gases) but vacuum is also used. There are some types of larger furnaces in which the heat source is directed into the material that is being treated such as to melt (e.g. metal melting), burn (e.g. incinerators) or react (e.g. cement kilns and smelters). The aim of this task is to define the boundaries for laboratory and industrial ovens and furnaces and investigate possible differentiating characteristics.

Ovens and furnaces often have additional functions as well as heating. Examples include:

- Cooling such as with fans or sometimes using refrigeration (or immersion in oil)
- Movement such as on a conveyor or by rotating cylindrical enclosures
- Controlled atmosphere, inert gas, humidity, vacuum, etc.

Many ovens and furnaces are designed for specific purposes and so include features that enable these to be carried out. For example:

- Condensation and removal of flux residues from conveyorised oven soldering processes (reflow ovens)
- Specific temperature profiles are used for many procedures including metals heat treatment, reflow soldering, firing thick-film electronic circuits, thermal cycle testing of products and heat sterilisation
- Weighing materials automatically inside the furnace for analytical purposes such as thermal asphalt binder analysis
- Waste heat recovery is used with some larger furnaces either to preheat raw materials, the air used for combustion or as with some Japanese blast furnaces, waste heat is used to generate electricity.

Some ovens and furnaces are used as components that are part of other products. For example, several types of analytical instrument contain components that need to be heated to a precisely controlled temperature and this is achieved by placing them inside a heated cavity which is essentially an oven but the product that is placed on the EU market is the analytical instrument.

The following sections describe the wide variety of ovens and furnaces placed on the EU market, applicable standards and legislation.

## 1.1 Product definition

It is important for this study to define what is included and what is excluded from the definition of a furnace or oven. Some suggestions are:

1. Enclosed chamber in which materials are inserted, heated to raise their temperature in a controlled way to cause a physical or chemical change in the material which is then removed after completion of the heating process.
2. Enclosed space in which materials are heated to one or more specific temperatures as part of a production process or test procedure.
3. Enclosed structure in which the interior is heated and materials enter at one location, the heat causes chemical or physical changes to occur before the materials emerge from a different part of the enclosed structure.
4. Enclosed compartment in which parts are placed for a period of time where they are exposed to changes in temperature and other environmental conditions such as humidity, atmospheric pressure or chemical composition of the atmosphere.

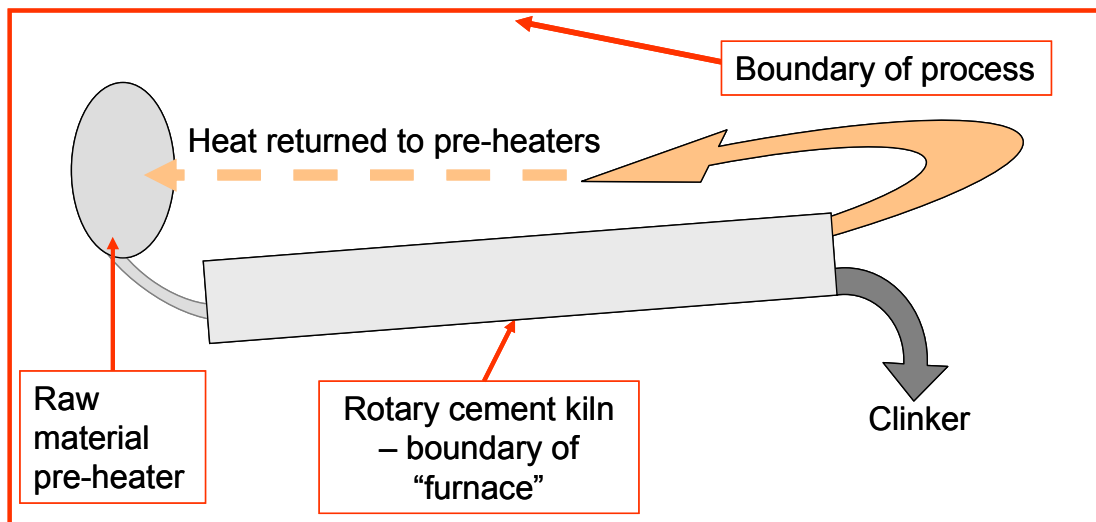
**Excluded** from the furnace or oven definition would be ancillary equipment such as hygiene equipment for emissions, external conveyers that feed material into the furnace or oven and external equipment that uses waste heat for electricity generation or heating buildings. Carbon capture and storage would be excluded from the functional unit. Materials that are processed by the furnace or oven are also excluded. One type of furnace, for example could be used to heat many different materials. The energy consumed and any emissions will depend on the quantity and type of material that is heated as the material itself will usually adsorb heat and chemical changes may occur that emit other substances. Heating limestone ( $\text{CaCO}_3$ ), for example will emit  $\text{CO}_2$ . This emitted  $\text{CO}_2$  is inevitable and cannot be prevented if limestone is heated at above its decomposition temperature, moreover, where this occurs it is the intended process. Equipment whose primary function is not heating materials should also not be considered as being an oven or furnace.

**Included** within the functional unit would be the heaters or burners, internal fans, internal supports for materials (shelves, conveyers), temperature control equipment and actuators and motors that move internal parts of the oven or furnace or move the oven / furnace itself (such as a rotary furnace). Re-use of waste heat to pre-heat burner air may be considered part of the functional unit and external heat exchangers to pre-heat feedstock before they enter the furnace or oven enclosure could be included. Emissions from combustion of burner gases would be considered as part of the oven or furnace definition but emissions from materials that are processed in the oven or furnace are excluded.

**Possibly included or excluded:** – Some ovens and furnaces cool or quench parts and materials after heating. The cooling stage is usually an integral part of the furnace but there may also be heat

exchangers used to recover waste heat for reuse that are separate from the main oven / furnace function. Re-used heat can be used directly in the furnace or used elsewhere for heating buildings or other processes. Examples where heat reuse could be considered to be part of the functional unit may include:

- Recuperative and regenerative burners re-use hot emissions to preheat air and fuel for the burners giving improved energy efficiency. This equipment is an integral part of the furnace design although involves structures that are outside of the heated enclosure.
- Most cement kiln processes can use hot exhaust gases to pre-heat raw materials. This may be in separate cyclones prior to the rotary kiln itself rather than inside the rotary furnace. These cyclones are separate chambers to the kiln but are an integral part of the process equipment. The cement kiln is a type of furnace but the energy consumption and overall energy efficiency depend on the entire process design as shown in Figure 1.

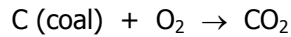
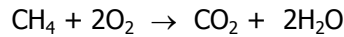


**Figure 1. Cement production process boundary of furnace process and furnace itself**

Figure 1 illustrates why it is important to consider the whole process to assess energy efficiency where the heat emissions from the furnace or oven are re-used within the process.

The impact on global warming of a furnace process is due to any global warming gases that are emitted. Carbon dioxide is usually the most significant but nitrogen oxides and other gases will contribute.

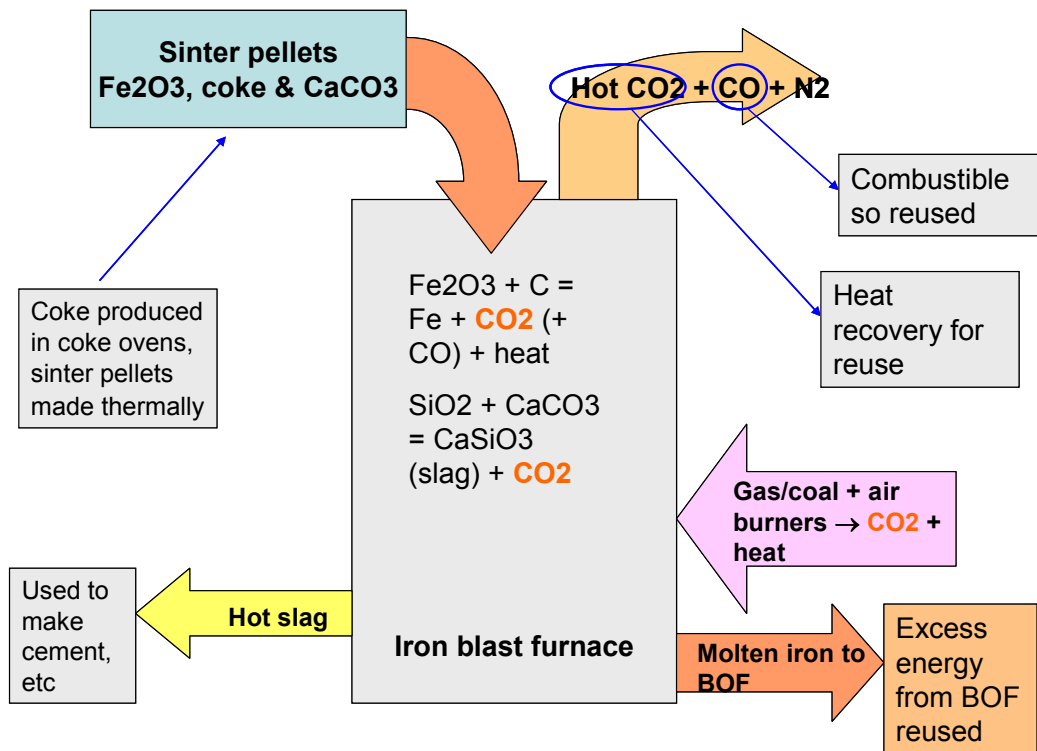
- Electric heating - Carbon dioxide is emitted during electricity generation where fossil fuels are used but electricity generation and transmission are excluded from the functional unit.
- Combustion for heating using fossil fuels directly, such as natural gas, coal and oil are included within the functional unit - these emit carbon dioxide:



- Chemical reactions within the process (so part of the functional unit) can also emit CO<sub>2</sub> such as heating limestone in cement kilns or blast furnaces:



This reaction can be reversible so that when cement cures, it re-adsorbs CO<sub>2</sub> but this occurs outside of the functional unit. However in a blast furnace, the lime (CaO) reacts with silica to produce calcium silicate so that there is a net evolution of fossil CO<sub>2</sub> but calcium silicate is fairly stable and so will not reabsorb the CO<sub>2</sub> resulting in a net emission. The overall blast furnace process is only a part of the steel production process and excess heat is used elsewhere in the production of steel. The blast furnace process is:



**Figure 2. Iron production in a blast furnace process showing three sources of CO<sub>2</sub>.**

If a process is selected for a base-case which emits CO<sub>2</sub> or other gases as process by-products, these would be included in the calculations of total environmental impact. Technologies to minimise these emissions will be examined in task 5.

### 1.1.1 Definitions from standards

Several standards define the terminology used for ovens and furnaces with UK standard BS4642:1970 being particularly useful for its comprehensive list of furnace types and some ovens. Useful standards include:

**Table 1. Standards that categorise and define furnaces and ovens**

Standard number	Title
BS 4642:1970 (UK)	Glossary of industrial furnace terms
UNI 7415 (Italy)	Forni Industriali. Termini, definizioni e classificazione (industrial furnaces – terms, definitions and classifications)
SAC GB/T 17195 (China)	Industrial furnace terminology
VDMA 24202 (Germany)	Industrial furnaces, classification
VDMA 24351 (Germany)	Drying technology – General terms

Several standards include key categories and definitions and these are listed in Table 2.

**Table 2. Definitions of furnaces and ovens from standards**

Standard number	Definitions
BS 4642:1970	<p>This standard defines over 210 different types of furnaces and ovens. Definitions include:</p> <p><b>Furnace</b> - A structure within which heat is generated to a controlled temperature by the combustion of fuel, or by the application of electrical or other energy, generally constructed or lined with refractory material and designed to suit the nature and dimensions of the material to be processed.</p> <p><b>Oven</b> - An alternative term for “furnace”, derived from the German; more properly, a heated chamber not normally used above about 500 °C.</p> <p><b>Incinerator</b> - A refractory lined chamber and equipment connected to a chimney, designed to burn solid, liquid or gaseous wastes and to produce inoffensive gases and sterile residues containing little or no combustible material.</p> <p><b>Muffle</b> - A furnace in which the working space and the charge therein are isolated from the heating medium and any combustion products.</p> <p><b>Blast furnace</b> - A vertical, refractory lined structure incorporating within its height a hearth, bosh and stack; used for the reduction of ores to metal.</p>
EN 50156-1:2004	<p><b>Furnace</b> - a structure within which heat is generated to a controlled temperature by combustion of fuel</p>
ASME EA-1-2009	<p><b>Furnace</b> – a term generically used (in this standard) to describe heating equipment such as furnaces, melters, ovens and heaters</p>

The definitions in Table 2 of furnaces and ovens include “structure in which heat is generated” and “controlled temperature” as key aspects. “Heated chamber” is used for ovens but not furnaces although the words structure and chamber may both be suitable for both ovens and furnaces. A clear and concise definition will be needed if any implementing measures are adopted although this can define the scope for ovens and furnaces by stating what is included and also what is excluded.

This could be:

**Equipment with a primary function to heat materials inside an enclosed compartment.**

This study could however exclude:

- Boilers (equipment used to boil water, i.e. kettles and boilers)
- Large combustion plant (electricity generation)
- Environmental chambers that control temperature with a maximum of less than 60°C (such as premature baby incubators)
- Analytical instruments that include heated compartments as component parts
- Thermal processes where materials are heated in the open without an enclosure
- Chambers which are also cooled using refrigeration
- Domestic and commercial catering ovens (need a definition to differentiate with factory food manufacture)
- Waste to energy incinerators as most of these do not consume primary energy for heating as their main function is energy recovery from waste materials.
- Ovens and furnaces that are part of other products that are not ovens or furnaces and so heating materials is not a primary function (e.g. analytical instruments)
- And others .... **Suggestions welcome**

All of these examples (except water boilers and large combustion plant) will be assessed in tasks 1 - 3 of this study to provide data that can use to determine what actions to take.

## 1.2 Product classification

It is possible to classify industrial and laboratory furnaces and ovens in several ways.

- By basic design – this is relatively straightforward as there are essentially four (see below) but each industry sector may use two or more of these

- By industry sector – clearly defined so that obtaining market data will be more straightforward but each sector will use many different types of furnace and oven

For this study, it would be easier to use basic design criteria, i.e. the shape of the heated compartment, as each could be used for a base case assessment. The four main types are:

**Table 3. Classification of furnaces and ovens into the four main design types showing typical shapes of heated enclosures**

Type	Shape	Characteristics	Examples
1		<p>Simple cubic or round thermally insulated enclosure, usually used for batch processes. Have an opening at the front, side, back, top or base.</p>	<ul style="list-style-type: none"> <li>• Laboratory oven</li> <li>• Muffle furnace</li> <li>• Heat sterilizer (medical)</li> <li>• Environmental test chambers</li> <li>• Furnaces in analysis instruments</li> <li>• Batch heat treatment furnace</li> <li>• Batch metal melting furnaces – with internal crucible</li> <li>• Reverberatory furnace</li> <li>• Batch furnaces for glass, ceramics, etc.</li> </ul>
2		<p>Continuous process where parts pass on a conveyer through a heated tunnel.</p>	<ul style="list-style-type: none"> <li>• Food manufacture – biscuit and bakery oven</li> <li>• Continuous metal heat treatment – “walking beam furnace”</li> <li>• Printed Circuit Board solder reflow oven</li> </ul>
3		<p>Vertical batch or continuous. Material fed into top and product removed from bottom. Heat input at or close to base.</p>	<ul style="list-style-type: none"> <li>• Lime kiln</li> <li>• Aluminium melting tower furnace</li> <li>• Blast furnace</li> <li>• Copper smelter</li> </ul>
4		<p>Horizontal tube, heated internally or externally, continuous or batch.</p>	<ul style="list-style-type: none"> <li>• Cement kiln (continuous)</li> <li>• Antimony oxide manufacture</li> <li>• Laboratory tube furnace</li> </ul>

There are many different basic designs used for ovens and furnaces. Designs are chosen to provide the required function of the oven or furnace. BS 4642 defines over 210 different types of furnace and oven each designed for a specific purpose and having characteristics selected for the process for which they are used. Table 4 describes the four basic design shapes in more detail:

**Table 4. Basic designs of furnaces and ovens**

Basic designs	Variations
<p><b>Type 1: Static enclosure</b> with a door at the front, top, sides or base. Materials being heated batch-wise are either solid or if these melt may be held in a separate container (a crucible) or supported on the base or “hearth” made of ceramic bricks. This is the most common design being essentially an enclosure having a roof, floor and four walls.</p>	<p>Heated internally or externally, fan assisted or gravity convection. Atmosphere can be air, controlled gases or vacuum.</p> <p>Heat can be applied by heaters on the side walls, the roof, the base or internally such as via heated shelves. Electric or gas / oil burner are used for heating.</p> <p>These can be constructed so that the materials are loaded into the oven or furnace through a door or the oven / furnace is hoisted up and down over the materials that are to be heated.</p>
<p><b>Type 2: Enclosed chamber with conveyor</b> that carries material through one or more hot zones. Used for continuous processes.</p>	<p>Internally heated with one or more heat zones. Atmosphere can be controlled. Many are linear but some circular designs are also used.</p>
<p><b>Type 3: Vertical cylinder</b> or similar shapes mainly used as continuous processes with feedstock loaded into the top and product removed from the base although products from some processes emerge from the top as fumes.</p>	<p>Usually filled from the top and heated either at the base, internally or externally. Blast furnaces have this type of shape although they are narrower at the top and base than in the middle region.</p>
<p><b>Type 4: Horizontal cylinder</b> used either batch-wise with material pre-loaded or continuously where material is fed in at one end and emerges after processing from the other.</p>	<p>Tube furnace, static or rotating, heated externally or internally. Atmosphere can be air, controlled gases or vacuum. Cement kilns are tilted about 5 degrees from horizontal so that material travels from one end to the other in a continuous process.</p>

The terms “laboratory”, “industrial”, “oven” and “furnace” can be interpreted in various ways. It is difficult to differentiate ovens and furnaces and laboratory and industrial as in both cases some overlap occurs.

**Ovens and furnaces**

Ovens and furnaces are similar as both heat materials within an enclosed chamber. In German these are both referred to as “Ofen” and so are not distinguished. There is no single universally agreed defined difference between ovens and furnaces but many manufacturers regard ovens as operating below ~600°C and furnaces at higher temperatures. Most ovens are used at up to ~300°C whereas

some so-called “high-temperature” ovens operate at up to 650°C. British Standard BS 4642:1970 states that ovens are not normally used at >500°C. Ovens tend to use sheet metal for the inner surfaces of the heating chamber whereas furnaces use ceramic materials. Sheet metal is more resilient to physical impact and is not prone to cracking from thermal shock but metals will corrode and oxidise. Various grades of stainless steels are often used, particularly for laboratory ovens, but the rate of oxidation becomes unacceptable at temperatures above ~700°C. All metals also soften as the temperature increases and so metals lose their strength at high temperatures. Melting of some metals would also be an issue at >1000°C so that ceramics are the only viable option for the inner surfaces of most types of furnace which operate at above ~700°C. Vacuum furnaces are an exception though which can be used at >1000°C but have water-cooled steel walls without ceramic insulation.

**Laboratory or industrial**

There is considerable overlap between laboratory ovens and furnaces and industrial ovens and furnaces although typically, laboratory products are smaller than industrial versions. There are some specific types of product that are designed and used exclusively in laboratories and other types that are designed exclusively for industrial applications. There are also some types of products that could be classified as an oven and used in other situations such as in hospitals (e.g. heat sterilisers).

**Table 5. Examples of furnaces and ovens used exclusively in either laboratories or industry**

Ovens and furnaces used only in laboratories or other non-industrial environments	Ovens and furnaces nearly always used only in industrial environments
Laboratory glassware dryers	Blast furnace
Incubators	Cement kiln
Environmental test chambers	Solder reflow ovens
Ashing furnaces (used for testing so could be located in factories)	Biscuit ovens
Heat sterilisers	Metal heat treatment furnaces

Many types of ovens and furnaces are used in both laboratories and in industrial environments so that their design or functions cannot be used to define their location of use. In all probability however, it may not be necessary to differentiate between laboratory or industrial as both are professional uses. However a small number of furnaces are used by consumers.

**Intended users – professional / consumer**

The vast majority of furnaces sold in the EU are used by professionals and in manufacturing processes but a small number are sold to consumers for hobbies such as pottery and jewellery production. These are usually purpose designed for this market with relatively low prices.

## **Intended users – Commercial catering / food manufacture**

Domestic cooking ovens are used by consumers and commercial catering ovens are used by small businesses such as restaurants and hotels but also by institutions such as schools and hospitals as well as in office canteens. Commercial catering ovens are currently being studied by the DG TREN Lot 22 preparatory study<sup>8</sup> and so these do not need to be covered by the present study. This study will however consider ovens used for food manufacture used in factories and it will be important to define these two types of oven. This may not be straightforward if some commercial catering ovens are used in food production factories and some small food manufacturing ovens are used in large catering establishments and in supermarket bakeries. In practice, the difference between food manufacture and commercial catering is:

- Food manufacture - food is prepared and packaged for distribution to retail and other outlets for sale to consumers who may not eat the food on the date of purchase. Factory-made bread, for example may be consumed on the same day of production but will be sold by a retailer to the customer. The retailer will be at different premises to the manufacturer but this cannot be used as a differentiator as some commercial catering is carried out centrally and then distributed to other locations where it is served.
- Commercial catering – food is usually prepared for immediate consumption. This might be at the same premises (e.g. restaurants) or elsewhere (e.g. pizza home delivery). Some consumers may however not consume the food immediately and decide to store it for a period. The essential characteristic though is that the food is prepared and then supplied directly to the consumer, not via a third party retailer. It will usually be intended for consumption soon after preparation (within the same day) although some consumers may choose to consume it later.

Typical catering ovens are different in design to food manufacture ovens but there will be some overlap. For example, smaller bread manufacturers may use the same type of oven as a large supermarket bakery. One differentiator for gas appliances is that gas ovens used for commercial catering are within scope of the EU Gas Appliances Directive (90/396/EEC) but industrial food manufacture ovens are excluded from scope. It is not possible to differentiate electrically heated ovens in this way.

## **Additional functions of heated chambers**

Ovens and furnaces are essentially enclosed chambers in which materials are heated and the main function is to heat materials. However there are many different types of equipment that heat materials within an enclosed chamber and have other functions. These ovens and furnaces are designed with either additional functions or for specific purposes and some of these are not normally referred to as "ovens" or "furnaces". For example:

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<sup>8</sup> DG TREN Lot 22 and 23 preparatory studies, [www.ecocooking.org](http://www.ecocooking.org)

- Incubators – enclosure at a controlled temperature. The temperature used typically varies from 5°C to 90°C. Where temperatures of <35°C are used, the incubators usually need to provide cooling with refrigeration as well as heating because controlling temperature at <35°C in hot climates is difficult or impossible without a refrigeration function. Some types of incubator also inject carbon dioxide and control the CO<sub>2</sub> concentration within the chamber. There are also anaerobic incubators that operate with an oxygen-free atmosphere.
- Environmental chamber – used for testing with two main types. One type cycles temperature between a maximum and minimum (and some can follow more complex cycles) whereas other types control and vary relative humidity as well as temperature. Much less common are heated chambers in which the atmosphere is controlled by injecting gases such as H<sub>2</sub>S that are used for corrosion testing. Environmental chambers usually provide both heating and cooling, often using refrigeration or cooling by evaporation of liquid CO<sub>2</sub>.
- Sterilisers – there are several types of product called sterilisers and several of these are “ovens”. Sterilisation can be achieved chemically, using radiation or by heat. Heat sterilisation can be achieved using immersion in hot water as well as by heating in a chamber i.e. an oven (typically at 180°C). Autoclaves are another type that sterilise by heating in pressurised steam (typically at ~130°C).
- Plant growth chambers – These are used to grow plants in a controlled environment. The temperature is set at ~30°C and the humidity and ambient light are controlled. Temperature control requires both heating and cooling (refrigeration).

Ovens and furnaces are available as many different designs and sizes many of which are defined in UK standard BS 4642:1970. This defines a fairly comprehensive list of ovens and furnaces although is nearly 40 years old and so new types are not included

A selection of types of ovens and furnaces are listed in Table 6 to illustrate the variety on the EU market:

**Table 6. Examples of common types of furnace and oven and their main uses**

Name of product	Main functions	Comments	Type
Drying oven	Oven designed for drying materials (chemicals, parts, paint, laboratory glassware, etc.)	Controlled air flow-through rate is necessary to remove water vapour from materials being dried. Drying ovens are designed for specified numbers of changes of air per hour	1
Vacuum oven	Heat materials at a relatively low temperature to remove moisture or solvents. Useful for heat-sensitive materials	Removes liquids at a lower temperature than is possible at room temperature. There is no air heat flowing through the chamber so heat transfer can be slow but no heat is lost in heating air inside the chamber.	1

Name of product	Main functions	Comments	Type
Infrared oven	Drying paint, curing resin coatings, etc.	Usually large tunnels ovens with infrared lamp heaters. Used to dry paint of new cars	1, 2
Analytical instruments	Ovens and furnaces are part of these products which are used to analyse materials. Examples include gas chromatographs, liquid chromatography, total organic carbon analysis, atomic adsorption analysers and thermal analysers for steel and for hydrocarbons.	Ovens and furnaces are designed specifically to be installed as part of the analytical instruments. Some models include low power modes.	1
Agricultural dryers	Drying grain and other crops	Large static or mobile fluidised bed ovens for drying of crops (e.g. wheat), before storage	1
Vacuum furnace	Heat materials in a vacuum. Heat treatment of metals followed by quenching with inert gases often used to cool the materials after heating is complete.  Melting/refining – volatile impurities can be removed from metal melts	Used for a variety of purposes including metal heat treatment and purification of metals. Industrial vacuum furnaces have internal electrical heating that relies on radiation of heat to the parts being treated. The external steel pressure vessel is usually water cooled to avoid distortion of seals and for worker safety. Induction heating can also be used.	1
Rotary furnace	Horizontal tube that rotates and is heated either externally or internally.	Cement kilns are one type which are heated internally. Also used for refining scrap metals	4
Muffle furnace	Furnace with an enclosed compartment which is heated externally	Common type of laboratory furnace	1
Tunnel or conveyor oven	Materials or parts travel on a conveyor through a chamber with one or more heating zones	Tunnel ovens can have more than 10 separate heating zones to provide a specific temperature profile suitable for a specific process, such as melting solder on printed circuit boards (these are referred to as reflow ovens).	2
Microwave assisted furnace	Standard furnace with magnetrons to heat susceptible materials	Faster heating than traditional furnaces using less energy. Suitable only with microwave susceptible materials	1, 2
Microwave oven	Similar to domestic microwave but designed for laboratory or industrial use.	Higher energy efficiency than direct electric heating but suitable only for materials susceptible to microwave energy	1, 2
Inert atmosphere ovens and furnaces	Sealed chamber with controlled gas atmosphere. Usually used with enclosed chambers but conveyer / tunnels furnaces with inert atmospheres are also used	Various uses including heat treatment of metals to prevent oxidation. Solder reflow ovens are often designed for use with inert nitrogen atmospheres	1, 2
Biscuit oven	Large conveyer / tunnel oven used for food manufacture	Usually custom designed with several heat stages	2

Name of product	Main functions	Comments	Type
Crucible furnace	Enclosed chamber with an integral crucible in which materials are melted.	Crucible may be integral to the furnace or separate so that it can be removed to transfer liquid metal	1
Induction furnace	Furnace which uses induction heating usually to heat a metal crucible in which materials metals are melted	Typically, RF coils which are usually a water-cooled copper pipe formed into a coil shape and connected to the high frequency generator and this surrounds a metallic crucible which is heated	1
Plasma furnace	Plasma heating can be used with a variety of furnace designs	Plasma provides high intensity heat directly and so can be very energy efficient. Used for producing nanomaterials, metal refining and waste treatment	1, 3
Blast furnace	A vertical, refractory lined structure fed with raw materials at the top, burners are situated towards the base and liquid iron is removed from the bottom.	Used for the reduction of ores to metal, particularly iron from iron ore on a very large scale (see Table 10 for more details)	3
Reverberatory furnace	Round or rectangular furnaces lined with refractory bricks and heated using burners on the walls and roof	Used for melting and refining of a variety of metals including aluminium. Designs vary depending on the intended process. Low energy efficiency although this can be improved by using regenerative burners	1
Shaft (tower) furnace	Vertical furnace in which material is fed into the top and heated at or near to the base.	Lime kilns, continuous metal melting, etc., can be fairly energy efficient	3
Electron beam furnace	Uses an intense electron beam to melt metals which have very high melting temperatures such as tungsten	Metal melted on a water-cooled copper hearth so that it is in contact only with itself to avoid contamination. No ceramics available that can withstand molten tungsten or other metals at ~3000°C.	1
Retort furnace	These utilise an enclosure that contains the parts that are to be heated. The retort is lowered and raised into and out of a separate outer enclosure that contains the heaters	The advantage is that the heated parts can be rapidly removed from the heat source and transferred to a second cooling chamber that, for example contain cold oil which cools much more quickly than air flow cooling.	1
Fluidised bed furnace	Various uses including incineration and mineral processing	Fluidised beds are used to achieve more uniform temperature control	1

### 1.2.1 Prodcum categories

EU Prodcum data for production and sales includes the following categories for “ovens and furnaces”, excluding domestic and commercial catering oven Prodcum categories. Categories from the 2008 version 2 data are as follows:

**Table 7. Prodcum categories that include furnaces and ovens**

Category number	Category description
28211130	Furnace burners for liquid fuel
28211150	Furnace burners for solid fuel or gas (including combination burners)
28211170	Mechanical stokers (including their mechanical grates, mechanical ash dischargers and similar appliances)
28211230	Non-electric furnaces and ovens for the roasting, melting or other heat-treatment of ores, pyrites or of metals
28211270	Industrial or laboratory furnaces and ovens, non-electric, including incinerators (excluding those for the roasting, melting or other heat treatment of ores, pyrites or metals, bakery ovens, drying ovens and ovens for cracking operations)
28211330	Electric bakery and biscuit ovens
28211351	Resistance heated industrial or laboratory furnaces and ovens (excluding bakery and biscuit ovens)
28211353	Electrical induction industrial or laboratory furnaces and ovens
28211355	Electrical industrial/laboratory furnaces/ovens, induction/dielectric heating equipment. Including dielectric furnaces/ovens excluding infra-red radiation ovens, resistance heated furnaces/ovens
28211357	Electric infra-red radiation ovens
28211430	Parts for furnace burners for liquid fuel, for pulverized solid fuel or for gas, for mechanical stokers, mechanical grates, mechanical ash discharges and similar appliances
28211450	Parts for non-electric industrial or laboratory furnaces and ovens
28211470	Parts for industrial or laboratory electric, induction or dielectric furnaces and ovens or heating equipment
28931530	Bakery ovens, including biscuit ovens, non-electric
28931580	Non-domestic equipment for cooking or heating food (excluding non-electric tunnel ovens, non-electric bakery ovens, non-electric percolators)
32501150	Instruments and appliances used in dental sciences (excluding drill engines)
32501200	Medical, surgical or laboratory sterilisers

Clearly, several of these categories are for furnace accessories such as burners and there are several relevant categories that are for ovens and furnaces. There are however two categories, 32501150 and 32501200, which include a variety of different products, many of which are not furnaces or ovens, particularly category 3251200 in which dental laboratory furnaces are a very small proportion. There are also several categories that include products within the scope of the TREN Lot 22 “oven” preparatory study such as 28931580.

### 1.2.2 Other classifications

Ovens and furnaces could be defined and differentiated by their functions and characteristics, such as:

**Temperature** - there is no standard definition for the boundary between ovens and furnaces. Manufacturers typically refer to ovens as having a maximum temperature of 600°C and furnaces as

having maximum temperatures >600°C although some furnaces can be controlled to operate at <600°C although the temperature control may be less precise than an oven at < ~300°C depending on the type of temperature controller and the furnace design. Most ovens sold in the EU operate at up to 250 or 300°C and can be controlled at a minimum temperature of ~40°C. If lower temperatures are required, refrigeration is also required.

**Size** – ovens and furnaces are produced in a wide range of sizes. In general, the smaller ovens and furnaces are standard off-the-shelf products although these can be modified to meet specific requirements. Some larger ovens and furnaces that are used in production lines are standard designs whereas others are custom designed and built for specific purposes. The largest ovens and furnaces on the market are all custom designs, sometimes being designed and constructed by the user for their own use. The largest types of ovens and furnaces include blast furnaces, cement kilns, mineral smelters and float glass production furnaces.

**Energy source** – these include:

**Table 8. Main energy sources used in furnaces and ovens**

Energy source	Sub-categories
Electricity	Resistance heating Induction heating Electric arc (AC or DC) Plasma Microwave Infrared
Gas	Gas burners, methane, butane, propane. There are several different types of gas burner used. These may be located within the material being heated such as with a submerged lance located in minerals that are being heated in a smelter. Some burners are located inside the chamber such as in a rotary cement kiln, externally to the heating chamber or inside the chamber but directed onto the walls or roof which act as radiant heaters (burner design will be discussed in more detail under tasks 4 and 5).
Kerosene, diesel and other oils	Refined grades and waste oils are used. Fossil fuels are more common but some biofuels are also used. Various burner designs have been developed for these fuels.
Coal	Refined coal such as coke which is produced in a "coke oven" is a source of heat energy and is also used for chemical reduction of oxides to metals (e.g. iron, copper). Powdered coal – injected into blast furnaces.
Waste	Municipal waste, waste oil, etc. are usually used as secondary energy sources with other energy sources. This is increasingly used in cement kilns as well as waste to energy incinerators.
Solar	Uncommon for industrial applications but can generate 3500°C.

Energy source	Sub-categories
Biomass	Often used with other fuels for example in cement production. Although a renewable energy source, most types of biomass require large areas of land that make this option unsustainable as a significant fuel. Also, significant quantities of fossil fuel are used to manufacture some types such as bio-ethanol and bio-diesel so that the reduction in carbon emissions by their use is relatively small. Research into new biofuels may develop more sustainable options.
Multiple sources	Some furnaces use more than one type of energy source. A few types of metal melting furnaces use gas to melt the metal and electricity to maintain temperature once molten. Cement kilns and blast furnaces both use several energy sources.

## Insulation

The choice of insulation material depends on several variables the most important being temperature and the materials with which they will come into contact. The choice is often a compromise between conflicting requirements; for example lightweight and low density materials have the best thermal insulation properties but are physically weak and are not resistant to many hot materials. Ceramic bricks are commonly used as insulation in large furnaces as these are physically strong and the correct composition selection will give the desired chemical resistance but thermal insulation is not as good as with low density materials. It is not uncommon for several layers of different materials to be used to achieve maximum thermal insulation with the required chemical resistance.

The important properties required for insulation materials include:

**Table 9. Important characteristics of insulation materials used in furnaces and ovens**

Property	Materials
Temperature	Metals are limited due to their resistance to thermal oxidation and are usually good thermal conductors. Ceramic materials can have good thermal insulation properties but all have maximum temperatures which can be as low as 350°C for glass wool, 900°C for mineral wool and 1700°C for high alumina bricks and refractory concrete. Thermal conductivity of ceramics varies with temperature with some materials being affected more than others. Transparent materials are less suitable at high temperature as infrared radiation will pass through them.
Mechanical strength	Materials may need strength depending on furnace design. The thermal insulation in small laboratory furnaces does not need high strength whereas insulation in very large furnaces needs to be strong under all use conditions. Materials with the lowest thermal conductivity have in general the lowest strength.
Thermal shock resistance	This is important in furnaces where sudden large temperature changes occur such as batch furnaces where burners impinge on ceramic surfaces or in heat treatment furnaces which are rapidly quenched. Slip-cast refractory bricks have relatively low thermal shock resistance whereas silicon carbide bricks have very high thermal shock resistance.

Property	Materials
Chemical resistance	Many processes carried out in furnaces involve corrosive materials being held within the furnace by the ceramic insulating lining. Float glass furnaces are lined with special bricks that are resistant to liquid glass and metal smelting furnaces need to be resistant to liquid metals, corrosive fluxes and liquid slags (ceramic materials). Resistance to corrosive gases and fuels is also important. Chemical resistant materials where liquid flow occurs is particularly difficult as erosion of the material can occur.
Tightness	Most furnaces have an outer steel shell and an inner ceramic insulation lining. The steel shell is necessary for the structure of the furnace but has poor chemical and thermal resistance so that the insulation material needs to prevent the contents of the furnace escaping. Ceramic insulation tends to have some porosity to gases as well as via cracks although there is considerable variation. Corundum and mullite bricks have very low porosity whereas light weight bricks (with better thermal insulation) have relatively large porosity.
Thermal conductivity	This property is most important for energy efficiency but the best materials may not be suitable for other reasons. Thermal conductivity is dependent on the composition of the ceramic, its porosity, the pore size and structure and the atmosphere in the furnace. Micro-porous materials which have closed pores so do not allow gas diffusion is one of the best types. Glass and mineral wools also perform well whereas magnesium oxide which has good chemical resistance, gas tightness and strength and silicon carbide (excellent thermal shock resistance) bricks are relatively poor.
Bulk density	As the thermal insulation absorbs heat from the furnace, improved energy efficiency can be achieved by using low density materials which also tend to be superior thermal insulators. Micro-porous and fibrous materials are superior to refractory concrete and most types of ceramic bricks. Specific heat capacity of the material also affects heat storage but is less significant than density.
Workability and toxicity	It is necessary to produce the thermal insulation in the required shape and this is easier with some materials than others. One concern is the toxicity of some types of ceramic insulation. The dangers of asbestos are well known but some forms of silica and some mineral fibre materials are also hazardous and can change their physical form during service life (e.g. fibres can break up under heat and vibration).
Cost	This depends on the cost of the material itself as well as the cost of fabrication (cutting, etc.) construction, support structures (more needed for heavier insulation materials), etc.

### Throughput

The throughput of furnaces varies enormously with small laboratory furnaces processing as little as a few kilograms per year to blast furnaces that can produce over 3 million tonnes of iron annually. The choice of furnace design is often based on throughput requirements. For example, tower furnaces are energy efficient for melting scrap aluminium but suitable only for large installations. SMEs may not process sufficient material for this type of furnace and so have to use a less energy efficient design such as a gas fired crucible furnace.

## Functions

Ovens and furnaces perform many hundreds of different functions utilising the design features described in this report. Smaller ovens and furnaces tend to be standard off-the-shelf products although many of these are modified to suit particular requirements. Many larger industrial ovens and furnaces are custom designs although most custom-designs are based one of the basic types described in this report with the size, dimensions, fuel, temperature and ancillary equipment being specific to the specific process requirements.

The design of an oven or furnace can affect its energy efficiency and other aspects of the process and these issues are described in task 4. Examples include the many designs of aluminium melting furnaces which are described in Table 11.

### 1.2.3 Definition by industry sector

Certain industries use specific types of oven and furnace although most sectors use many different types. More in-depth technical discussion of these furnaces will be included in task 5. Types of ovens and furnaces designed for specific industrial applications include the following examples:

**Table 10. Types of furnace and oven used by main industry sectors**

Industry	Description and design types of oven or furnace	Design type
Chemical analysis and testing laboratories	Use smaller laboratory ovens and furnaces. Furnace types include muffle furnaces and crucible furnaces. Microwave ovens are used to dissolve materials for chemical analysis. Fairly accurate temperature control is often essential for materials testing.	Use mainly type 1 but also some type 4
Steel industry	<p>The steel industry uses a variety of oven and furnace types which include:</p> <ul style="list-style-type: none"> <li>• <b>Coke ovens</b> are used to convert coal into coke which is mixed with iron ore and limestone to produce the sinter which is the blast furnace feedstock.</li> <li>• <b>Sinter plant</b> produce sinter pellets consisting of iron ore, coke and limestone. Wet pellets are heated to produce hard dry feedstock for the blast furnace.</li> <li>• <b>Blast furnaces</b> are used to convert iron ore into iron. Blast furnaces operate continuously for many years until the ceramic insulation needs to be replaced. A mixture of iron ore, carbon (coal or coke) and limestone are fed into the top and the furnace is heated usually by gas or oil burners located near to the base. Liquid iron and slag collect at the bottom and are run out either into moulds or to the next process step (the basic oxygen furnace).</li> <li>• <b>Basic Oxygen Furnace (BOF)</b> – these are used to purify crude iron and convert it into steel. Oxygen is injected via a lance into liquid iron. The oxygen reacts with impurities, especially carbon for gaseous oxides (such as carbon monoxide and dioxide). This type of furnace can be a net energy producer as the oxygen / carbon reaction is exothermic.</li> </ul>	<p>Array of units each type 1</p> <p>Type 2</p> <p>Type 3</p> <p>Type 1</p>

Industry	Description and design types of oven or furnace	Design type
	<ul style="list-style-type: none"> <li>• <b>Open hearth furnace</b> – used to convert pig iron into steel. Less energy efficient than the BOF and so most have been closed down in the EU and elsewhere.</li> <li>• <b>Electric arc furnace</b> – these are used to melt scrap iron although they are also used by other industries mainly for melting metals. Some arc furnaces are used to treat a mixture of scrap metal and mineral feed-stocks (These are essentially type 1).</li> <li>• <b>Heat treatment furnaces</b> – uses a variety of designs. Include very large continuous furnaces that consume very large amounts of energy.</li> </ul> <p>Furnaces are also used for holding liquid steel for moving it from one process stage to another and for feeding into casting processes. There are also newer alternative steel production processes such as direct reduction (one plant in Germany).</p> <ul style="list-style-type: none"> <li>• <b>Direct reduction furnaces</b> use either gas or coal so there is no need to make coke. Fourteen different direct reduction furnace designs have been developed and these are all used with electric arc furnaces to produce steel.</li> </ul>	<p>Type 1</p> <p>Type 1</p> <p>Types 1, 2</p> <p>Type 3</p>
Foundries / metal melting	Metals are melted in melting furnaces for producing specific alloy compositions and for casting into moulds to make metal castings. Used primarily for aluminium alloys, steel, zinc alloys and copper alloys.	Types 1, 3
Non-ferrous metals production and recycling	<p>A wide variety of purpose designed furnaces are used. The design depends on the metal ore or scrap composition. There are several designs that have been developed by metal refiners and others developed by furnace manufacturers. Some examples are:</p> <ul style="list-style-type: none"> <li>• Production of copper metal from sulphide ores (and some scrap) uses two basic types of smelting furnace – <b>bath smelting</b> or <b>flash smelting</b> although the draft non-ferrous metals IPPC BREF lists 14 types of furnace that are used to refine copper. Flash smelters operate at a very high rate whereas bath smelters produce sulphur dioxide emissions at a higher concentration that is easier to collect. Further furnace processes are used to purify crude copper and scrap copper (fire refining) and others are used to recover metals from slags which are by-products of smelting. Fabricated parts are produced with furnaces, for example wire is made by first melting copper in a shaft furnace (vertical furnace with internal burner) then transferring liquid copper to a holding furnace. Various types of melting furnaces are used to produce copper alloys and fabricated parts.</li> <li>• Aluminium metal is produced by <b>electrolysis</b> of a molten salt bath containing bauxite and cryolite. The high electric current passing between anode and cathode generates enough heat to maintain the melt as well as to reduce the oxide to metal. This is a very energy intensive process but a significant proportion is used for conversion of oxide to metal. Aluminium alloys are produced and aluminium scrap treated in a variety of melting furnace designs. These are designed to</li> </ul>	<p>Types 1, 3</p> <p>Types 1, 3, 4</p>

Industry	Description and design types of oven or furnace	Design type
	<p>be resistant to corrosive fluxes and limit the generation of hazardous emissions. The main types of furnace used for aluminium are listed in Table 11.</p> <ul style="list-style-type: none"> <li>Lead ores are usually sulphides and so lead is smelted by heating with a limited oxygen supply in a variety of <b>"bath smelter" furnaces</b>. Most lead scrap is from vehicle batteries and lead is recovered from these using a variety of furnace types including blast furnaces, rotary, reverberatory, ISA Smelt (also used for copper and other metals) or electric furnaces. Impure lead is refined in externally heated furnaces in which liquid lead is held and impurities removed.</li> <li>Zinc occurs as sulphide ores with impurities of lead and other metals and is refined in smelting furnaces or by hydrometallurgical processes after roasting in a <b>fluidised bed furnace</b> to convert the sulphide to oxide which can then be dissolved in acid. Secondary zinc which also contains lead, from electric arc steel manufacture is treated in a Waelz kiln which is a <b>rotary furnace</b> operating at up to 1400°C. Zinc is recovered by selective distillation.</li> <li>Different types of furnace are used for processes for production of precious metals such as gold, chromium, tungsten, ferro-alloys, etc.</li> </ul>	<p>Types 1, 3, 4</p> <p>Types 1, 3, 4</p> <p>Types 1, 3, 4</p>
Cement and lime production	<p>There are several cement production processes which involve thermal processes. Portland cement is made using high temperature heating of limestone, with a variety of other ingredients to convert the calcium carbonate into calcium oxide and carbon dioxide. Waste heat from the cement kiln can be used to preheat the limestone which saves energy and waste materials are sometimes used as fuels. Cement is manufactured in a rotary furnace which heats the ingredients to a high temperature in a rotating tube with a gas, oil or powdered coal flame inside the tube. Cement production is reported to produce as much as 5% of total CO<sub>2</sub> emissions globally and ~2% of total CO<sub>2</sub> emissions in EU<sup>9</sup>. At least half of this is CO<sub>2</sub> emitted from the calcium carbonate to produce calcium oxide. An equivalent amount of this emitted CO<sub>2</sub> is re-absorbed however when the cement (or concrete) sets so that there is no overall CO<sub>2</sub> emission from limestone although fuel for the thermal process emits a large amount of CO<sub>2</sub> from fossil carbon sources. The cement industry is carrying out research into methods of reducing greenhouse gas emissions mainly by improving energy efficiency<sup>10</sup>.</p> <p>There are other types of cement which will be discussed in task 5 such as cement made from the "blast furnace slag" from steel manufacture.</p> <p>Lime is produced in several types of furnace which convert calcium</p>	Cement kilns are type 4, lime kilns usually type 3.

<sup>9</sup> Battelle report "Towards a sustainable cement industry, Climate Change" 2002, states that Europe consumed 22% of world cement production in 2000.

<sup>10</sup> Cement Technology Roadmap 2009, World Business Council for Sustainable Development and International Energy Agency, <http://www.wbcsd.org/includes/getTarget.asp?type=d&id=MzY3NDM>

Industry	Description and design types of oven or furnace	Design type
	carbonate into calcium oxide. These include <b>rotary kilns</b> (similar to cement kilns), <b>shaft kilns</b> (top-fed vertical structures) and <b>parallel flow regenerative kilns</b> (the most numerous type in EU and is essentially a U-shaped structure).	
Metal heat treatment	<p>A variety of heat treatment processes are carried out with metal parts. The process conditions depend on the alloy and the treatment required. For example:</p> <ul style="list-style-type: none"> <li>• Steels are re-heated in batch or continuous processes for subsequent metal forming processes and this is usually carried out in air. Annealing is usually carried out in protective atmospheres such as hydrogen in bell-type batch furnaces but strip steel can also be annealed by continuous processes.</li> <li>• Nickel alloys and copper alloys are heat treated in either vacuum furnaces or furnaces containing an inert atmosphere. Some processes require high pressure such as nitriding of steel in which steel is heated in ammonia gas which dissociates into nitrogen and hydrogen. Most heat treatment procedures require rapid quenching which is achieved by injecting cold inert gases after the heating cycle.</li> <li>• Aluminium alloy heat treatment requires lower temperatures in air, typically ~200°C and so ovens can be used.</li> <li>• Brazing of aluminium, copper and steel alloys may be carried out in vacuum or inert gas furnaces.</li> </ul>	Mainly types 1, 2
Ceramics	<p>Ceramics are brittle materials and are susceptible to cracking when exposed to rapid temperature changes. Ceramics production may require a drying stage followed by a high temperature treatment. Furnaces designed for sintering industrial ceramics, bricks, pottery, tiles, etc. are designed with low rates of temperature increase and cooling. Tunnel kilns can be used for some products but these are inevitably large with long heat treatment times (typically 36 hours)<sup>11</sup>.</p> <ul style="list-style-type: none"> <li>• Brick and tile kilns tend to be very large but the design depends on the type of clay used</li> <li>• Pottery kilns are of a wide range of size and design depending on throughput.</li> </ul>	Types 1, 2, 3
Glass	<p>Glass is produced from a mixture of raw materials often with some scrap glass. These materials melt fairly slowly and a variety of chemical reactions occur before the final glass composition is produced. Different types of furnace are used depending on the scale of the process and the product but glass making and melting is the most energy consuming phase of glass product manufacture accounting for ~75% of the total furnace energy.</p>	Types 1, 2, 3

<sup>11</sup> BBC Radio 4 interview "You and yours", Simon Parks, December 2009.

Industry	Description and design types of oven or furnace	Design type
	<p>Glass production can involve many furnace steps: glass melting, formation into shapes (containers, sheet, etc.), controlled cooling (Lehrs), annealing, coating, toughening, etc. Glass melting, float glass production and controlled cooling are three separate furnaces but operate consecutively and continuously.</p> <p>Large scale processes use cross-fired regenerative furnaces and these are used for float glass and often for container glass.</p> <p>Regenerative end port furnaces, recuperative unit melters, oxy-fuel and electric furnaces are used for medium and small size installations.</p> <p>Batch furnaces are used for smaller scale production whereas large-scale installations are continuous processes.</p> <p>Glass articles when made are in a highly stressed state and susceptible to cracking. These are heat treated in a furnace at a temperature below the softening temperature and cooled slowly to remove these stresses.</p> <p>Glass sheet manufacture furnaces are designed and built by the users.</p>	
Waste incineration	<p>Used for disposal of organic waste. Incinerators are designed for three types of application:</p> <ul style="list-style-type: none"> <li>• Destruction of clinical waste (e.g. from hospitals) and hazardous waste such as chemicals. Energy recovery is not normally carried out.</li> <li>• Cremation of deceased persons and animals</li> <li>• Municipal waste disposal, either with or without energy recovery although most new waste incinerators in EU do not consume primary energy for heating (except at start up) and use waste materials as the fuel for energy generation. Energy may be recovered as heat, electricity or both. Waste to energy incinerators are essentially design type 3.</li> </ul> <p>Incineration of waste can produce a variety of toxic emissions such as chlorobenzodioxins and furans from organohalogens if the process is not operated correctly although halogen-free plastics also emit toxic emissions such as polycyclic aromatic hydrocarbons (PAH). The waste gases are heated to high temperature to destroy these toxic substances. Municipal incinerators did emit toxic substances in the 1990s but modern plant are much safer and meet very strict emissions standards. Waste incinerators are designed and constructed by specialist furnace manufacturers.</p> <p>Municipal wastes contain plastics and so the CO<sub>2</sub> emitted contributes to global warming as the original source of carbon in the plastics is oil. Combustion of biomass such as food waste however does not contribute towards global carbon as the original carbon source is carbon dioxide removed from the air by plants. It is considered that 50% of energy produced from municipal waste is renewable.</p>	<p>Type 1</p> <p>Type 1</p> <p>Type 3</p>
Drying and curing of coatings	<p>Low temperature processes used by many industry sectors. Used for example for drying paint coatings on car bodies. Continuous ovens would design type 2 whereas batch ovens are type 1.</p>	Types 1, 2

Industry	Description and design types of oven or furnace	Design type
Galvanising and hot metal dipping	Steel is coated with zinc and by some other metals (e.g. tinfoil and terne plate) by immersion of steel sheet in a bath of molten zinc or other metals. This is usually carried out as a continuous process where rolls of steel sheet pass through the molten metal bath. A process used to make zinc coated steel for automotive applications involves first annealing the sheet in continuous annealing ovens following by zinc coating. The zinc coating tank is not a typical "oven" or "furnace" process and it may be only one of the thermal steps in a more complex production process.	Type 1 (??)
Oil refinery furnaces	Oil refineries carry out a variety of chemical processes in equipment that is referred to as "furnaces". For example, high molecular weight hydrocarbons are "cracked" to produce lower molecular weight hydrocarbons such as ethylene in " <b>cracker furnaces</b> ". These consist of arrays of metal pipes through which the feed materials pass and are heated. As the feed materials are heated in an enclosed chamber by a continuous process, these are types of furnace. These furnaces do not exactly match any of the four basic designs described in Table 4 but the nearest would be type 1. 90% of oil refinery furnaces are designed and built by the oil companies for their own use.	Type 1
Medical sterilizers	Various types are available including simple heat sterilisers that are essentially ovens which heat parts at 80°C or 150°C for a specific time period. Some heat steriliser manufacturers produce sterilisers and laboratory ovens which appear externally to be identical.	Type 1
Incubators	Incubators are enclosed chambers in which materials are held at controlled temperature and the environmental conditions may also be controlled, e.g. humidity and CO2 concentration. As these tend to control temperature at around 30 - 40°C, cooling is also necessary, especially in southern Europe.	Type 1
Laboratory instrument components	Some laboratory instruments include components that are small heated chambers which may be regarded as being ovens or furnaces. Examples include:  <b>Gas chromatograph:</b> The gas separation coil is housed in a heated chamber to maintain an elevated temperature. This chamber is a type of oven.  <b>Atomic absorption spectrometer:</b> Some types use small carbon furnaces to vaporise the substance being analysed.  The shape of heated compartment varies depending on the type of analytical instrument.	Type 1  Various designs
Large combustion plant	Used for electricity generation and steam heating. These are very large energy consumers and emitters of global warming gases which utilise heat to generate steam that is used either to generate electricity with turbines or directly for heating. The heat is used to boil water so these are not normally referred to as ovens or furnaces. However the most common definition of oven or furnace is an enclosed heated chamber which could be a water boiler. As large combustion plant are so different to industrial ovens and furnaces, these will not be considered further in this study.	

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Industry	Description and design types of oven or furnace	Design type
Other heated enclosed chambers	There are many other examples of equipment in which an enclosed chamber is heated. These include premature baby incubators which are clearly not "ovens". Therefore a definition is required that excludes heated chambers that are not ovens or furnaces.	

**Table 11. Furnace designs used for aluminium scrap processes<sup>12</sup>**

Description and design type	Typical capacity	Uses	Advantages	Disadvantages	Energy source	Energy efficiency / consumption
Reverberatory (hearth) type 1	≤150 tonnes batch for scrap processes	Melting scrap, holding & refining primary aluminium	Large-scale, low operating costs. May be fitted with regenerative burners	High oxidation rate, low energy efficiency, requires large space	Gas / oil	15 - 40%
Electric crucible – type 1	< 1 tonne batch	Small-scale alloying	Very low emissions, low oxidation rate	High energy cost & small scale	Electricity	450 - 550 KWh/t
Rotary – type 4	2 - 5 tonnes	Low grade scrap and dross	Can treat materials that cannot be processed by other techniques	Low efficiency, high maintenance cost, salt waste hazard	Gas	<15%
Electric reverberatory – type 1	<1 tonne	Holding furnace	Low emissions and low oxidation rate	High energy cost	Electricity	400 - 500 KWh/t
Tower (shaft) – type 3	10 tonnes / hour continuous	Large-scale continuous melting	High efficiency, low oxidation rate	High capital cost, need very high structure. Suitable only for cleaner scrap grades	Gas / oil	40 - 70%
Gas crucible – type 1	< 1 tonne batch	Small-scale holding furnace	Can change alloys quickly, low oxidation rate, low cost	Low efficiency and high emissions	Gas	12% (~24% with recuperation)
Induction melting – type 1	≤50 tonne batch	Melting of scrap and holding & refining primary aluminium	Low emissions, low oxidation, stirs melt	High energy cost (electricity), suitable only for cleaner grades of scrap	Electricity	450 - 550 KWh/t
Sweating – type 1	Separation of Al, Fe and Zn	Used only for separation of Al from separate pieces of Fe and Zn	Designed specifically to separate these metals	Cannot be used for any other process	Gas	
Tilting furnace – type 1	~45 tonnes	Holding molten aluminium prior to casting	Purpose designed for holding melt prior to casting	Does not melt metal	Gas	210 KWh/t (excludes energy for melting)

<sup>12</sup> Data from several sources: [www.energysolutionscentre.org](http://www.energysolutionscentre.org), IPPC draft reference document on BAT (BREF) for Non-Ferrous Metals Industries, July 2009 and "Handbook of Thermoprocessing Technologies" ed. A. von Starck, A. Muhlbauer and C. Kramer, Vulkan Verlag, 2005.

### 1.3 Primary production performance parameters “functional units”

For this study, the most important performance parameter is energy consumption but this can be measured in a variety of ways such as:

- Power rating in KWh - this is usually not the same as energy consumption. This is always quoted for electric laboratory ovens and furnaces.
- Power consumption per unit weight of materials processed e.g. in KWh / tonne, MJ/kg, etc. Usually known for larger-scale processes although the value for a specific furnace or oven will depend on throughput. Care needs to be taken when quoting energy consumption for electric ovens and furnaces. The electric energy consumed is not the same as the total energy consumed when including electricity generation, typically 30% efficient in EU.
- Annual energy consumption such as GWh/year defines the energy consumed annually by a furnace or oven. It can be calculated from energy consumed per unit weight multiplied by throughput. This parameter will be specific to one process and depends on many variables. Energy consumed during one year for all furnaces in a specific sector is of limited value as this will inevitably include many different types of furnace and process of different ages and efficiency.
- Energy efficiency (%) – an important parameter which may be calculated for large-scale processes but is usually not known for small-scale ovens and furnaces.

Power or energy consumption and energy efficiency are the two most useful performance parameters although these are measured only for larger-scale industrial processes. Manufacturers usually measure energy consumption as this has a direct influence on operating costs but would be able to determine energy efficiency. For this study, we propose to use KWh/tonne for energy consumption as industrial furnaces usually use these units and it is possible to convert others.

### 1.4 Measurement and other standards

There are many standards that are applicable to industrial and laboratory furnaces and ovens. Most relate to safety and there are very few that concern energy consumption. Relevant standards are listed below in three groups; EU standards, EU Member State standards and standards published outside the EU.

### 1.4.1 Standards at community level

**Table 12. European standards for furnaces and ovens**

Standard number	Title	Status & EU directive
EN 1539	Dryers and ovens, in which flammable substances are released - safety requirements	Current
EN 1547	Industrial thermoprocessing equipment - noise test code for industrial thermoprocessing equipment including its ancillary handling equipment	Current
EN 12950	Thermal installations for the cement, lime and gypsum industry – safety requirements	Current
EN 14001: 2004	Environmental management systems—Requirements with guidance for use	Current
EN 14681:2006	Requirements for machinery and equipment for production of steel by electric arc furnaces	Current, ATEX
EN 50014:1993	Electrical apparatus for potentially explosive atmospheres. General requirements	Current, ATEX
EN 50519.	Assessment of workers' exposure to electric and magnetic fields of industrial induction heating equipment	Draft only
EN IEC 60398	Industrial electroheating installations - general test methods	Current
EN 60676:2002, IEC 60676:2002	Industrial electroheating equipment. Test methods for direct arc furnaces	Current
EN 60779:2005	Industrial electroheat Equipment. Test methods for electros slag remelting furnaces	Current
EN 61307.	Industrial microwave heating installations. Test methods for the determination of power output	Current
EN 61308:2006	High-frequency dielectric heating installations. Test methods for the determination of power output	Current
EN 61922:2002	High-frequency induction heating installations. Test methods for the determination of power output of the generator	Current
EN 62076:2006	Industrial electroheating installations. Test methods for induction channel and induction crucible furnace	Current
EN 50156-1:2004	Electrical equipment for furnaces and ancillary equipment. Requirements for application design and installation	Current
EN 60519-1:2003	Safety in electroheat installations — Part 1: General requirements (IEC 60519-1:2003)	Current, LVD
EN 60519-2:2006	Safety in electroheat installations — Part 2: Particular requirements for resistance heating equipment	Current, LVD
EN 60519-3:2005	Safety in electroheat installations — Part 3: Particular requirements for induction and conduction heating and induction melting installations	Current, LVD
EN 60519-4:2006	Safety in electroheat installations. Particular requirements for arc furnace installations	Current, LVD

Standard number	Title	Status & EU directive
EN 60519-6:2002	Safety in electroheat installations. Part 6. Specifications for safety in industrial microwave heating equipment	Current, LVD
EN 60519-8:2005	Safety in electroheat installations. Particular requirements for electrosag remelting furnaces	Current, LVD
EN 60519-9:2005	Safety in electroheat installations — Part 9: Particular requirements for high frequency dielectric heating installations	Current, LVD
EN 61010-1:2001, also IEC 61010:2001	Safety requirements for electrical equipment for measurement, control and laboratory use - part 1: general requirements	Current, LVD
EN 601010-2-010	Safety requirements for electrical equipment for measurement, control, and laboratory use - part 2-010: particular requirements for laboratory equipment for the heating of material	Current, LVD
EN 746-1:1997 + A1:2009	Industrial thermoprocessing equipment - part 1: common safety requirements for industrial thermoprocessing equipment	Current, Machinery
EN 746-2	Industrial thermoprocessing equipment - safety requirements for combustion and fuel handling systems	Current, Machinery
EN 746-3	Industrial thermoprocessing equipment - part 3: safety requirements for the generation and use of atmosphere gases	Current, Machinery
EN 746-4	Industrial thermoprocessing equipment - part 4: particular requirements for hot dip galvanizing thermoprocessing equipment	Current, Machinery
EN 746-5	Industrial thermoprocessing equipment - part 5: particular safety requirements for salt bath thermoprocessing equipment	Current, Machinery
EN 746-8	Industrial thermoprocessing equipment - part 8: particular safety requirements for quenching equipment	Current, Machinery

### 1.4.2 Standards at Member State level

**Table 13. Standards at EU State level for furnaces and ovens**

Country	Standard number	Title	Status
Germany	DIN 12880	Electrical laboratory devices - heating ovens and incubators	Current
Germany	DIN 17052-1:2000-10	Heat treatment furnaces - Part 1: Requirements for temperature uniformity	Current
Germany	DIN 24201	Industrial furnaces - heating and heat-treating furnaces - concepts	Current
Germany	VDG S 80	Ausfuehrung von notauffanggruben	Current
Germany	VDI 2046	Safety code for operation of industrial furnaces with protective and reaction gases	Cancelled
Germany	VDI 3730	Characteristic noise emission values of technical sound sources; processing furnaces	Current
Germany	VDMA 24202	Industrial furnaces, classification	Current
Germany	VDMA 24206	Acceptance and ordering of thermoprocessing equipment for the steel, iron and non-ferrous metals industry	Current

Country	Standard number	Title	Status
Germany	VDMA 24351	Drying technology - general terms	Current
Italy	UNI 7415	Forni industriali. Termini, definizioni e classificazione	Cancelled
Italy	UNI 7416	Industrial furnaces - rules for ordering, testing and acceptance	Current
Italy	UNI 8016	Agglomeration furnace for ferrous minerals - terminology	Current
Italy	UNI 8129-1	Refractories for industrial furnaces - classification, sizes and test methods	Withdrawn
Italy	UNI 8129-2	Refractories for industrial furnaces - data for offer, order, testing and acceptance	Withdrawn
Poland	PN H-01201	Heat treatment - furnaces using a controlled atmosphere - safety requirements for construction and operating	Current
Poland	PN H-01202	Heat treatment - furnaces for heat treatment with a controlled atmosphere - requirements and tests	Current
Poland	PN H-01203	Heat treatment - vacuum furnaces - safety requirements for construction and operating	Current
Poland	PN H-01204	Heat treatment - industrial vacuum furnaces - requirement and investigation	Current
UK	BS 2648(1955)	Performance requirements for electrically-heated laboratory drying ovens	Current
UK	BS 4642(1970)	Glossary of industrial furnace terms	Current
UK	BS 6466(1984)	Code of practice for design and installation of ceramic fibre furnace linings	Current

### 1.4.3 Third country standards

**Table 14. Standards from outside EU for furnaces and ovens**

Country	Standard number	Title	Status
China	SAC GB/T 17195	Industrial furnace terminology	Current
India	BIS IS 14860	Guidelines on fuel saving in vertical mixed-feed lime shaft kilns (Bureau of Indian Standards)	Current
Japan	JIS G0702	Method of heat balance for continuous furnace for steel	Current
Japan	JIS G0703 :1995	Method of heat balance of electric arc furnace	Current
Japan	JIS R0303:2004	Heat balancing of cement rotary kiln	Current
Japan	JIS R0304	Heat balancing of continuous dryer for ores and other materials	Current
Russia	GOST 12.2.007.9	Safety in electro-heat installations - part 1: general requirements	Current
South Africa	SANS 329	Industrial thermoprocessing equipment - safety requirements for combustion and fuel-handling systems	Current, Same as EN 746-2
USA	SAE AMS 2750 D2005	Pyrometry	Current

Country	Standard number	Title	Status
USA	SAE AMS 2759:2004	Heat Treatment of Steel Parts–General Requirements	Current (under revision). Standards also exist for other alloy types
USA	AMS 2769	Heat treatment of parts in vacuum	Current
USA	ASTM D 2436	Specification for forced-convection laboratory ovens for electrical insulation	ASTM D 2436 Superseded by ASTM D 5423 and ASTM D 5374
USA	ASTM D 5374	Test methods for forced-convection laboratory ovens for evaluation of electrical insulation	Current
USA	ASTM D5423	Specification for Forced-Convection Ovens for Evaluation of Electrical Insulation	Current
USA	ASTM E145	Specification for Gravity-Convection And Forced-Ventilation Oven	Current
USA	NFE 33 060	Industrial driers - guide for acceptance testing	Current
USA	NFPA 86	National Fire Protection Association, USA. Standard for ovens and furnaces	Current
USA	ASME EA-1 :2009	Energy Assessment for Process Heating Systems	Current
IEC	IEC/TS 60680:2008	Test methods of plasma equipment for electroheat and electrochemical applications	Current
International	ISO/NP 13577	Industrial furnace and associated thermal processing equipment -- General safety requirements	Draft
International	ISO/NP 13578	Industrial furnaces and associated thermal processing equipment -- Safety requirements for combustion and fuel handling systems	Draft
International	ISO/NP 13579-1	Industrial furnaces and associated thermal processing equipment -- Method of energy balance and efficiency -- Part 1: General methodology (more details below)	Draft
International	ISO/NP 13579-2	Industrial furnaces and associated thermal processing equipment -- Method of energy balance and efficiency -- Part 2: Reheating furnace for steel	Draft
International	ISO/NP 13579-3	Industrial furnaces and associated thermal processing equipment -- Method of energy balance and efficiency -- Part 3: Batch type aluminium melting furnace	Draft
International	ISO/NP 13579-4	Industrial furnaces and associated thermal processing equipment -- Method of energy balance and efficiency -- Part 4: Controlled atmosphere furnace	Draft

The only detailed standard (currently draft) for measurement of energy efficiency of industrial thermo-processes is ISO 13579-1. ASME EA-1-2009 also describes the requirements for conducting an assessment of a thermal process but it does not however provide a procedure for measurement of energy consumption or energy efficiency and it does not provide detailed instructions for

measurement of energy consumption or losses. ASME has however published guidance on how to implement their standard.

**ISO 13579-1** "Industrial furnaces and associated thermal processing equipment -- Method of energy balance and efficiency -- Part 1: General methodology". This draft standard describes a detailed procedure for determining the energy consumption and energy efficiency of a specific thermal process. It calculates energy efficiency and consumption for one batch of production but the method is suitable for both batch and continuous processes. The standard describes how to calculate the energy efficiency of the overall process and it defines the boundary of the process which includes energy used to heat the product as well as product handling (e.g. electricity for internal conveyers). The standard defines the methods for measurement of process inputs and outputs variables such as fuel volume, temperatures and gas analysis and it defines procedures used for recuperative and regenerative burners. The calculation method is described in detail and includes energy consumed by compressors, fans and pumps as well as heat input and losses. This ISO standard is ideal for calculation of the energy consumed and energy efficiency of one specific furnace process as it includes the raw materials and the output materials. The results reflect only this one process and if the same equipment is used for treating different materials, the energy characteristics would be different and would need to be recalculated. The standard will be useful for comparison of alternative furnaces that could be used for a specific process in order to select the most energy efficient and also to calculate how much energy would be saved by using one process instead of another.

The main limitation of ISO 13579-1 is with smaller furnaces and ovens that are not designed for a specific production process. Laboratory ovens and furnaces are frequently designed to heat any materials to a range of possible temperatures. Heating rate and time are also flexible. Although this ISO standard is not intended to be used with laboratory ovens and furnaces, it can be used to obtain data that can compare different ovens and furnaces (different models or from different manufacturers), but a realistic test load would need to be used and there is no standard test load defined.

Very few standards cover environmental impacts and none were found on the environmental impact other than energy consumption.

## 1.5 Existing legislation

A wide variety of legislation affects ovens and furnace in EU and the rest of the world. Legislation affects the design of ovens and furnaces by regulating safety aspects, energy consumption or emissions. Other legislation affects these products indirectly.

### 1.5.1 Legislation and agreements at EU level

EU directives and regulations that directly or indirectly affect industrial and laboratory furnaces and ovens are listed here. Some are applicable only to large installations whereas others apply on to specific industry sectors.

**Table 15. EU legislation applicable to furnaces and ovens (in date order)**

Directive or regulation	Legislation and status	Description and impact on ovens and furnaces
90/396/EEC	Gas Appliance directive	Scope includes gas fired ovens and furnaces except for those designed specifically for industrial applications. This is a safety directive.
93/42/EEC	Medical Devices Directive	Includes sterilisers in its scope.
94/9/EC	Equipment and protective systems intended for use in potentially explosive atmospheres (ATEX) directive	Ovens and furnaces that are intended for use in potentially explosive atmospheres need to be designed to comply with this directive.
96/61/EC	Integrated Pollution Prevention and Control (IPPC) directive amended four times. Codified version: 2008/1/EC.  This directive is currently being amended and combined with other directives including the Large Combustion Plant Directive 2001/80/EC and waste incineration directive 2000/76/EC	Requires that operators apply for permits for specified processes (listed in Annex I). Many EU operators of larger furnaces and ovens will be obliged to comply with this directive and obtain approvals for operating production processes and these must rely on using BAT. Includes in scope; steel installations, coke ovens, metal refineries and smelters (ferrous and non-ferrous), cement and lime kilns, glass production, ceramics production and municipal waste incinerators. This is described in more detail below.
98/37/EC	Machinery directive	This will apply particularly where ovens or furnaces with automated moving parts. For example, remotely controlled doors, conveyors, etc.
2000/60/EC	Directive establishing a framework for the Community action in the field of water policy,	Sets up framework for managing water (rivers, lakes, coastal water, etc.) to prevent pollution including from industrial processes.
2000/76/EC	Directive on incineration of waste under review and will be combined with IPPC	Incinerators are a type of furnace. This directive regulates waste incineration, waste to energy incinerators and processes such as cement manufacture that use waste as fuel.
2002/95/EC	Restriction of certain Hazardous Substances (RoHS) directive (under review)	Laboratory ovens and furnaces are regarded by manufacturers as being in category 9 of the WEEE directive and so currently excluded from RoHS. However RoHS is under review and it is likely that this category will be included in the scope of the recast directive.
2002/96/EC	Waste electrical and electronic equipment (WEEE) directive (under review)	The scope of this directive includes laboratory ovens and furnaces but excludes ovens and furnaces used as part of large-scale stationary industrial tools which are understood to be manufacturing processes. This directive requires manufacturers and importers to finance the cost of end-of-life safe and environmentally sound disposal.

Directive or regulation	Legislation and status	Description and impact on ovens and furnaces
2003/87/EC	Scheme for greenhouse gas emission allowance trading	Sets up the European Union Greenhouse Gas Emission Trading System (EU ETS) which affects the largest carbon emitters, e.g. coke ovens (for steel production), mineral refining including blast furnaces, cement kilns, glass manufacture and ceramic production (firing bricks, tiles, pottery, etc. in furnaces).
Regulation 850/2004	Persistent organic pollutants	Requires the reduction in emissions of dioxins and furans that may be emitted from some furnace processes. Emission limits set nationally
2004/107/EC	Directive restricts certain toxic substances in ambient air	Large furnaces including incinerators may emit a variety of toxic substances such as polycyclic aromatic hydrocarbons and so these need to be designed to minimise these emissions.
2004/108/EC	Electromagnetic compatibility (EMC) directive	Applicable to electrical products ensuring that electromagnetic emissions are within specified limits and that the equipment is not affected by electromagnetic energy.
2004/35/CE	Environmental liability with regard to the prevention and remedying of environmental damage directive	Intended to apply to large-scale industrial processes and requires polluters to pay for remedial action to repair damage. Large-scale processes would include blast furnaces, smelters and cement kilns.
2004/40/EC	"EMF" Directive (minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields))	May affect induction and microwave ovens and furnaces.
2006/118/EC	Groundwater directive	Imposes limits in ground-waters for substances that may be emitted from furnaces and ovens.
2006/21/EC	Management of waste from extractive industries	Many extractive metallurgical processes rely on a variety of large furnaces so this directive will regulate the use of smelters.
2006/32/EC	Energy end-use efficiency and energy services	Requirement for energy efficiencies with a binding national target of 9% savings in energy use within 9 years. This allows Member States to fund energy efficiency improvements (grants, loans, guarantees, etc.).
2006/95/EC	Low voltage directive (LVD)	Regulates the safety of electrical equipment. This affects the design to prevent electric shock, excessively hot surfaces, radiation, sharp edges and other hazards.
1907/2006/EC	Registration, evaluation, authorisation of chemicals (REACH) regulations	Requires that downstream users are informed of safe use of substances of very high concern if present at >0.1% of articles. These include several refractory insulation materials. REACH also restricts certain materials such as asbestos which were used in EU furnaces previously and is still used in some countries.

Directive or regulation	Legislation and status	Description and impact on ovens and furnaces
2023/2006/EC	Food contact materials Regulation	Relevant to ovens used for food manufacture.
2008/50/EC	Ambient air quality directive	Will affect larger furnaces.
2009/105/EC	Simple pressure vessels (2009/105/EC replaces 87/404/EEC)	Furnaces that operate at pressures of >0.5 bar and intended to contain air or nitrogen need to comply with these directives. This sets limits of 300°C for steel vessels and 30 bar maximum pressure. Autoclaves which use pressurised steam may be considered a type of oven and could be included. Vacuum ovens are excluded as this directive excludes vessels with pressure of <0.5 bar.

### Integrated Pollution Prevention and Control (IPPC) directive 2008/1/EC

The IPPC directive requires operators of certain installations to apply for and obtain an operating permit before commissioning their processes. Processes within scope include many types of industrial processes that use furnaces as well as others such as meat processing. There were 14,592<sup>13</sup> installations in EU in 2008 which had been granted IPPC permits and would have contained one or more furnaces or ovens (i.e. including cement, steel, ceramics and glass production, etc). Germany had the most with 3054 of which 1286<sup>13</sup> were involved with processing of metals (heat treatment, etc.).

The IPPC directive specifies the minimum daily production of installations to be within scope and 20 tonnes per day is fairly typical for those involving furnaces. Installations can include more than one furnace and there will be many smaller installations with furnaces that are excluded from the scope of this directive as they produce less than the minimum amounts specified by IPPC. However because of the nature of certain processes which are viable only on a large scale, all or most of these will be in scope and this includes cement product, steel production, float glass manufacture and most brick and roof tile production. Some processes usually operate on a small scale such as pottery production and so most installations are excluded from IPPC.

The main aim of the IPPC directive is to prevent pollution to air, water and land. The approach used is to ensure that processes use the best available technology for the prevention of pollution and this should be used in order to be granted a permit. The European Commission has developed a series of detailed guidance references (BREFs) for all industries in scope of IPPC. These explain the best available technologies and give indications of the emissions levels that can be achieved. Member States grant permits for installations within their jurisdiction and these impose limits on emission levels that are based on the data in the BREF guidance although these levels can vary considerably between Member States. Energy efficiency is a requirement of IPPC except where the installation is within the scope of the EU greenhouse gas trading directive. Energy efficiency issues are described

<sup>13</sup> Calculation using data from sectors that use ovens and furnaces extracted from [http://eea.eionet.europa.eu/Public/irc/eionet-circle/reporting/library?!=/ippc/ippc\\_permitting/permitting\\_eu27xls/\\_EN\\_1.0\\_&a=d](http://eea.eionet.europa.eu/Public/irc/eionet-circle/reporting/library?!=/ippc/ippc_permitting/permitting_eu27xls/_EN_1.0_&a=d)

in specific sector BREFs as well as in a BREF specifically on energy efficiency which is aimed at all sectors including for use by SMEs. BREFs describe best available technology for energy efficiency, although often there are several options for a process and no specific limits are given in BREFs. **As a result, energy efficiency is not strongly regulated by IPPC.**

Permits vary considerably and the European Commission has found that both the timescales for permits and the limit values in permits vary considerably. Some permits have emission limits that are higher than the range specified in the relevant BREF document. This is allowed as BREFs are guidance only and so best available technology is not always required. As a result, new installations may not be as energy efficient as they could be. The IPPC directive is being recast at present (in 2010) and one aim is to ensure that the BREF guidance is more closely followed although energy efficiency will probably still not be a strict consideration for granting permits.

Currently, once a permit is granted the length of time until it is reviewed depends on each Member State and this varies considerably. Some States such as UK and Germany do not specify the review and update period for permits in their national IPPC legislation and so these are determined on a case by case basis. Other States specify the maximum period between reviews and this can be as short as less than 5 yearly (e.g. Poland, Hungary). Spain and Italy have specific validity periods (Spain is 8 years, Italy 5, 6 or 8 years). Some States have much longer review periods with Denmark specifying 10 years, Brussels, Belgium 15 years and Flanders, Belgium 20 years. When a permit for an installation is reviewed, the permit would be re-approved as long as the best available technology was being used and the plant met the current emission targets. The best available technology and emission targets are specified in the BREF guidance which is constantly under review but this process takes about ten years. The first BREFs were published in 2001 and draft updated versions of some of these were published in 2009 with final versions likely in 2010, nine years after the first publication. The result is that the BREFs will always be somewhat out of date and newer better technology may be available since the most recent applicable BREF was published. This delay combined with the length of time that can occur between permit reviews means that the IPPC directive cannot enforce the continuous use of best possible energy efficiency in EU installations. The IPPC recast may specify 5 yearly permit reviews which will be helpful but it will be difficult to increase the frequency of BREF guidance publication due to the complexity of the technology involved. This means that the best available technology recommended at any review point could technically be 5 to 14 years out of date.

Installations included in scope of IPPC include:

- Steel production
- Non-ferrous metals
- Cement and lime
- Ceramics
- Glass
- Incinerators and waste treatment.

Emissions covered by IPPC tend to be production process specific but for furnace processes these include:

- Nitrogen oxide
- Sulphur dioxide
- Carbon monoxide
- Volatile organic carbon (VOCs)
- Mercury
- Dioxins and furans
- Greenhouse gases other than CO<sub>2</sub>
- Polycyclic aromatic hydrocarbons
- Dust (e.g. SiO<sub>2</sub>)
- Acid gases (e.g. HCl, Cl<sub>2</sub>, HF)
- Metal compounds in waste-water
- And many others.

### **Scheme for greenhouse gas emission allowance trading - 2003/87/EC**

The largest multi-country greenhouse gas trading scheme in the world began operation in January 2005 in EU. The scope includes only the largest industrial consumers of energy although this includes over 11,000 installations including many that rely on large furnace and oven processes such as steel and cement production.

The approach used is to impose a cost on every tonne of CO<sub>2</sub> emitted but give (currently free of charge) manufacturers' allowances to cover a proportion of their CO<sub>2</sub> emissions. There could be a risk that this might make EU industry less competitive against its competitors but the Commission estimates that the cost of only 0.1% GDP is lower than from other approaches<sup>14</sup>. In the initial phase, manufacturers were given free allowances which covered at least 95% of their emissions whereas in phase 2 which ends in 2012, free allowances cover a smaller proportion although this will be at least 90%. "Allowances" are given to manufacturers by Member State governments and can be traded on the open market. As a result the price of allowances can rise and fall depending on demand. If a manufacturer is given allowances that cover 95% of his carbon emissions he can decide to:

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<sup>14</sup> The EU Emissions Trading Scheme, 2009 Edition, [http://ec.europa.eu/environment/climat/pdf/brochures/ets\\_en.pdf](http://ec.europa.eu/environment/climat/pdf/brochures/ets_en.pdf)

- Reduce emissions by 5% (then there is no need to buy extra allowances)
- Reduce emissions by more than 5% and sell the unneeded allowances. Income from this sale offsets the cost of reducing carbon emissions
- If the cost of reducing carbon emissions is greater than the cost of buying allowances, then he can buy enough of these to allow him to continue at the same level of emissions.

Since the scheme started in 2005 there have been criticisms about over-allocation of allowances that resulted in the market prices falling to almost nothing<sup>15</sup> so that there is little incentive to cut emissions. The EU is making changes that it is hoped should resolve these problems. For example, there will be an annual decrease of 1.74% per year on the total number of allowances giving a 21% reduction by 2020 based on 2005 emissions. Also, by 2027, all allowances will have to be bought at auctions instead of the current free allocation system. The EU is aware that this could put some sectors of EU industry at a competitive disadvantage with other countries that do not introduce equivalent carbon trading schemes. If manufacturing processes are relocated out of the EU to other countries without an emissions scheme there would be no global decrease in carbon emissions (this is referred to as "carbon leakage"). There could potentially be an increase if the relocated process is less energy efficient. If the need to buy allowances results in it being cheaper to manufacturer products in countries outside EU, EU industry would become uncompetitive and so the EU would suspend the requirement to buy allowances to prevent this situation from occurring.

One research study in Korea into the potential carbon emissions reduction from steel production shows that a reduction of 5.1% is economically viable without carbon taxes but a reduction of 36% may be possible with carbon taxes of 90US\$/tonne carbon (by 2030)<sup>16</sup>. These carbon taxes increase overall production costs and so will be effective only if all countries world-wide adopt the same level of taxation as otherwise, manufacturers will relocate their facilities.

The types of installations in scope of the EU ETS is the same as IPPC.

### **Hazardous substance legislation**

Several pieces of EU legislation regulate hazardous substances that may be used in the construction of furnaces and ovens and others that may be emitted from processes carried out in furnaces and ovens.

2002/95/EC RoHS restricts lead, cadmium, mercury, hexavalent chromium and two flame retardants, PBB and PBDE, in electric household ovens which are not in scope of this study as they are included

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<sup>15</sup> After Copenhagen, Oscar Reyes, 04 February 2010, , <http://www.carbontradewatch.org/carbon-trading-how-it-works-and-why-it-fails.html> and Carbon Trade Watch, Fact Sheet 1, [http://www.carbontradewatch.org/downloads/publications/factsheet01-cap\\_and\\_trade.pdf](http://www.carbontradewatch.org/downloads/publications/factsheet01-cap_and_trade.pdf)

<sup>16</sup> Heesung Shina, Jongchul Hong, Younggu Park "A Study on Carbon Dioxide Emission Reduction Potential in the Iron and Steel Industry in Korea"

in the DG TREN Lot 22 study. The Commission has proposed that the scope of RoHS be broadened to include categories of equipment that would include laboratory ovens and furnaces and medical ovens and furnaces. Some of the RoHS substances are used in these products, mainly lead in control and power electronics and hexavalent chromium in passivation coatings to prevent corrosion.

1906/2006/EC REACH has replaced the Marketing and Use directive 76/769/EC and incorporated its substance restrictions which include a restriction on asbestos. REACH also has a mechanism for controlling substances of very high concern (SVHC) which are included in a "candidate list" of substances. This list includes Aluminosilicate Refractory Ceramic Fibres and Zirconia Aluminosilicate Refractory Ceramic Fibres (RCFs) both of which are used as flexible furnace insulation materials. The current obligation is to inform customers if a product contains more than 0.1% by weight of an SVHC. Candidate list substances may be proposed to require authorisation for use in EU. This requires the applicant (who wants to use the substance) to show that no suitable alternatives exist or that the substance can be used safely and does not pose a risk.

2023/2006/EC Food contact materials – specifies which materials may come into contact with food so applies to ovens used to manufacture food.

Several pieces of legislation listed in Table 15 (on page 49) control emissions of hazardous substances from industrial processes including:

- 96/61/EC IPPC
- 2004/107/EC Toxic air emissions
- 2006/118/EC groundwater emissions.

### 1.5.2 Legislation at Member State level

**Dioxin and furan emission limits:** Germany – 17<sup>th</sup> Federal Emission Control Ordinance limits emissions of dioxins and furans. These substances may be emitted by incinerators and furnaces that burn halogenated plastics.

**Maximum workplace exposure limits for refractory ceramic fibres** – these materials are used as insulation materials for furnaces and ovens and air concentration limits are set by Member States for the safety of workers. Limits include:

**Table 16. National emission limits for refractory ceramic fibres in EU Member States**

Country	Limit for refractory ceramic fibres	National regulation or source of data
France	1 fibre/cm <sup>3</sup>	Circulaire DRT no 95-4 1995
Germany	3mg/m <sup>3</sup> , 1.0 or 0.5 fibre/cm <sup>3</sup>	TRGS Bunderarbeitsblatt 2005 (0.5f/cm <sup>3</sup> limit is for new installations)
UK	1 fibre/cm <sup>3</sup>	HSE EH40 Maximum Exposure Limits
Austria	0.5 fibre/cm <sup>3</sup>	Ref. 17
Italy	0.2 fibre/cm <sup>3</sup>	Ref. 17
Norway	1.0 fibre/cm <sup>3</sup>	Ref. 17
Sweden	0.2 fibre/cm <sup>3</sup>	Ref. 17

### 1.5.3 Third country legislation

Survey incomplete

## 1.6 First screening of the volume of sales and trade, environmental impact and potential for improvement of the products

### 1.6.1 EU Sales

There are no published accurate sales data for ovens and furnaces including in PRODCOM. PRODCOM has data missing for many types of furnace and oven, and for some types sales are included with data for other types of equipment. The only PRODCOM data available for 2008 is:

**Table 17. Oven and furnace sales data available from PRODCOM Eurostat data**

PRODCOM category	PRODCOM data
Non-electric furnaces and ovens for the roasting, melting or other heat-treatment of ores, pyrites or of metals	7300 manufactured and sold
Electric bakery and biscuit ovens	113,118 manufactured /sold. This total probably includes commercial catering ovens which are covered by Lot study 22
Bakery ovens, including biscuit ovens, non-electric	28,300 manufactured /sold. This total probably includes commercial catering ovens which are covered by Lot study 22

<sup>17</sup> <http://www.thermalceramics.com/site.asp?siteid=146&pageid=165>

There are also several PRODCOM categories with weight data only. As ovens and furnace weight vary considerably, this data cannot be used to calculate numbers sold.

PRODCOM category "Non-domestic equipment for cooking or heating food (excluding non-electric tunnel ovens, non-electric bakery ovens, non-electric percolators)" had 988,000 manufactured / sold most of which are commercial catering products outside the scope of this study.

### 1.6.2 Potential for energy efficiency savings

Significant energy savings that reduce global greenhouse gas emissions can be achieved by changes to oven and furnace design. Replacement of an old inefficient furnace located in the EU with a new more efficient design located at the same site clearly has a benefit to EU emissions reduction and globally. However, if changes in legislation cause manufacturers to relocate production outside the EU, this would appear to reduce the emissions from within the EU but there is no benefit globally unless the new plant is more energy efficient. Furthermore, the EU has little influence over production processes carried out outside the EU, even for the production of goods placed on the EU market. Many products consumed in the EU are manufactured using ovens and furnaces outside the EU and the energy consumed is not included in the EU's carbon emission totals.

Some products manufactured using ovens and furnaces are usually made locally to where they are used. Cement is usually made and used in the same EU Member State because it is a relatively unstable material which deteriorates if it becomes wet. Glass and ceramics (e.g. bricks) are relatively heavy and fragile so most is made and consumed within Member States. The EU is fairly self-sufficient in steel although does import some low grades and exports high grade steels. Steel is heavy and so expensive to ship over large distances so for example, if there is excess capacity in EU and insufficient in India, it is more economical in the long-term to build a new plant in India. Of course labour costs, grants and local restrictions on process plant also influence where new installations are constructed. Fabricated goods consumed in EU and made of steel will contain steel produced locally to where the fabricated goods are assembled which for many types of product consumed in EU, this is from outside the EU.

One publication<sup>18</sup> claims that currently only 40% of energy, on average, is used in furnaces and that 60% is lost. Energy efficient recuperative and regenerative burners can reduce consumption considerably but there are technical limitations so that these recover only 5 – 30% of energy in exhaust gases, although in some cases larger reductions in energy consumption are possible<sup>19</sup>. The potential for energy efficiency improvements will be discussed in more detail in tasks 4, 5 and 6 but an initial estimate is made here.

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<sup>18</sup> US Patent application US 2008/0014537 A1, A. Atreya, 12 July 2007.

<sup>19</sup> Energy Efficient Crucible Furnaces, Institute of Cast Metal Engineers, <http://www.icme.org.uk/news.asp?ID=114>

## Ovens and furnaces for manufacturing processes

Research sponsored by the IHEA (Industrial Heating Equipment Association) and the US Department of Energy estimated in 2001 that it is possible to reduce the energy consumption of existing industrial process heating, which is primarily ovens and furnaces, by 5 – 25% and this should be possible within 10 years<sup>20</sup>. This is the difference between older less energy efficient processes that were already in use with new more efficient furnaces and ovens and is not the difference between new standard designs and new BAT designs.

Energy is lost through three main areas: through insulation, by ventilation and by water cooling. There are many scientific publications describing techniques to improve the energy efficiency of ovens and furnaces and many oven and furnace manufacturers advertise energy efficiency as an important benefit of some of their products. Clearly there is potential for energy savings in this sector but quantification is not straightforward. Estimates can be made for some sectors from data published in IPPC BREFs but this is limited to the largest installations only. The IPPC Energy Efficiency BREF states describes several design options that its states are BAT (e.g. regenerative burners), however, these may cost more than the price of the energy saved (this depends on the payback period) and so some new furnaces and ovens are not as efficient as is technically feasible. It is possible that further energy savings beyond those already being adopted by industry are achievable. Discussions with furnace manufacturers and users of furnaces indicate that for the larger furnaces at least, energy efficient designs using BAT are available on the EU market but these are more expensive than standard designs. Most EU users expect a return on investments within three years and so if the additional cost of energy savings features has a longer payback time than this, these are often not used, even though the furnace may be used for over 20 years, during which time, the more energy efficient design would cost less overall. This means that there is a potential for energy savings when comparing furnaces and ovens that users are willing to install and the most energy efficient designs that are available. Various methods described below have been used to attempt to estimate the potential for energy savings although, without data from manufacturers, this will not be very accurate.

Industrial total energy consumption in the EU is estimated by JRC<sup>21</sup> to be 316.9Mtoe (million tonnes oil equivalent) which according to the IEA converter<sup>22</sup> is 3685 TWh (this converts the oil equivalent figure to energy as TWh). In United States of America, 17% of industrial energy is used for process heating whereas the figure for Germany is 32%<sup>23</sup> although CECOF estimate ~40%. Using the 32% figure for EU, the total energy used by thermal processes, which are mostly various types of furnace and oven would be 1179 TWh. This figure includes steel and cement production which together accounts for 48% of industrial CO<sub>2</sub>

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<sup>20</sup> "Roadmap for Process Heating Technology. Priority Research & Development Goals and Near-Term Non-Research Goals To Improve Industrial Process Heating", Capital Surini Group International, Inc. and Energetics, Incorporated, 16 March 2001.

<sup>21</sup> "Electricity Consumption and Efficiency Trends in European Union - Status Report 2009", Paolo BERTOLDI and Bogdan ATANASIU, Joint Research Centre.

<sup>22</sup> IEA unit converter, <http://www.iea.org/stats/unit.asp>

<sup>23</sup> H. Egger "Efficient use and recuperation of energy within a state of the art commercial heat treatment facility" Heat Processing, issue 4 2008, p269

emissions<sup>24</sup> in EU. Therefore to obtain a figure for all industry except for these two largest energy consumers (steel and cement), 52% of 1179 = 613 TWh energy is used by ovens and furnaces in EU (excluding steel and cement). Using the IHEA estimate for potential energy savings of 5 – 25%, the EU's saving would be equivalent to 31 - 153 TWh/year. This is only a rough estimate but shows that large energy consumption decreases are technically feasible.

Significant reductions in energy consumption have already been made by several industry sectors that use furnaces including steel and cement but there is a very large stock of old inefficient furnaces and ovens in the EU. The aim of this study is to determine the potential energy savings that could be achieved by using the best available technology instead of standard average energy efficiency products, not the potential savings by replacement of old existing stock with average new furnaces. Opinions within the furnace and oven industry vary with some claiming that new furnaces are best available technology and so could not be more efficient whereas others point out that users have financial constraints so if the cost of energy efficiency innovations is not paid for within a relatively short time period, these designs may not be selected. As explained above, if the added cost has a payback period of more than 3 years, many EU furnace users will not fund these more expensive design options even though the furnaces will be used for up to 20 years or longer. If a longer payback period were used, the more energy efficient option would be cheaper overall. Furnace manufacturers endeavour to make their products as energy efficient as possible but will offer a selection of products to satisfy their customers' needs for function and price.

In general, new designs of the largest furnaces that use the most energy including steel production (blast furnaces, etc.), cement kilns, float glass, etc. will use the best available technology but they may not always be as energy efficient as possible due to the cost of some features. Medium and small size furnaces may also not be as energy efficient as possible due to cost constraints and sometimes due to a lack of expertise by users and so there will be a difference in energy consumption between different designs. One example relates to the type of gas burner used. Recuperative burners use pre-heated air and so consume about 15 - 20% less energy than similar burners fed with cold air<sup>25</sup>. It is possible for users to buy new metal melting furnaces either with standard burners or with recuperative burners, the latter being more expensive but considerably more energy efficient. There are many other energy efficient design innovations being offered which users could choose to purchase and these will be discussed in detail in tasks 5 and 6. One that is used only in larger furnaces is the regenerative burner. These are now standard in large glass melting furnaces but optional in many other types of furnace. They are relatively expensive to install and also add to maintenance costs. They may also have payback periods of more than 3 years but they can give very significant energy consumption reduction; typically ~40% or better is possible

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<sup>24</sup> Technical report No 04/2009, "Annual European Community greenhouse gas inventory 1990 – 2007 and inventory report 2009. Submission to the UNFCCC Secretariat", 27 May 2009, European Environment Agency

<sup>25</sup> There are several furnace manufacturers that offer metal melting furnaces with either standard or recuperative burners including Morgan Metal Melting Systems [www.morganmms.com](http://www.morganmms.com)

when compared to standard burners. However the cost of replacement of a recuperative system with a regenerative system can be several million Euros (one example quotes \$3.7 million<sup>26</sup>).

The potential energy saving in other sectors varies depending on the types of oven and furnace that are available and suitable for the specific processes, all of which are different.

## Cement production

WBCSD (World Business Council for Sustainable Development) and IEA (International Energy Agency) have produced a roadmap for reductions in global warming emissions from cement products until 2050<sup>27</sup>. Carbon emission reductions are planned from several aspects of cement production:

- Thermal energy consumption decrease from an average of 3.7 GJ/tonne clinker to an average of 3.2 GJ/tonne clinker by 2050. The reduction by 2020 will be ~3.6 GJ/tonne clinker
- Electrical energy use – efficiency savings of up to 10% by 2050 although savings by 2020 will be more modest
- Use of biofuels – decreases use of fossil fuels
- Reduction of the proportion of clinker (made in the rotary furnace) in cement from currently ~79% to ~72% – reduces energy required per tonne of cement
- CO<sub>2</sub> capture – potentially could make cement production and use a net absorber of atmospheric CO<sub>2</sub> although the carbon capture process will consume additional energy
- Phasing out less efficient processes. The most efficient kilns produce cement with ~3.3GJ/tonne of clinker whereas the least efficient consume ~4.4 GJ/tonne of clinker.

There is also research<sup>27</sup> into alternative types of cement that may produce benefits such as magnesium silicate based materials (Novacem). When this is calcined, no CO<sub>2</sub> is emitted unlike from limestone but the cement made from this feedstock adsorbs CO<sub>2</sub> when it sets so that potentially this type of cement could be a net consumer of CO<sub>2</sub>.

The potential energy saving that should be achievable by using the most energy efficient kiln designs (excluding use of biofuels and other measures) can be calculated:

- World cement production in 2006 = 2559 Mtonnes, EU produces ~10% = 256 Mtonnes.

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<sup>26</sup> Hughes P., Sebestyen A., High Temperature Air Combustion (HiTAC) for Industrial Applications, Asia-Pacific Partnership Steel Task Force, 13 Jan 2009, [www.asiapacificpartnership.org/pdf/Steel/6th\\_meeting/High\\_Temperature\\_Air\\_Combustion\\_\(HiTAC\)\\_for\\_Industrial\\_Applications.pdf](http://www.asiapacificpartnership.org/pdf/Steel/6th_meeting/High_Temperature_Air_Combustion_(HiTAC)_for_Industrial_Applications.pdf)

<sup>27</sup> Cement Technology Roadmap 2009, Carbon emissions reductions up to 2050, <http://www.wbcscd.org/includes/getTarget.asp?type=d&id=MzY3NDM>

- WBCSD and IEA estimate that thermal energy efficiency can reduce energy consumption from 3.9GJ/tonne to 3.6 GJ/tonne in 2020 and 3.2 GJ/tonne in 2050, i.e. a reduction of 0.3 GJ/tonne by 2020 and 0.7GJ/tonne by 2050. This would be equivalent to 84 KWh / tonne clinker by 2020 and 195 KWh /tonne clinker by 2050.
- The estimated potential thermal energy saving in EU from energy efficiency measures in cement production in EU (current production about 256 million tonnes in EU, assuming no increase in production) by 2020 could be 21.3 TWH/year and by 2050 could be 50TWh/year. This is without other changes that would give further reductions in energy consumption.
- The German cement industry trade association VDZ claim that German cement kilns have an energy efficiency of ~70%<sup>28</sup> which is high for a rotary furnace. Achieving further energy efficiency savings will be difficult although some may be possible. The other way to reduce total carbon emissions is by reduced consumption of cement (unlikely to be popular) or technology developments into alternative types of cement.

Very significant energy saving may be achievable by 2020 and 2050 if the industry plan is followed and one of EU's largest cement manufacturers "Lafarge" recently reported it had met its CO2 emission reduction target<sup>29</sup>. All new plant should be built and existing plant should be refurbished utilising the best available technology. The cement industry should do this because of the industry plan to reduce carbon emissions, but also to comply with the IPPC directive and importantly to gain the reductions in cost from using less energy and emitting less CO2 from fossil carbon.

Further benefits from carbon capture and storage are possible but this would incur a net cost with no financial benefit to the kiln operator. Energy savings are being made but some will occur only when existing plant is refurbished or replaced as this requires considerable investment. New cement kilns should be BAT but cement kilns have long lives between refurbishment or replacement and so further reductions in the EU's annual energy consumption would occur if the rate of refurbishment or replacement of kilns could be accelerated.

## Steel production

The steel production industry is in some ways a special case because it is very unlikely that new iron and steel production plant will be installed in EU. Existing coke ovens and blast furnaces will be refurbished but not replaced.

Japanese research indicated in 2008 that EU steel manufacture could reduce energy consumption by ~16% whereas the difference in energy efficiency between the average EU steel installation and the best is 7.2% (based on IPPC BREF data). It is important to note that these efficiency improvement

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<sup>28</sup> [http://www.vdz-online.de/fileadmin/gruppen/vdz/3LiteraturRecherche/UmweltundRessourcen/Umweltdaten/Umweltdaten2008\\_e\\_WEB.pdf](http://www.vdz-online.de/fileadmin/gruppen/vdz/3LiteraturRecherche/UmweltundRessourcen/Umweltdaten/Umweltdaten2008_e_WEB.pdf)

<sup>29</sup> [http://www.lafarge.com/wps/portal/6\\_2\\_1-CADet?WCM\\_GLOBAL\\_CONTEXT=/wps/wcm/connect/Lafarge.com/AllPR/2010/PR100329b/MainEN](http://www.lafarge.com/wps/portal/6_2_1-CADet?WCM_GLOBAL_CONTEXT=/wps/wcm/connect/Lafarge.com/AllPR/2010/PR100329b/MainEN)

estimates are for steel production installations which include blast furnace, BOF, holding furnaces, heat treatment, etc.

The draft IPPC BREF for steel states that in 2004, EU steel production used on average 19.4GJ/tonne whereas the best EU plant used 18GJ/t which is 1.4GJ/tonne less. As EU production of steel is 206 million tonnes, this indicates an energy saving of 80 TWh, calculated as follows;

206 million tonnes @ 1.4 GJ/tonne = 288 million GJ/year.

The conversion factor for MJ to TWh is 3.6GJ= 1MWh

So 288 million GJ/3.6 = 80 million MWh = 80 TWh

In fact efficiencies are already being made and this predicted saving should eventually be made in EU without intervention. The energy efficiency technology is not solely Japanese and much was developed in EU but Japan was the first to modify its steel industry, possibly because of the Japanese policy of planning much further into the future than European industry. Longer payback periods are acceptable in Japan than in EU. In EU, modifications are made only when existing plant is due for refurbishment which is typically every 25 years. It could therefore take many years to accomplish these efficiency savings unless the process can be accelerated. However if EU plant are closed and steel imported from inefficient plant located outside the EU, there would be no reduction in global greenhouse gas emissions or even an increase in global emissions.

According to one steel production furnace manufacturer, the cost of blast furnace refurbishment is from €10 – 100 million. The best energy efficiency would be achieved by investment of the higher amount (€100 million) whereas this also has the longest payback time that may not always be acceptable to EU steel manufacturers without financial incentives from EU governments.

These estimates do not take into account the potential for newer steel processes such as direct reduction. Opinions on whether direct reduction / EAF is more economical than blast furnace / BOF vary. One report claims that this can give a potential reduction in CO2 emissions of ~20%<sup>30</sup>. Direct reduction eliminates the need for coke ovens but the product needs to be melted in an electric arc furnace (EAF) instead of being treated in a basic oxygen furnace (BOF). The BOF is a net energy generator but EAF consumes electrical energy so the comparison of the blast furnace and direct reduction routes are not straightforward. One publication suggests that the combination of Direct Reduction with EAF could reduce total CO2 emissions per tonne of steel from 1557 kg CO2 / tonne of hot rolled steel from a blast furnace / BOF to only 1080 kg CO2 /tonne from direct reduction / EAF representing a reduction of 30%<sup>31</sup>. However another indicates that direct reduction / EAF uses more energy than blast furnace /BOF<sup>32</sup>. It is not clear whether these new technologies would give energy

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<sup>30</sup> Draft IPPC reference to BAT for the production of iron and steel, July 2009.

<sup>31</sup> P. E. Duarte et al. "Energiron Direct Reduction Technology".

<sup>32</sup> "Energy use and carbon dioxide emissions in the steel sector in key developing countries" April 2001  
<http://ies.lbl.gov/iespubs/46987.pdf>

efficiencies in EU as they rely on the availability of large quantities of natural gas which has a limited supply in EU.

## **Ceramics**

The manufacture of bricks, tiles and other ceramics uses large quantities of energy. Energy efficiency has significantly improved, by up to 30%, since the 1980s mainly due to improved insulation<sup>33</sup> but further improvements should be possible. A study carried out to establish benchmarks for the EU Energy Trading Scheme (ETS) found that the energy consumption of brick kilns varies considerably depending on the type of kiln. Hoffman kilns use 573 KWh/tonne whereas tunnel kilns use 658 KWh/tonne<sup>34</sup>. The choice of kiln type is not however based only on energy consumption because energy consumption also depends on the type of clay used. Some clay types that are used for certain types of bricks contain high organic content and so chamber kilns that can be used for these types of clay have much lower energy consumption (benchmark = 245 KWh/tonne) but this is due to the energy from combustion of this organic material, not from lower total CO<sub>2</sub> emissions. For many types of ceramics, new technology such as microwave assisted heating could further provide opportunities for further reductions in energy consumption. There are also options for other changes that could reduce energy consumption such as brick design, choice of raw material (clay), etc., which are not furnace-related and so outside the scope of this study.

## **Glass**

Glass sheet and containers manufacture consumes very large amounts of energy. One glass melting furnace producing ~500 tonnes glass per day will consume ~360GWh annually at a cost of €3 – 4million. There are 58 flat glass installations in EU so total energy consumption for this process step alone only for glass sheet is 21 TWh/year (container glass consumes far more). One glass manufacturer has provided information that research has indicated that energy efficiencies of up to 5% may be achievable but the cost would incur a payback of over 7 years and so due to limits on capital availability, these would not be adopted. All other EU glass manufacturers have the same policies.

## **Laboratory furnaces and ovens**

There is no quantitative data on laboratory ovens and furnaces (heat sterilisers, etc.). There is no published sales data available and so this information will need to be provided by industry. Manufacturers usually do not measure energy consumption or energy efficiency and no standard test method is available. Our preliminary estimate is that 50,000 – 100,000 laboratory ovens and furnaces are sold in EU annually although this may be incorrect. If we assume that energy consumption is about half of the energy rating, the average energy consumption (based on the range of power ratings available) is about 2KWh (this assumes that many more ovens are sold than

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<sup>33</sup> David Shemanski, Managing Director of Measham Brick Quarry, Hanson and Jane Anderson, Principal Consultant at BRE, Watford interviewed on "You and Yours", BBC Radio 4, Dec 2009.

<sup>34</sup> Study carried out by Enviros Consulting for UKDTI 2006, <http://www.berr.gov.uk/files/file33274.pdf>

furnaces). If we assume that these are used 12 hours per day and 30 days per year, energy consumption is up to 720GWh / year. If energy efficiency savings of 30% are achievable, this would reduce EU energy consumption by 21.6GWh / year from one years sales and 3.2TWh per year if all of EU stock were to be replaced (assumes 15 year life) but this is a very approximate estimate and the true figure needs to be calculated using detailed data from industry.

## **Sector estimates**

A semi-quantitative matrix for industrial and laboratory furnaces and ovens has been developed (and will be refined during this study).

The improvement potential depends on what is assumed to be business as usual (BAU). Two extreme definitions could be used:

- Industry takes no action to improve energy efficiency
- All new and refurbished furnaces and ovens include the best available technology for energy efficiency.

In reality, BAU will be somewhere between the two. Some industry sectors such as the cement industry have ambitious plans to reduce energy consumption whereas others incorporate energy efficiency modifications only if a financial saving, often in the short term (< 3 years), can be demonstrated.

Energy costs are largest with the biggest furnaces and so the trend is that energy efficiency is considered as a higher priority with the largest energy consumers and least with small laboratory ovens and furnaces. New and refurbished furnaces for steel production, cement kilns, float glass furnaces, etc. will usually use BAT although not necessarily every energy saving modification possible due to cost. Medium size furnaces may not always adopt the most energy efficient design due to a relatively long payback period on the high investment cost.

In order to determine predicted improvement potential, BAU has been assumed to be what industry sectors will do with no action taken by the EU. This assumes that industry sectors will follow energy consumption reduction improvement plans where these have been agreed such as by the cement industry or the most energy efficient designs will always be used such as for waste to energy incinerators.

For other types of furnaces however, BAU assumes that energy efficiency improvements will be restrict by users due to constraints on capital availability.

**Table 18. Sales, stock energy consumption and estimated improvement potential for main industry sectors**

Oven / furnace sector (design types)	Sales 2009 new units	Stock 2009 units*	Average energy consumption (MWh/Yr)	Total sales energy consumption (GWh/Yr)	Total stock energy consumption (TWh/Yr)*	Improvement potential (by 2020)	Estimated EU energy savings TWh/yr by 2020 based on stock
Cement kiln (4)		437			277	0 - 7.7%	21.3
Steel production (1 - 3)	no new (~10 refurbished/yr) a	538		None, no sales of new furnaces	1100	0 - 7.2%	80 (refurbishment of stock only)
Glass - total (1, 2)		>787			64	Up to 20% g	0 - 12.8
Container glass (1, 2)	17 b	~250			40 d	5%	2.0
Flat glass (1, 2)	3 - 4 c	58			22 e	5%	1.1
Ceramics total (1, 2)		>1800			113	20% g	0 - 22.6
Bricks (ceramics) (1, 2)		>1200			35	0 - 20%	
Decorative tiles (ceramics) (1, 2)		Many more than 450			39	~20%	
Oil refining (1,2?)		?			329 - 1050		
Incinerators WIE** (3)	<10	430	12,500 h			0%	0
Other incinerators (1)							
Metal smelting & melting (1, 3, 4)					Scrap AI = ~3 f Others ?	20 - 40%	AI = 0.6 - 1.2
Metals heat treatment (1, 2)	?	?				~20%	

Oven / furnace sector (design types)	Sales 2009 new units	Stock 2009 units*	Average energy consumption (MWh/Yr)	Total sales energy consumption (GWh/Yr)	Total stock energy consumption (TWh/Yr)*	Improvement potential (by 2020)	Estimated EU energy savings TWh/yr by 2020 based on stock
Laboratory (1 mainly) <i>estimated</i>	<i>~100,000 i</i>	<i>1,500,000</i>	<i>7.2</i>	<i>720</i>	<i>10.8</i>	<i>30%</i>	<i>3.2</i>
Food production (1, 2)							
Medical sterilizers (1)							
Laboratory analysis instruments (1 mainly)	17,000	170,000	3.6	62	0.62	<5%	<0.05 ((1 year sales) <0.5 (stock)
Totals (estimated from incomplete data)	<b>100,000</b>	<b>1,000,000</b>			<b>1200 - ~2000</b>	<b>10 - 20%</b>	<b>~100</b>

\* Estimated from data in IPPC BREFs.

\*\* WtE – waste to energy incinerators only; excludes the large number of waste incinerators with no energy recovery.

- a only one new steel production plant installed in the last 10 years in EU and no new plant likely in EU. There are ~90 blast furnace / BOS facilities which are refurbished every 10 - 25 years so at least 9/year will be blast furnaces. Industry information is that there are ~10 refurbishment projects for steel production furnaces annually in EU.
- b EU production in 2007 was 22 million tonnes and a medium size furnace would produce 87,500 tonnes / year so there are about 250 container glass stock in EU. Time between refurbishment is ~15 years so 25/15 = 17 per year.
- c 3 – 4 rebuilds per year, which was calculated from stock of 58 having a life of ~15 years between rebuilds. New plant less common.
- d 22 million tonnes produced with an average consumption = 8.7GJ/tonne although only 75% of this is furnace energy.
- e 9.37 million tonnes produced with an average energy consumption of 7.5 GJ/tonne although only 83% is furnace energy (data from one manufacture indicates usage is 18 (average of 14 – 22) TWh / year for flat glass melting plus energy for subsequent process steps so total is ~22 TWh/y).
- f Calculated from 4.1 million tonnes recycled in Western Europe in 2003 (data from [www.eaa.net](http://www.eaa.net)) and IPPC draft BREF guidance, non-ferrous metals industries 2009, table 4.21.
- g The Carbon Trust claim that the ceramic and glass industries could reduce energy consumption by 20%. This refers to replacement of existing furnaces not the difference between standard new and BAT new furnaces.

- h The principal energy source for waste to energy incinerators is the waste materials feedstock. Electricity is used to operate the equipment such as for air pumps, controllers, hygiene etc but there is a net surplus of electricity generated. Electrical energy consumed is 0.1MWh / tonne waste. ~20% of EU municipal waste = ~ 50 million tonnes / year is incinerated by 430 incinerators = average of 125,000 each.  $125,000 \times 0.1 = 12,5000$  MWh/year.
- i. Cobham's preliminary estimate, not based on industry data as this has not yet been provided. Calculation assumes 100,000 sold per year, average energy consumption is 2KWh and these have a life of 15 years so there are 1.5 million stock in EU.

**STAKEHOLDERS ARE INVITED TO COMMENT AND PROVIDE INPUT ON THIS TABLE, INCLUDING OTHER TYPES OF OVEN AND FURNACE**

## 2. Task 2 – Economic and Market Analysis

This task reviews the market for furnaces and ovens in order to produce data that will be needed in other tasks to calculate the environmental and cost impacts of existing stocks, new sales and future sales taking account eco-design and other options. Data required include the number of furnaces and ovens sold annually and the energy consumed by this equipment. This will be used to calculate the total energy consumption. The results of a technology review will determine the potential for reducing energy consumption which will have environmental and cost benefits. Other data such as typical life and refurbishment periods will be used to determine when energy reduction measures will have an effect. Task 4 will calculate base-cases based on the four design types described in task 1 but it is apparent that market data based on industry sectors is more readily available than on design types and so industry sector classification has been used for task 2. This classification is used to some extent by PRODCOM Eurostat. However it will be necessary to estimate the proportion of each design type sold in EU in order to carry out tasks 4, 6 and 7. EU State data is included in Appendix 1 and only EU totals are included in this section.

### 2.1 Generic economic data

The Prodcum database is useful for an initial analysis as it contains transparent and publicly available data provided by Member States on manufacturing and production within the EU.<sup>35</sup> Prodcum data included in this study are in the following categories:

- EU production
- Extra-EU trade, including imports/exports into/from the EU
- Apparent EU consumption<sup>36</sup>

The data is in physical units and by Member State for 2008 – the latest full year for which at least half of the Member States have reported.

Data was extracted from each of the relevant Prodcum categories identified in subtask 1.1 as partly or fully matching the product definitions. In order to facilitate the data analysis, those categories have been grouped together in five major functional groups, not taking into account the differences in energy source or type of technology:

- Furnace burners
- Mechanical stokers

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<sup>35</sup> Preliminary estimates of 2006 EU sales and stocks of industrial and laboratory furnaces and ovens were made by the consultants EPTA for the first Ecodesign Working Plan in 2007 based on Prodcum.

<sup>36</sup> Apparent consumption = Production + Imports – Exports.

- Furnaces and ovens for the treatment of ores and metals
- Bakery ovens
- Industrial/laboratory furnaces and ovens

The following tables present data from the Prodcum equipment categories only. Other categories identified in subtask 1.1, such as those including parts for furnaces or instruments used in dental sciences, were not analysed.

### Furnace burners

Two main categories are found for this product group, defined according to the energy source: liquid fuel (Prodcum category: 28211130) and solid fuel or gas, including combination burners (Prodcum category: 28211150).

According to the data reported by Member States, the production of furnace burners for liquid fuel in 2008 was over 1.1m units, of which 690 000 units were sold inside the EU. The tables below present data for imports, exports, production and apparent consumption for this category by Member State.

**Table 19. Number and value of exports, imports and production of furnace burners for liquid fuel in EU, 2008**

Country	Exports		Imports		Production	
	Volume (Number of units)	Value (€m)	Volume (Number of units)	Value (€m)	Volume (Number of units)	Value (€m)
<b>EU-27 total</b>	<b>587 487</b>	<b>122.4</b>	<b>124 745</b>	<b>10.7</b>	<b>1 153 836</b>	<b>392.6</b>

The apparent consumption of furnace burners for liquid fuel in EU, 2008 was 691,094 units. No data was available for exports or imports of furnace burners for solid fuel or gas. Total production in numbers of units and their value for 2008 are presented below. Italy reports a number of produced units that accounts for 99% of total production at the EU-27 level. Production of furnace burners for solid fuel or gas (including combination burners) in EU during 2008 was 53.9 million units worth €705 million.

### Mechanical stokers

The completeness of the reported 2008 data for mechanical stokers (Prodcum category: 28211170) was very poor with no detailed information on exports or imports. In terms of production, the total number of units reported for the EU-27 is 60 000 units, of which 12 400 were produced in Austria. There is no data available for other countries. The estimated value of the units produced in 2008 was €201m.

### Furnaces and ovens for the treatment of ores and metals

Non-electric furnaces and ovens for the roasting, melting or other heat-treatment of ores, pyrites or of metals are reported in Prodcom category 28211230. Production takes place mainly in Italy (50%), Spain (12%), Germany (6%) and France (1%). The total number of units produced in 2008 was 7 300 with a value of €668m. No data was available on exports or imports.

### Bakery ovens

Two categories are included in this group, defined according to the energy source: electric bakery and biscuit ovens (Prodcom category 28211330) and non-electric bakery and biscuit ovens (Prodcom category 28931530).

Information on production is available: more than 113 000 units were produced in the EU-27 in 2008 with a total value of €242.3m. Italy is the main producer, followed by Germany and Spain. Non-electric bakery oven production data is presented in the table below. Italy is an important centre of production with 56% of the units reported, followed by France (16%) and Spain (16%). Total production in 2008 was 28 300 units for a value of €267.3m.

**Table 20. Production of electric and non-electric bakery and biscuit ovens in EU, 2008**

Type of bakery and biscuit ovens	Volume (number of units)	Value (€m)
Electric	113,118	242.3
Non-electric	28,302	267.3

### Industrial/laboratory furnaces and ovens

There are five categories in this group that define the type of furnace/oven according to the energy source:

1. non-electric industrial or laboratory furnaces and ovens (including incinerators, excluding those for the roasting, melting or other heat treatment of ores, pyrites or metals, bakery ovens, drying ovens and ovens for cracking operations – Prodcom category 28211270),
2. resistance heated industrial or laboratory furnaces and ovens (excluding bakery and biscuit ovens – Prodcom category 28211351),
3. electrical induction industrial or laboratory furnaces and ovens (Prodcom category 28211353),
4. electrical industrial/laboratory furnaces/ovens, induction/dielectric heating equipment, including dielectric furnaces/ovens excluding infra-red radiation ovens, resistance heated furnaces/ovens (Prodcom category 28211355)
5. electric infra-red radiation ovens (Prodcom category 28211357).

Data is available for exports, imports and production for nearly all Member States but the unit used to report the volume of transactions is a unit of weight: kg. Products vary widely by weight and so this cannot be used to make an accurate estimation of the number of units (needed for later tasks). Estimates can be made based on this data using average machine weight, to be obtained mainly from stakeholders through the questionnaire.

Data for these five categories are presented below.

**Table 21. Volume and value of exports, imports and production of non-electric industrial or laboratory furnaces and ovens in EU, 2008**

Category of industrial & laboratory oven and furnace	Exports		Imports		Production	
	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)
Non-electric	56,641	379.8	5,121	35.7	145,242	744.2
Resistance heated	13,563	388	3,153	53	31,805	811
Electric induction	5,495.3	99.9	649.5	10.7	10,189.4	255.4
Electrical industrial & laboratory furnaces & ovens, including induction & dielectric heating equipment	12,792.4	305.5	6,276.1	103.8	27,149.4	480.0
Electric infrared radiation	434.2	7.6	157.4	4.7	1,000.0	16.3

The apparent consumption of the EU-27 for the non-electric category in 2008 was 93 700 tonnes. Sweden and Italy seem to be important producers (by volume). In the category of resistance heated industrial or laboratory furnaces and ovens (excluding bakery and biscuit ovens), apparent consumption was 21 400 tonnes in 2008. Germany accounts for 42% of total production by volume. Data on exports, imports and production of electrical induction industrial or laboratory furnaces and ovens is presented below. Germany and Italy accounted for more than 75% of total EU-27 production by volume in 2008. The calculated apparent consumption for the EU-27 in 2008 is 5,300 tonnes. In the electric equipment category (this includes, electric ovens and furnaces of all types), production takes place mainly in Germany, Italy, Portugal, Poland and the Czech Republic. Apparent consumption was 20 600 tonnes. Electric infra-red radiation ovens seem to have a lower volume of production and trade when compared to other categories such as electric or induction industrial furnaces/ovens. Only Italy reports significant production of appliances in this category. Apparent consumption was 723 tonnes.

The following three categories previously identified in the Technical Proposal were excluded of the analysis as they were removed from the Prodcom categories in the 2008 version. Data for these appliances cannot be found in the databases as they are no longer reported under these descriptions:

- Non-electric furnaces and ovens for the incineration of rubbish
- Non-electric industrial tunnel ovens (including biscuit ovens)

- Dryers for the treatment of agricultural products by a process involving a change in temperature.

## **2.2 Market and stock data**

### **DATA REQUIRED FROM STAKEHOLDERS**

#### **2.2.1 Annual sales**

##### **Data from stakeholders**

**Table 22. Current EU stock of furnaces and ovens, current sales estimated future sales**

Type of oven or furnace	Current EU Stock	EU Sales 2008	Estimated EU Sales 2012	Estimated EU Sales 2020
Steel production	>540	0	0	0
Cement and lime kilns	4887			
Glass production	> >800			
Ceramic production	> >2000			
Non-ferrous metal production				
Metals heat treatment				
Laboratory ovens and furnaces	1,500,000 (estimate)	100,000 (estimate)		
Analytical instruments that include ovens or furnaces	170,000 (10 times 2007 sales)	17,000 (2007 sales)	20,000	27,000
Biscuit and bakery ovens				
Medical sterilizers				
Dental furnaces				
Plasma heat treatment furnaces				
Agricultural driers				
Oil refinery furnaces				
Incubators				
Waste to energy incinerators	430	10	8	10
Other incinerators				

**STAKEHOLDERS ARE INVITED TO COMMENT AND PROVIDE INPUT ON THIS TABLE, INCLUDING OTHER TYPES OF OVEN AND FURNACE**

## 2.2.2 Industry financial estimates of EU oven and furnace production and consumption

Data from JIFMA and VDME, 2006 data, US \$millions.

**Table 23. Published data on sales of furnaces and ovens<sup>37</sup>**

EU production	9,500	68% of world production
EU exports	4,400	
EU imports	1,100	
EU consumption (production – exports + imports)	6,200	45% of world consumption
<b>World production and consumption</b>	<b>13,900</b>	

CECOF estimate that in 2005/6, the EU produced furnaces valued at €6 billion and consumed furnaces to the value of €3.8 billion including imports from outside EU.

National EU furnace production by country (top 9) in 2008 (data from CECOF)

**Table 24. Market share of furnaces and ovens in top 9 EU Member States<sup>38</sup>**

Country	Percentage of EU production by value
Germany	35%
France	13%
Italy	12%
Austria	7%
Netherlands	5%
UK	4%
Spain	3%
Sweden	2%
Belgium	1%

<sup>37</sup> Business plan from TC 244, Industrial furnaces and associated thermal processing equipment, [http://www.iso.org/iso/standards\\_development/technical\\_committees/other\\_bodies/iso\\_technical\\_committee.htm?commid=561961](http://www.iso.org/iso/standards_development/technical_committees/other_bodies/iso_technical_committee.htm?commid=561961)

<sup>38</sup> Data from CECOF.

### 2.2.3 Installed ovens and furnaces and average product life

The numbers of ovens and furnaces installed in EU for some industry sectors is published, with useful data included in IPPC BREF (best available technology reference) guidance. Available data is listed below with estimates of typical life and time between refurbishment or rebuild.

**Table 25. Numbers of furnace and oven installations in EU**

Industry sector	Numbers of installations with ovens and furnaces installed EU based on IPPC directive data	Typical life	Source of data
Iron and steel production	47 – sinter plant 106 – coke ovens 81 – blast furnaces 95 – basic oxygen furnaces 203 – AC electric arc and 6 DC electric arc <b>538 – Total</b>	Heat treatment furnaces can be up to 40 years, coke ovens up to 100 years  Up to ~25 years between blast furnace refurbishing Average age of EU-15 plant 21 – 28 years BOF average = 100years EAF and coke ovens average = 67 years Others = 34 years	Communication from Corus and IPPC guidance, BREF (best available technology reference), figures for 1993.  Average lifetimes of BOF, EAF (electric arc furnace), coke oven and others from ref. <sup>39</sup>
Cement and lime production	437 – cement kilns 450 – lime kilns <b>887 – Total</b>	>20 years	IPPC guidance, BREF (best available technology reference), figures for 1995
Glass	175 – installations container glass 58 – float glass furnaces 34 – glass fibre installations >300 – domestic glass installations >100 – special glass installations 64 – mineral wool installations 6 – ceramic fibre installations 50 – glass frit installations <b>&gt;787 – total</b> (some will have more than one furnace)	Varies between ~1 and 20 years depending on process and type of glass. Container glass furnaces are refurbished typically every 12 years and flat glass furnaces ~10 years	IPPC guidance, BREF (best available technology reference), 1997 and draft 2009 guide
Ceramics	>1200 – brick and roof tile installations >55 – refractory installations	>20 years	IPPC guidance, BREF (best available technology)

<sup>39</sup> E. Worrell and G. Biermans, @Move over Stock turnover, retrofit and industrial energy efficiency@, Energy Policy 33 (2005), p949 -962

Industry sector	Numbers of installations with ovens and furnaces installed EU based on IPPC directive data	Typical life	Source of data
	<p>(many more are out of scope of IPPC)</p> <p>5 – clay pipe installations (one has 3 kilns)</p> <p>&gt; 450 – glazed tiles, most in Italy and Spain. More are out of scope of IPPC</p> <p>Large number of tableware and pottery kilns but most out of scope of IPPC</p>		reference), figures for 2003 and IPPC study <sup>40</sup>
Oil refineries	~100 – refineries in EU each of which will have more than one furnace		IPPC guidance, BREF (best available technology reference) , figures for 1999
Incinerators	430 – Waste to energy installations, each with one waste incinerator	35 years (refurbished after 10 – 15 years)	CEWEP and ESWET
Production and processing of metals	5245 – IPPC permits granted in 2008. Many will have more than one furnace and small installations are excluded	>20 years	IPPC data summary <sup>41</sup>
Foundries	575 – IPPC permits granted in 2008. Many will have more than one furnace and small installations are excluded	>20 years	

<sup>40</sup>

[http://circa.europa.eu/Public/irc/env/ippc\\_rev/library?l=/gathering\\_amendments\\_1/final\\_report/ceramics\\_finaldoc/\\_EN\\_1.0\\_&a=d](http://circa.europa.eu/Public/irc/env/ippc_rev/library?l=/gathering_amendments_1/final_report/ceramics_finaldoc/_EN_1.0_&a=d)

<sup>41</sup> [http://eea.eionet.europa.eu/Public/irc/eionet-circle/reporting/library?l=/ippc/ippc\\_permitting/permitting\\_eu27xls/\\_EN\\_1.0\\_&a=d](http://eea.eionet.europa.eu/Public/irc/eionet-circle/reporting/library?l=/ippc/ippc_permitting/permitting_eu27xls/_EN_1.0_&a=d)

### 2.2.4 Energy consumption

Estimates for energy consumption by sector are needed for this study and some estimated data can be calculated from IPPC BREF guidance (and other published sources) as in the table below:

**Table 26. Calculated energy consumption by furnaces and ovens by main industry sectors and type of energy source used**

Industry sector	Estimated annual EU energy consumption (assumes most is energy used by furnaces and ovens) TWh / year	Main energy sources
Iron and steel production	1100 (based on IPPC BREF data)	Predominantly coal with some oil, gas and electricity
Cement production	277 (Calculated using data from WBCSD)	Coal and petroleum coke but also uses wastes, electricity and oil
Glass	64 (using data from IPPC BREF Guide)	Fuel oil and gas
Ceramics	113 (using data from IPPC BREF Guide)	Natural gas
Oil refineries	329 – 1050 (using data from IPPC BREF Guide)	Oil
Incinerators (includes waste to energy plant, medical and hazardous waste incinerators, etc.)		Electricity, diesel and natural gas

Note that waste to energy incinerators generate energy. Data from CEWEP states<sup>42</sup> that total renewable energy produced by EU incinerators in 2006 was 38TWh (electricity and heat) from an estimated 12.5GWh electricity consumed. It is assumed that 50% of the energy generated is from renewable sources and so total energy generated (electricity and heat) was ~76 TWh.

Actual data from industry is required but not yet available.

## 2.3 Market channels and production structures

The market channels for small-scale and large-scale equipment are different. There are also differences between industry sectors.

### 2.3.1 Laboratory and smaller- medium size industrial ovens and furnaces

There are many oven and furnace manufacturers located within the EU as well as manufacturers located outside the EU who supply to the EU market. Sales are made both directly to users and via

<sup>42</sup> Confederation of European Waste to Energy Plants (CEWEP), E. Stengler and J. Manders "Energising waste: how waste-to-energy helps to reach the EU's renewable energy targets"

distributors. Most sales are to business users (B2B) with relatively small numbers sold to consumers (B2C).

According to one of the larger EU manufacturers of small and medium size furnaces, users in general do not make purchasing decisions based on energy efficiency although some will consider the maximum energy output because of constraints to the available ventilation where the equipment is to be located. Some users of even quite large furnaces for example that are used for heat treatment of metals do not consider energy efficiency as a high priority when buying new equipment as their functions are of primary importance. It is fairly common for industrial users and some laboratory users of ovens and furnaces to purchase standard ovens and furnaces that have been modified for their specific needs. Larger ovens and furnaces are more often custom designed for each specific application although these are based on standard materials, techniques and components. Modified and custom designs are supplied by the manufacturer to the user whereas standard laboratory ovens and furnaces are more often supplied via distributors.

One EU manufacturer has reported that about one third each of their laboratory products are sold in EU, one third to the USA and one third to rest of the world whereas the majority of larger industrial products are sold in the EU. Shipping large and heavy equipment can be costly but there may be other reasons why local producers will be selected.

The ovens and furnaces market in the EU includes a large number of manufacturers, most of which are SMEs although some of these are owned by large holding companies (e.g. Thermo Fisher Scientific with 30,000 employees worldwide). In general, each manufacturer produces a specific range of ovens and or furnaces. Frequently, a manufacturer will specialise in one or a few specific market segment such as laboratory equipment, metal heat treatment, PCB manufacture, food, etc. A selection of the larger manufacturers and their main markets are listed below.

**Table 27. Furnace and oven manufacturers**

Name of manufacturer	Location	Main target markets
Carbolite	UK	Laboratory and industrial furnaces
Ipsen	Germany	Vacuum furnaces (heat treatment)
LOI	Italy / Germany	
Memmert	Germany	Laboratory ovens
Nabertherm	Germany	Laboratory and small to medium size industrial ovens and furnaces
Sanyo	Japan	Incubators, ovens and sterilisers mainly for the medical sector
Thermo Scientific	Global, US owned	Laboratory ovens, furnaces, incubators, sterilisers

Market segmentation (B2B vs B2C, direct or through distributors, use of installers, etc) – data needed from stakeholders

### 2.3.2 Larger-scale furnaces and ovens

Most larger-scale furnaces and ovens are designed and constructed by specialist manufacturers. Many of these manufacturers will build furnaces and ovens for many of the industry sectors described in this report although some specialise in certain types such as metal melting furnaces, ceramic kilns, bakery and biscuit ovens, etc. Some manufacturers specialise in specific technologies such as:

- Induction heating – metal melting and heat treatment processes
- Plasma heating – a wide variety of applications
- Infrared heating – used in ovens for drying, baking (food) and curing coatings

Some manufacturers of larger-scale furnaces and ovens use distributors but those that build the largest sell directly to users.

Some new furnaces are designed by specialists but installed by other organisations including sometimes the end-user.

Some large-scale furnaces and ovens are designed, installed and constructed for own use by the user and this is common with petrochemical furnaces and also occurs with glass melting furnaces.

### 2.3.3 Iron and steel manufacture

There are very few steel plant in EU, with a few specialist manufacturers of furnaces that supply markets world-wide.

**Table 28. Main manufacturers of furnaces and ovens used for steel production**

Name of manufacturer	Location	Product range
Danieli Corus	Netherlands and UK	Coke ovens, blast furnaces, basic oxygen furnaces and electric arc furnaces
Paul Wurth	Luxembourg	Coke ovens, blast furnaces, basic oxygen furnaces and direct reduction furnaces
Siemens VAI	Austria	Coke ovens, blast furnaces, basic oxygen furnaces and electric arc furnaces
SMS	Germany	Electric arc furnaces and converters

**Information from stakeholders on other industry sectors is required.**

## 2.4 User expenditure base data

Basic user data are compiled in this section. This includes EU expenditure on machinery as well as operating costs, in particular energy costs and end-of-life costs.

Based on the categories defined in subtask 1.1, average prices including VAT, applicable rates for running costs (e.g. electricity and fossil fuels, repair and maintenance, disposal) and other financial parameters (e.g. taxes, interest and inflation rates) have been determined.

The total lifetime costs of an industrial or laboratory furnace or oven can be divided into five relevant categories:

- Purchase costs – the cost incurred to purchase the furnace or oven
- Operating costs – the costs incurred to operate the furnace or oven throughout a typical lifetime. They may include electricity and fossil fuel costs, and costs of consumables (water, etc.)
- Installation costs – the costs required to install a furnace or oven
- Maintenance costs – the costs incurred by the owner of the furnace or oven throughout the lifetime of the machine to ensure its proper and effective operation
- Disposal costs – the quantifiable costs borne by the owner of the machine at the end of life

Some furnaces require cooling and some very large designs use large amounts of water. Waste heat may be used, for example for heating buildings, but this is relatively uncommon and requires additional expenditure though long-term savings would be achieved. Other economic parameters such as energy rates, interest and inflation rates have been collected at EU level based on Eurostat.

The data that will be identified for the products defined in subtask 1.1 are:

- Average prices, including VAT, in euros;
- Fossil fuel rates (€/GJ);
- Installation costs, in euros;
- Costs per unit produced, in euros (if applicable);
- User prices of other consumables (€/kg or €/piece);
- Repair and maintenance costs (€/product life);
- Disposal tariffs/taxes (€/product).

The Commission provided the following rates by EU Member State and for EU 27:

- Electricity rates (€/kWh);
- Interest and inflation rates (%).

These data will serve primarily as cost inputs when conducting life-cycle analysis later in the study.

## 2.4.1 Purchase costs

### Furnace and oven prices

All users consider price as a high priority, usually second only to the functions available. Minimising price can influence whether eco-design options are included. Prices of furnaces sold in EU range from about €500 for a standard laboratory oven to over €1.1 billion for a blast furnace installation<sup>43</sup> with a capacity of 3.5 million tonne per year. Newer direct reduction furnace installations with a smaller capacity of 1.36 million tonnes per year cost much less at €210 million (there is only one plant of this type in EU). Industrial furnace installations can be very costly not only for the furnace itself but also for equipment to prevent emissions of hazardous substances, energy recovery, etc. For example:

**Table 29. Selected illustrative examples of price, throughput or capacity of ovens and furnaces**

Oven / furnace	Capacity	Installation cost*
Steel blast furnace	3.5 million tonnes / year	€1.1 billion
Steel direct reduction furnace	1.36 million tonnes per year	€210 million
Average EU cement kiln	586,000 tonnes / year <sup>44</sup>	~€120 million (equivalent to three years turnover)
Float glass installation (includes several furnaces)	Up to ~700 tonnes per day = 250,000 tonnes / year	€100 – 150 million
Isa-smelt furnace for primary lead production	6500 tonnes per year	€70 million
Float glass melting furnace	180,000 tonnes per year	€10 million
Soda lime domestic glass furnace, gas fired	47,000 tonnes per year	€12 million (refurbishment of existing furnace = €4 million)
Secondary aluminium melting furnace	-	€2.7 million
Induction furnace for steel foundry	24,000 tonnes per year	€3.5 million
Oven with conveyer (RDM Engineering model jup3201 from 2007 price list)	Interior volume is 99,000 litres	£47,000 (gas heated version)
Despatch Industries small conveyer oven (PCC2-15-1E)	3 meter conveyer in oven 354 litres internal volume maximum throughput = 3 kg/minutes	
Large batch oven (RDM Engineering, 2007 price list)	90,000 litres internal volume	£31,000 electrically heated

<sup>43</sup> Draft IPPC BFREF steel processes 2009

<sup>44</sup> Based on 256 million tonnes cement produced in 437 EU installations.

Oven / furnace	Capacity	Installation cost*
		£28,000 gas heated
High temperature laboratory furnace (Carbolite HTF 18/8/3216P1)	8 litre internal volume, 1800°C maximum	£13,923 (price from <a href="http://www.fisher.co.uk">www.fisher.co.uk</a> )
Small laboratory muffle furnace (Carbolite CWF 11/5/301)	4 litre internal volume, 1100°C maximum	£1637 (price from <a href="http://www.fisher.co.uk">www.fisher.co.uk</a> )
Small laboratory convection oven (Memmert UFB 400)	53 litre internal volume	£971 (price from <a href="http://www.fisher.co.uk">www.fisher.co.uk</a> )

\* Data from IPPC BREF guidance, from manufacturers, manufacturers' websites or [www.fisher.co.uk](http://www.fisher.co.uk)

### Purchase criteria of users

Manufacturers of smaller laboratory ovens and furnaces report that their customers' main criteria are the functions of the equipment. Manufacturers of larger industrial ovens and furnaces claim that the most important purchase criteria is suitability for one specific process and some report that product price and energy efficiency are equally important to most customers although some manufacturers report that purchase price is more important than energy efficiency. The price is directly related to the oven or furnaces design and functions but the total life-cost of ownership includes the cost of energy in use and any maintenance and repair costs. Additional features that ensure high reliability will add to the price but this might be far less than the cost of unexpected down-time should failures occur. Limitations on the availability of capital for investment is reported by many stakeholders to limit the purchase of energy efficient features with new furnaces and ovens.

For small laboratory ovens and furnaces, energy costs are usually unknown and not considered and so the lowest price available for equipment having the required functions is selected. Users of very large furnaces such as blast furnaces will provide detailed specifications to potential suppliers and will base their choice of supplier on various factors including price but energy efficiency is also very important as this affects lifetime costs. Purchase decisions for medium size furnaces are made based on price and energy consumption in use but suitability for use is most important.

### Data for this study

In the context of this study, average furnace or oven prices are of interest as they are required as an input for the LCC calculations that will be performed in Task 5.<sup>45</sup>

Prices within a furnace or oven category can vary widely.

Average prices for the furnaces and ovens within the classification are shown in the table below. The figures were obtained from manufacturers and other stakeholders. An average value for furnaces and ovens of similar capacities will be calculated.

<sup>45</sup> LCC consists of two main components: the initial cost of purchasing and installing the furnace or oven and discounted annual operating costs.

**More data is needed from stakeholders who are welcome to comment on the figures given below.**

**Table 30. European average energy consumption and price by furnace and oven category**

Common name or application	Heat source	Operating principle	Operating temperature range	Typical capacity range	Price range (€)	Range of energy consumption	Average energy consumption	Average price (€)
Laboratory furnaces	Electric - Resistance	Batch	800 - 1 800	3-120 l	1,500 – 13,000	0.5 – 60 KWh		
Laboratory ovens	Electric - Resistance	Batch	200 - 650	6 – 750 l	500 – 4,800	0.25 – 10 KWh		
Sterilizer ovens	Electric - Resistance	Batch	80 - 250	14 – 749 l	680 – 5,600	0.25 – 5 KWh		
Metal melting furnaces	Electric, gas	Batch						
	Gas	Batch, continuous						800,000*
Metal heat treatment furnaces	Electric, gas	Batch	200 - 900					
	gas	Batch, continuous	200 - 900					2,000,000*
Waste incinerators	Waste to energy	Continuous	1000					
	Gas / oil	Batch	1000					160,000*
Induction furnace	Electric	Batch						5,500*
Electric arc furnace	Electric	Batch	1000 - 1600					
Tunnel kiln / furnace	Electric, gas	Continuous	150 - 1200					
Bakery / biscuit ovens	Electric, gas	Continuous	150 - 350					
Smelting furnace	Electric, gas, coal	Batch, continuous	800 - 1800					400,000*
Batch furnace for ceramics	Electric, gas	Batch	600 - 1600					20,000*
Glass melting furnace	Electric, gas	Batch	600 - 1200					
	Gas	Continuous	600 - 1200	250 – 900 t/day		Up to 360 GWh/y		€10 million
Glass annealing furnace (Lehr)	Gas	Batch, continuous	100 - 800	- 900 t/day	To €10M	Up to 1 GWh/y		
Infrared ovens	Electric	Batch, continuous						14,000*
Hydrocarbon cracker	Gas, oil	Continuous	300 - 600					

Common name or application	Heat source	Operating principle	Operating temperature range	Typical capacity range	Price range (€)	Range of energy consumption	Average energy consumption	Average price (€)
Cement kiln	Oil, gas, wastes	Continuous	1400 - 1600					
Lime kiln			~1000					
Others ...								

\* Note that these figures are UK PRODCOM averages and do not reflect EU average prices. EU average prices will be needed for future calculations and for the final version of this report.

Note that Table 30 has an incomplete list of furnace types / sectors. This table will be revised and amended when more complete data is available and will be intended to reflect the main furnace types described in task 1.

**STAKEHOLDERS ARE INVITED TO COMMENT AND PROVIDE INPUT ON THIS TABLE, INCLUDING OTHER TYPES OF OVEN AND FURNACE**

These prices will be used later in the study in Task 5 during the life cycle assessment, to help determine the LCCs of these products in the base case analysis.

The relationship between the capacities of the furnaces and ovens and their prices is expected to be directly proportional. The reference prices were found all over Europe. The difference between countries can reach up to 50%.

## 2.4.2 Operating costs

Operating costs, understood as costs generated by the use of the furnace or oven, can be split into:

- Energy costs (separate costs for electricity and fossil fuels)
- Consumable costs (water, etc.)
- Maintenance costs could also be considered in this category; however they have been neglected because they are not expected to be significant for this product type.

Energy costs are the most significant running cost of furnaces and ovens. Fossil fuels are used for combustion while electricity is used for fans and other components. The EU average electricity and fossil fuel prices for industry according to the different consumption classes will be used in LCC calculations at a later stage of the study (Task 5 and Task 7). Member State data is given in the Appendix to this report.

### *Electricity rate*

The evolution of electricity rates between 2008 and 2009 as reported by Eurostat, are presented in Table 31 and Table 32.

**Table 31. The evolution of electricity rates between mid-2007 and mid-2009 for customers (500-2000 MWh) in EU-27<sup>46</sup> (all taxes included)**

Rate [€/kWh]			
2008S1	2008S2	2009S1	2009S2
0.1194	0.1253	0.1305	0.1253

<sup>46</sup> Eurostat (2010), "Electricity - industrial consumers - half-yearly prices - New methodology from 2007 onwards".

**Table 32. Electricity rates in the first semester of 2009 according to taxes breakdown in EU-27<sup>47</sup> for average industrial consumers (500 – 2000MWh)**

Rate [€/kWh]		
Without taxes	Without VAT	All taxes included
0.0913	0.1026	0.1253

For this study, preliminary estimates show that a typical industrial facility operating ovens within the intended scope are expected to consume electricity in the IC electrical consumption band (500MWh – 2000MWh). Therefore, for this study the cost of electricity, including all taxes, will be the 2009 prices, without taxes **9.13 EUR/100kWh**

*Natural gas rates*

Natural gas rates have to be taken into account for furnaces and ovens which use natural gas fuel for heating. The evolution of natural gas rates between 2007 and 2009 as well as rates that vary depending on the customers' consumption as reported by Eurostat are presented in Table 33 and Table 34.

**Table 33. Natural gas rates (including taxes) for consumers in the consumption band IC (1000-10000 GJ), between 2008 and 2009 in EU-27<sup>48</sup> (taxes included)**

Rate [€/GJ]			
2008S1	2008S2	2009S1	2009S2
11.0670	12.8311	11.7462	9.6012

For industrial applications, the higher category consumption band IC is estimated to be most appropriate at a preliminary stage will therefore be used in the context of this study.

**Table 34. Natural gas tax rates for consumers in the range 1000-10000 GJ, between 2008 and 2009 in EU-27<sup>49</sup>**

Rate [€/GJ]		
Without taxes	Without VAT	All taxes included
7.5557	8.2166	9.6012

The cost used in this study will be the rate without taxes found in 2009, giving a **natural gas cost of 7.56 €/GJ**.

<sup>47</sup> Eurostat, <http://nui.epp.eurostat.ec.europa.eu/nui/submitViewTableAction.do>

<sup>48</sup> Eurostat (2009), "Environment and Energy, Data in focus, 49/2009".

<sup>49</sup> Eurostat (2009), "Environment and Energy, Data in focus, 49/2009".

### Coal Prices

Coal rates have to be taken into account for furnaces and ovens which use coal fuel for heating. The product types that are particularly relevant to coal as a fuel include steel manufacturing furnaces and coking furnaces where the high carbon content of coal is an advantage to the treatment of the steel.

It is acknowledged that there is a very wide and diverse range of coal products available on the market which vary based on chemical composition, source and applicability. The prices here are a simplification of average coal prices in Europe. This table presents a typical price for a commonly used coal type in the relevant Member States.

**Table 35. Average EU Coal price without VAT based on 18 Member States, in June 2005<sup>50</sup>**

State	Coal price (€/GJ)
EU average	8.05

### Oil Prices

Oil rates have to be taken into account for furnaces and ovens which use oil fuel for heating. It is acknowledged that there is a very wide and diverse range of oil products available on the market and that the prices here are a simplification of average oil prices in Europe for use in industrial ovens. Typically industrial fuel oil prices differ from those for residential oil heating or for the transportation sector (both automotive diesel oils and marine 'bunker' oils), however the definition and distinction between different types of fuel oils can be obscure, especially on an international level. There tends to be less difference in fuel oil prices between member states also when compared to coal for example.

This table presents a typical price for a commonly used oil type in the relevant Member States, estimated to be approximately equivalent to Fuel Oil #2, or distillate fuel oil.

**Table 36. Fuel prices without VAT from 2006 to 2009 based on weekly spot price history of distillate heating oil excluding taxes (in €/GJ)<sup>51</sup>**

Member State	2006	2007	2008	2009
Belgium	10.54	11.74	17.19	10.20
France	11.37	12.36	17.95	11.02
Germany	11.07	11.68	17.25	10.65

<sup>50</sup> E. Alakangas et al. (2007) Biomass fuel trade in Europe, Summary Report. Eubionet II.

<sup>51</sup> US Department of Energy, International Energy Price Information Page, <http://www.eia.doe.gov/emeu/international/prices.html#Distillate>

Assumptions for conversion include:

- 1.00 USD = 0.751 EUR as per April 26<sup>th</sup> 2010
- 1.00 US gal = 3.785 L
- Rotterdam distillate heating oil, NCV = 40.4MJ/kg (estimate)

Member State	2006	2007	2008	2009
Italy	12.34	13.43	18.93	12.04
Netherlands	12.54	13.81	16.53	8.16
UK	10.56	11.06	16.06	9.27
<b>Average</b>	11.40	12.35	17.32	10.22

The price of distillate heating oil has been highly volatile over the years and is directly correlated with the price of crude oil. As the supply of distillate heating oil is less common for furnace applications in Europe it is much more difficult to determine average prices for each country. It is expected that prices are generally negotiated directly between delivery / supply companies and the furnace owners, and that these supply contracts are generally confidential based on the spot price plus a premium.

For the purposes of this study, a linear extrapolation over the previous prices found, gives an oil price equivalent without taxes to **13.74 €/GJ**.

To summarise, the following energy rates in Table 37 will be used:

**Table 37. Summary of the rates used for energy in this study**

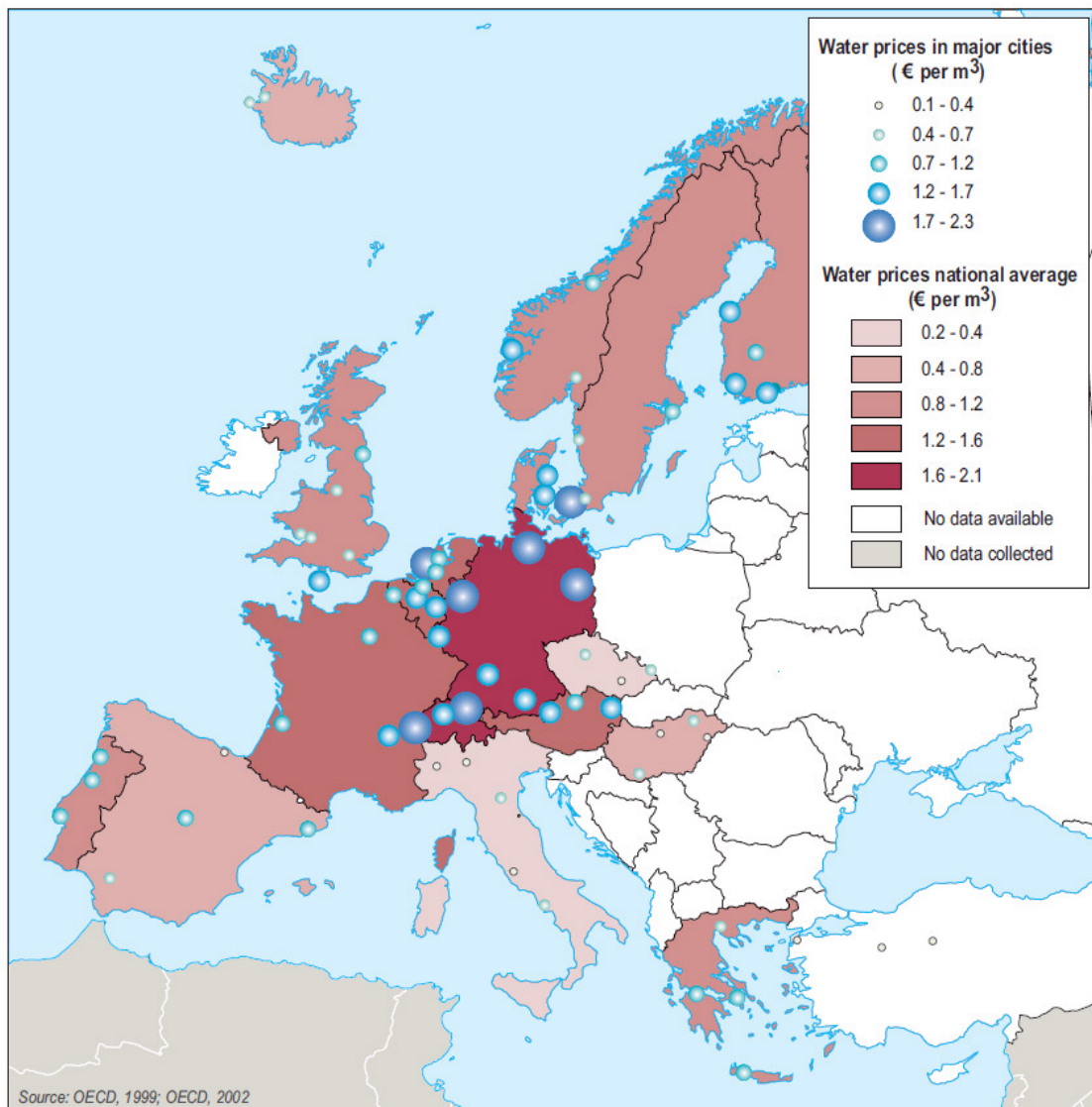
Category	Rate	Unit
<b>Electricity</b> - Industrial use IC Band	9.13	(€/100 kWh)
<b>Gas</b> - Industrial use IC Band	7.56	(€/GJ)
<b>Coal</b> - European average	8.05	(€/GJ)
<b>Oil</b> - Distillate #2 Fuel Oil equivalent	13.74	(€/GJ)

### **Consumables (water, etc.)**

The costs of consumables will be discussed in this section.

#### **Water – used in large quantities for cooling**

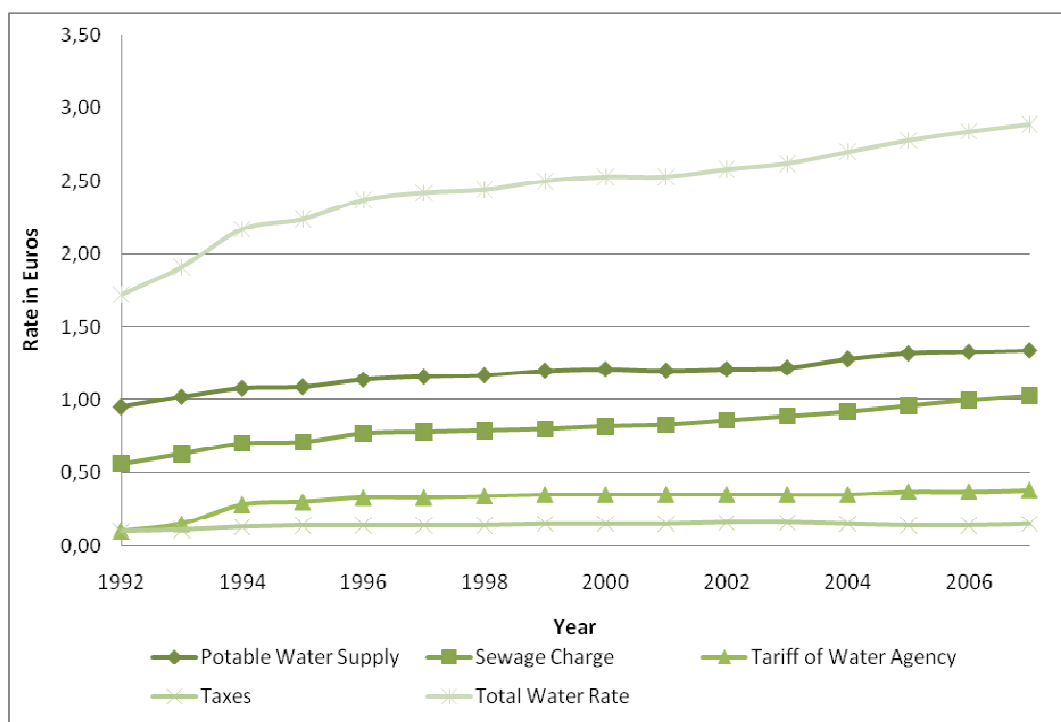
The cost of water to consumers can be difficult to evaluate as it is often based on a variable rate which corresponds to consumption. Figure 3 shows the estimated water prices for major city centres and estimates for national averages for countries in Europe, from a study completed by the OECD in 2003. City data is for 1998 and national data is for 1996.



**Figure 3. Water prices in Europe<sup>52</sup>**

A more recent indication of water prices in France is shown in Figure 4, where a breakdown in the cost of water to consumers is given over 15 years.

<sup>52</sup> OECD 2003 – Water Indicators



**Figure 4. Water cost break down in Rhone region of France for 15 years**

A final water tariff to the consumer can be observed at 2.90 €/m<sup>3</sup> with an average increase of 0.064 €/m<sup>3</sup> per year, suggesting a current water tariff in this region of France of 3.08 €/m<sup>3</sup>.

The preparatory study for Lot 14 (domestic dishwashers and washing machines) proposed a water rate of 3.70 €/m<sup>3</sup> for domestic water use in 2008 across Europe.

BIPE analysed the water rate for eight major European cities in 2006. The relevant information is presented in Table 38.

**Table 38. Water consumption and effective rate for eight European cities<sup>53</sup>**

City	Water Consumption (m <sup>3</sup> /capita/y)	Average persons per household	Average water bill per household (€)	Effective water rate (€/m <sup>3</sup> )
Amsterdam	57	2.3	506	3.86
Athens	61	2.7	171	1.04
Berlin	43	1.8	360	4.65
London	54	2.4	312	2.41
Madrid	61	2.9	207	1.17
Paris	52	1.9	229	2.32
Rome	104	2.6	229	0.85
Stockholm	77	2	302.5	1.96

Based on the population of the above cities, the weighted average water rate for the eight cities cited by BIPE is 2.38 €/m<sup>3</sup>.

Based on the above sources, a water rate extrapolated from the weighted average of the eight largest cities in the EU to the year 2010 based on the evolution of water price experienced in France over 15 years gives a water price of 2.64 €/m<sup>3</sup> for the EU-27.

This figure will be used to estimate the LCCs of furnaces in Task 4 of this study and may impact the LCCs of these appliances when considered on the scale of the entire European market.

From 2010, the Water Framework Directive<sup>54</sup> requires Member States to improve their water management strategy through setting pricing and policy incentives to preserve the natural water systems of Member States. It can be expected that in years to come, the price of water will become an increasingly large concern for furnace and oven manufacturers and likewise, furnace and oven users, as Member States gradually increase the cost of water to reflect environmental and resource use costs more adequately, as defined in the Directive.

#### *Interest and inflation rates*

The table below lists the interest rate in each Member State as well as the overall EU-27 rate as published by Eurostat and the European Central Bank. This study assumes an interest rate of 4.5%.

<sup>53</sup> Consumption, persons per household and average water bill per household taken from: BIPE, Analysis of Drinking Water and Wastewater Services in Eight European Capitals : the Sustainable Development Perspective, 2006.

<sup>54</sup> Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Available at: [http://europa.eu/legislation\\_summaries/agriculture/environment/l28002b\\_en.htm](http://europa.eu/legislation_summaries/agriculture/environment/l28002b_en.htm) accessed February 1 2010.

**Table 39. EU-27 interest rates<sup>55</sup>**

State	2006	2007	2008
EU 27	4.08%	4.57%	4.55%

Annual inflation rates are shown in the Table below. This study assumes an inflation rate of 3%.

**Table 40. EU-27 annual inflation rates (%)<sup>56</sup>**

State	2006	2007	2008
EU 27	2.30	2.40	3.70

### Summary

The table below summarises the consumer expenditure data presented in the previous sections. This data will be useful in later tasks (Task 5) for estimating life cycle properties of these products.

**Table 41. User expenditure base data**

Category	Cost items	Units	Value for Lot 4 study
Use	Water rates	€/m <sup>3</sup>	2.64
Use	Electricity	(€/100 kWh)	9.13
Use	Gas	(€/GJ)	7.56
Use	Coal	(€/GJ)	8.05
Use	Oil	(€/GJ)	13.74
Use	Interest-inflation rate	%	1.6

**Stakeholders are welcome to comment on these figures.**

<sup>55</sup> Eurostat, Interest Rates, Long-term interest rates, Maastricht criterion interest rates, EMU convergence criterion series - Annual data, accessed 26 November 2009.

<sup>56</sup> Eurostat, Prices, Harmonised indices of consumer prices (HICP), HICP (2005=100) - Annual Data (average index and rate of change), accessed 27 November 2009.

### 3. Task 3 – User requirements

This task investigates the technical requirements of users of furnaces and ovens. There are many different applications for furnaces and ovens and users' requirements in each sector will be different and this is discussed here. Oven / furnace price is always a consideration for users but is not considered here in task 3; it will be considered in task 7. Adopting improved eco-design may have implications on price which is important because many users will have a choice of investing in new equipment in either the EU or elsewhere. Installing cheaper and less energy efficient furnaces outside the EU would be harmful to the EU not only in lost jobs but also as global CO2 emissions would not be reduced.

#### 3.1 User information

There are a wide variety of users of ovens and furnaces all of which have different requirements. These include:

- Analytical and research laboratories – will use smaller ovens and furnaces, some designed for specific analytical procedures. Medical research facilities will use incubators and sterilisers
- Schools, colleges and other education establishments – Small ovens and furnaces are used for teaching science subjects, metal working and jewellery and pottery fabrication
- Domestic environments – small furnaces are used by craft-workers and artists to make jewellery and pottery, either as a hobby or for sale
- Test houses – establishments that carry out standard tests to equipment or materials may use small and medium size ovens, furnaces and environmental chambers.
- Hospitals and doctors practices – use sterilisers and incubators
- Dental facilities – sterilisers and dental furnaces
- Semiconductor manufacture – require purpose designed clean room furnaces
- Electronics manufacture – solder reflow ovens and PCB dryers. Wave soldering equipment includes a bath of liquid solder so could be classified as an oven
- Food manufacture – biscuit and bakery ovens
- Drying materials – range from small laboratory ovens, vacuum ovens, large industrial ovens and agricultural dryers
- Ceramic manufacture – medium and large furnaces of various designs for bricks, tiles, pottery, industrial ceramics, etc.

- Glass manufacture – window glass, containers (e.g. bottles), glass fibre, domestic products, etc.
- Metal parts fabrication – metal melting furnaces and heat treatment furnaces
- Curing materials (paints, adhesives) – Various size ovens including large infrared heated conveyor ovens for curing paint coatings of cars
- Brazing metals – vacuum and inert gas atmosphere furnaces
- Steel manufacture – blast furnace, basic oxygen furnace and arc furnace
- Cement and lime manufacture – cement and lime kilns
- Waste disposal – incinerators for organic wastes (animals, medical, municipal, sewage sludge, etc.), plasma furnaces are used for inorganic wastes
- Non-ferrous metals – furnaces for production of metals from ores and waste materials, purification and alloy production
- Oil refineries – include many thermal processes using some equipment referred to as furnaces. These are purpose designed for oil refinery applications.

The above list includes examples of users of ovens and furnaces but there are many more. For example, some types of nanomaterials are produced with purpose designed furnaces.

### 3.1.1 Information on products

Product information required by and supplied to users varies considerably and tends to be different for smaller off-the-shelf models than for larger custom designs.

#### Smaller products

Marketing information for smaller laboratory ovens and furnaces describes primarily the functions of the equipment. Standard information that is usually provided includes:

- Maximum operating temperature
- Dimensions – internal and external
- Power rating – this is not the same as energy consumption and is defines the power supply that is needed to operate the equipment.

Products are supplied with operating instructions but these will not describe how to use the equipment in an energy efficient manor.

## Large furnaces and ovens

Marketing information for larger furnaces and ovens provides similar function information but many manufacturers also claim energy efficient features or lower energy consumption. Some provide technical papers that explain the energy efficient design features that are utilised. Users who are large energy consumers will be aware that energy efficiency is important and so will look for data on energy consumption when deciding on the purchase of oven and furnace equipment. The choice will however be based on overall cost, not necessarily a desire to reduce emissions. If the additional cost of inclusion of energy efficiency design features are perceived to be greater than the future saving in energy costs plus any carbon trading costs (if these are applicable), they are unlikely to include these in their new plant design.

When selecting new custom-designed large furnaces, users either design their own or ask the furnace manufacturer. Designs often use however standard components and materials such as burners, valves, insulation, etc. for which the manufacturers of these parts will provide appropriate data that is required to design a new furnace.

### 3.2 User requirements in the use phase

Requirements of users of ovens and furnaces vary considerably depending on the specific application. Use patterns will be needed for base-case assessments and this information is being sought from stakeholders.

Variables that are important to the way that furnaces and ovens are used include:

#### Continuous or intermittent use

Some types of furnace such as blast furnaces, cement kilns, waste to energy incinerators, etc. are used continuously for many years whereas many others are operated batch-wise. Ovens and furnaces with conveyers can be operated continuously but many are used for only part of each day, typically 8 – 10 hours for one shift during each working day. Users of large furnaces have high energy costs and so are conscious of energy consumption and try to minimise their energy costs and so ensure that furnaces are switched off when not in use although continuous processes operating 24 hours / day and 365 days / year will usually be more energy efficient than batch processes which lose energy when they cool down.. Users of smaller ovens in particular but also furnaces are less concerned by energy costs and so may leave ovens switched on continuously even though they may be required intermittently. Automatic power management to switch equipment into a standby mode is not a standard feature.

Continuous processes can be more energy efficient as this avoids the need to heat up the oven or furnace to its operating temperature before it can be used and energy is not lost when the process is complete and the furnace cools down. For example, if a furnace is used for batch heating, the furnace needs to be heated up to its operating temperature and this consumes a certain amount of energy. Some will be lost from the exterior of the furnace when the furnace is being used but all of it is lost after the furnace is switched off at the completion of the process. Continuous production is not

always feasible however as there may not be sufficient material or parts for a continuous process. Also, the salaries for three shifts may affect economics of the operation.

In practice, the choice between continuous or batch processing is made on the basis of many variables which include:

- Scale and energy efficiency – this is usually the most important. Very large scale processes such as cement and steel manufacture are more economical and energy efficient on a large scale with a continuous process. Aluminium scrap melting is more economical and more energy efficient in a large continuous tower furnace than by smaller-scale batch processes but SMEs will usually not have the resources, throughput requirements or space for this type of furnace.
- Process requirements – some processes can be carried out only with continuous process. This is often to ensure that high product quality is achieved. This is the main reason that surface mount printed circuit boards are soldered in conveyerised tunnel ovens. Some processes such as cement and steel production could in principal be carried in batches but this never occurs as the energy consumption would be far greater. Some processes are better carried out in batches such as heat treatment of metals especially where long heat treatment times are required. Metal parts need to be heated at a specific temperature for many hours and then rapidly quenched and this would require unreasonably long tunnel ovens for a continuous process. Some alloys are heat treated in vacuum or inert gas atmospheres to prevent oxidation. This is much easier to achieve in a batch process as the chamber can be sealed unlike with a tunnel furnace which must have openings at both ends.
- Space availability – continuous processes tend to require much larger spaces and so small-scale operators have to use batch processes

## Safety

All equipment must be safe to use and this includes avoiding risk of harm from hot external surfaces. The methods used to prevent external surfaces from becoming dangerously hot include:

- Thermal insulation around the chamber. This not only protects workers but also conserves energy by reducing losses to the surrounding environment. This is the preferred option. The performance of thermal insulation varies and is considered in task 5.
- Guards around accessible hot surfaces. These are used where surfaces become unacceptably hot despite using insulation. This is applicable where furnaces operate for very long periods at high temperatures and at locations where it is not possible to use sufficient insulation.
- Water cooling of external surfaces. This is used with vacuum furnaces and some other types. The parts inside vacuum furnaces are heated by radiation as conduction and convection are ineffective in a vacuum. However, heat losses from the heated parts is minimal as a vacuum does not allow conduction or convection heat losses. Thermal insulation is not always used between the radiant heaters and the outer walls so that the external walls are also heated by radiant energy and so need to be cooled. Some types of very high temperature furnace such

as electric arc furnaces need water cooling to cool heat-sensitive parts that cannot be protected by insulation.

- Tube furnaces are insulated around the tube but it is not always possible at the ends. When very hot, intense infra-red radiation is emitted from the ends of the tube which needs to be blocked, usually using a ceramic barrier.

### Temperature control accuracy

The temperature control performance can significantly affect energy consumption and so is important with most furnaces. Smaller laboratory ovens and furnaces usually have fairly accurate temperature control as standard with accuracy of  $\pm 5^\circ$  or better. This is often needed for research and development. Metals heat treatment furnaces also need accurate temperature control as the required physical properties are achieved only by heating at specific temperature for a precise period of time. Rapid cooling is also often required. The use of electronic temperature control of larger furnaces and ovens usually has a payback time of much less than 1 year due to energy savings. Electronic controllers are also used to regulate gas and oil burners for maximum efficiency which minimises fuel consumption.

### Ventilation

Ventilation may be required for several reasons. Where fuels such as coal, oil and gas are burned the combustion products need to be removed. In some processes such as metals smelting, cement production and waste incineration, hazardous substances are produced as gases and as dust and so air flow through the furnace is needed to carry these substances to the scrubbers which collect these substances for safe disposal.

Ovens are often used to dry parts or materials in which case air is needed to flow through the chamber to carry water or solvent vapour away. Curing some types of coatings produces organic substance by-products which need to be removed. Drying materials can also be carried out in a vacuum oven which avoids the need for ventilation but there is additional energy consumption by the vacuum pump and heat transfer to the material can be slow as convection will not occur.

Drying ovens are designed to exchange the internal air in a controlled way to remove water or solvent vapour. All of the air entering the oven must be heated to the operating temperature and so this should be with a minimum number of air changes per hour to minimise energy losses from this heated air. From a review of technical data-sheets for laboratory ovens available in EU, it is apparent that the number of air changes varies considerably. Typical examples are:

**Table 42. Examples of laboratory oven ventilation data**

Oven brand and model	Internal volume	Air changes per hour
Thermo Scientific Blue M Deluxe with forced air convection	71 litres	61 times

Oven brand and model	Internal volume	Air changes per hour
Thermo Heraeus hot air steriliser	Version without fan 57 litres	8 times
	Version with fan 64 litres	50 times
Carbolite oven with internal fan AX 30	28	65 times
	AX60	28 times
AX120	128	14 times
Carbolite PF 30	28	Internal fan only 50 times Also with external exhaust fan 360 times per hour
Carbolite PF800	910	15 times

In general there are fewer air changes per hour with large ovens than with small ovens but there is considerable variation even within the range of one manufacturer. A large number of air changes per hour has the advantage of faster drying but energy costs would be higher. The use of an internal fan gives better temperature control within the oven but it also appears to increase the frequency of air changes. Some electric ovens have vents (manually operated) that can be closed if no drying is required and this clearly reduces running costs. Users need to consider all of these variables and their own specific requirements when selecting the most appropriate oven.

### Maximum temperature

Users select ovens and furnaces on the basis of the maximum temperature they require. In general, the higher the temperature, the higher the purchase price and running costs although other features also affect these variables. Materials cost is related to temperature as different more expensive materials are required for insulation, heating elements and support structure where higher temperatures are required. In general, high temperature ovens and furnaces are less able to control low temperatures and so many laboratories will have a selection of types of oven and furnace to provide different temperature capability.

### Size of oven or furnace

The size of a specific type of oven or furnace will be roughly proportional to its price and so there is an incentive to buy equipment that is as small as possible for the user's needs. Limited available space may also be an issue so that large ovens or furnaces cannot be used by some SMEs. Some manufacturers in EU are aware of the IPPC directive and do not want to be included in its scope and so select equipment that does not require IPPC permits. This will be smaller-scale furnaces which are not always the most energy efficient.

## Climate and building heating implications

The climate at the location where an oven or furnace is installed is not usually important although there may be an impact with laboratory products. The use of laboratory ovens and furnaces in buildings in cold climates can reduce or increase the need for building heating and in hot climates they may increase the need for air-conditioning. Where oven or furnace heat is emitted into the building, this heat reduces building heating costs but if there are hazardous emissions that need to be ventilated outside of the building, the extracted air will need to be replaced and in cool climates heated, resulting in higher heating costs.

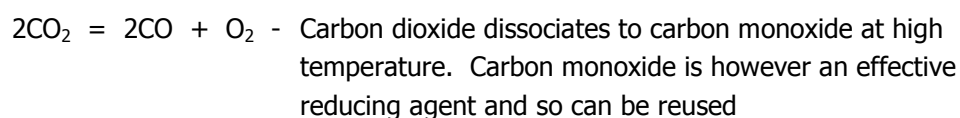
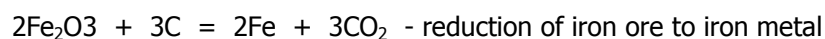
Ovens can control temperature as long the set temperature is at least 10°C above ambient. Low temperature ovens may therefore need cooling to maintain temperature accurately in hotter climates.

## Energy source

Many different energy sources are used with ovens and furnaces and the optimum choice often depends on many variables.

Energy cost – cost of heating will be affected by the source of energy with electricity in general being more expensive / KWh than gas and coal.

- Gas may be used instead of electricity to minimise the electric load where electricity prices increase with higher load levels. The use of gas also avoids the need for power transmission equipment which can be costly to install. Connection to natural gas supply networks is not available to all commercial locations. Pressurised propane and butane or other hydrocarbon fuels are an option but may be more expensive than natural gas.
- Coal can be a relatively low cost fuel and so is used in the largest energy consumers such as cement kilns. Powdered coal has recently been introduced as a more energy efficient fuel in blast furnaces. However coal or coke may be required for processes where chemical reduction of oxides to metals is required. Coal and coke are fairly pure forms of carbon which reacts with oxides of iron, copper, lead and several other metals to convert these to the metals and carbon dioxide (or monoxide at high temperature). Coke is mixed with the other feed stocks (iron ore and limestone to produce "sinter") in blast furnaces and coal is also used in energy efficient designs as a combustion fuel.



Coal or coke are also used in some non-ferrous metal smelting processes.

- Waste materials can be used in some processes as low cost energy sources and to reduce the use of fossil fuels. Incinerators are designed to burn wastes and to recover the energy as heat or electricity. Cement kilns use about 10% of waste materials which include waste oil, biomass, etc.

and so some of these are renewable energy sources. The disadvantage of waste materials as fuels is that they often contain substances that can be converted into toxic and carcinogenic by-products when they burn. These can include chlorobenzodioxins from chlorinated polymers such as PVC and polycyclic aromatic hydrocarbons from halogen-free polymers such as polyethylene. It is necessary therefore to either control the process (ensure a high temperature is reached) to destroy these substances or install dedicated hygiene equipment to remove toxic substances in order to comply with EU and national emissions legislation.

### **Energy costs and efficiency**

Users of larger ovens and furnaces are conscious of energy costs as these can be considerable. For ceramics the overall average cost is ~30% of total production costs<sup>57</sup> and for the metals industry ~20%<sup>58</sup>. Therefore the energy efficiency of the oven or furnace is an important criterion for selection. This can also affect the furnace design and choice of energy as different energy sources incur different costs. This is particularly noticeable when comparing fossil fuels such as natural gas with electricity. There are advantages and disadvantage with each type of fuel source and so some furnaces are designed for use with more than one type. For example, Morgan manufacture an aluminium melting furnace which uses gas to melt the metal and electric resistance heating to maintain temperature of the melt.

### **Carbon emissions targets**

Users of large quantities of energy may be included in Climate Change Agreements or European Emissions Trading Scheme (ETS) and this will affect all installations within the scope of the IPPC directive. This may require involvement in carbon trading schemes or taxation imposed to encourage reductions in carbon emissions. Energy efficiency is an important issue for users of larger furnaces and ovens due to the high cost but the ETS scheme potentially adds to this cost and so encourages both the reduction in energy consumption as well as the use of renewable energy sources in order to meet carbon emission targets. However this not only affects furnace and oven design but also feedstock type and how the equipment is used. The potential added cost of ETS could make certain energy efficiency design options more cost-effective than they would otherwise be. For example, it could encourage the use of recuperative or regenerative burners and the installation of monitoring and control equipment to minimise energy consumption and it may also encourage waste heat re-use as the CO<sub>2</sub> emission targets are based on installations, not individual furnaces. The additional costs must however not be so large that it is cheaper to build a less energy efficient plant outside EU where no carbon trading schemes exist.

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<sup>57</sup> British Ceramics Confederation  
<http://www.ofgem.gov.uk/MARKETS/WHLMKTS/DISCOVERY/Documents1/British%20Ceramic%20Confederation.pdf>

<sup>58</sup> Carbon Trust UK [www.carbontrust.co.uk](http://www.carbontrust.co.uk)

## Power management

Power management is the control of energy consumption by automatically switching equipment into a low power mode after a period of inactivity. Apart from the use of temperature controllers, power management features are very unusual in industrial and laboratory furnaces and ovens. This is not needed with furnaces and ovens that operate continuously but may be beneficial with batch ovens and furnaces. For power management to operate there needs to be a way for the furnace or oven to determine when it is possible to switch into a low power mode. One patent describes the use of controllers to automatically switch ovens into "energy saving modes"<sup>59</sup>. Commercial gas-heated catering ovens can include "energy management" that use sensors to determine if there is anything in the oven and this can save at least 30% of energy according to the manufacturer's literature<sup>60</sup>.

## Reliability and scheduled maintenance

Reliability is extremely important for furnaces and ovens, especially large-scale manufacturing equipment as any unexpected stoppages result in loss of production which can amount to many millions of Euros per day. Furthermore, failures can pose severe safety risks and there have been incidents where failures have caused injuries and deaths<sup>61</sup>.

Some types of continuous furnace process cannot be stopped as this would cause irreparable damage to the furnace. If for example, the liquid metal in a metal melting furnace or a blast furnace were to cool and freeze, this would block valves and pipework which could not easily be repaired. The insulation of furnaces must also be reliable as this prevents heat losses and also prevents damage to the support structure. Temperature control equipment reliability and accuracy is important for good control of the process and also to minimise energy consumption.

High reliability is achieved by the correct choice of furnace and oven design and importantly also by following a schedule of preventive maintenance to check for incipient damage and replace parts before they fail. Operating the furnace under precisely controlled conditions not only minimises energy consumption but it also extends the furnace life by preserving insulation, valves, etc. and avoiding early failures. The temperature must be high enough for the process but no higher. It is a general rule that a 10°C rise in temperature can double the rate of chemical reactions including those that cause parts to deteriorate (thermal oxidation, corrosion, etc.).

The type and frequency of maintenance is affected by design but some examples of energy efficient designs require more frequent maintenance such as the use of regenerative burners.

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<sup>59</sup> Patent WO 2008033519, D. Yoder, J. Blake and R. Nevarez, Lincoln Foodservice Products USA, 20 March 2008.

<sup>60</sup> [http://www.middleby.com/midmarsh/wow/WOWbroch\\_web.pdf](http://www.middleby.com/midmarsh/wow/WOWbroch_web.pdf)

<sup>61</sup> For example, smelter explosion, USA in 1961 <http://www3.gendisasters.com/indiana/13126/east-chicago-in-furnace-explosion-sep-1961> blast furnace, UK in 2001 <http://www.hastam.co.uk/hands/corus.html> and oven, Russia in 2010 <http://finance.yahoo.com/news/Mechel-Announces-Accident-at-pz-1966565063.html?x=0&.v=1>

### 3.3 End of life behaviour

This task identifies actual user requirements (EU averages) regarding end-of-life aspects. This includes:

- Present fractions to recycling, re-use and disposal;
- Present fraction of second hand use and refurbishment.

Smaller (often laboratory) furnaces and ovens can and should be collected and recycled at end-of-life as most will be within the scope of the WEEE Directive, either as an electrical tool (category 6) or a control instrument (category 9).<sup>62</sup>

Large-scale furnaces and ovens that are built in-situ at manufacturing sites would be regarded as large-scale industrial tools and so excluded from the WEEE Directive. They are usually dismantled at end-of-life and at least some of the materials recycled (steel, for example). Some materials may be classified as hazardous waste as a result of contamination during the production process and these materials will need to be treated appropriately. Other materials such as used insulation may be discarded to landfill.

The energy and materials issues arising from end-of-life recycling have been investigated as part of this subtask.

Some self-contained equipment could be refurbished for reuse and the extent to which this occurs has been established.

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<sup>62</sup> EC (2003) *Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE)*.

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## Appendix A - EU Member State data

The following tables include data for section 2.1 (PRODCOM Eurostat data).

**Table 43. Number and value of exports, imports and production of furnace burners for liquid fuel by Member State, 2008**

Country	Exports		Imports		Production	
	Volume (Number of units)	Value (€m)	Volume (Number of units)	Value (€m)	Volume (Number of units)	Value (€m)
Austria	1 581	1.6	4 614	2.7	n/a	0.0
Belgium	3 276	0.5	38 139	11.6	n/a	0.0
Bulgaria	19	0.2	12 971	1.3	n/a	0.0
Croatia	n/a	0.0	n/a	0.0	0	0.0
Czech Republic	1 620	1.8	2 072	0.5	n/a	0.0
Denmark	2 205	0.5	19 511	7.7	0	0.0
Estonia	10	0.0	372	0.2	0	0.0
Finland	2 167	9.9	1 977	1.5	11 578	19.3
France	139 793	29.0	94 190	12.7	NA	0.0
Germany	103 939	74.0	40 185	17.3	147 935	129.4
Greece	1 242	0.3	91 523	10.1	0	0.0
Hungary	0	0.0	17 122	0.3	0	0.0
Iceland	n/a	0.0	n/a	0.0	0	0.0
Ireland	71	0.0	60 650	7.4	n/a	0.0
Italy	589 430	75.2	29 486	3.5	700 318	131.6
Latvia	79	0.0	11 529	0.2	0	0.0
Lithuania	163	0.2	554	0.3	0	0.0
Luxemburg	502	0.2	2 485	0.9	0	0.0
Malta	0	0.0	18	0.0	0	0.0
Netherlands	94 445	7.5	30 053	5.6	NA	19.0
Norway	n/a	0.0	n/a	0.0	0	0.0
Poland	351	1.7	4277	2.0	n/a	0.0
Portugal	140	0.1	82 548	1.1	0	0.0
Romania	266	1.1	8 299	2.4	0	0.0
Slovakia	33	0.0	1 512	0.1	0	0.0
Slovenia	1 186	0.8	5 524	1.7	0	0.0
Spain	29 737	2.2	538 142	15.8	2 847	5.0
Sweden	74 083	16.0	5 065	2.2	n/a	0.0
UK	51 738	12.8	141 485	18.1	13 545	6.1
<b>EU-27 total</b>	<b>587 487</b>	<b>122.4</b>	<b>124 745</b>	<b>10.7</b>	<b>1 153 836</b>	<b>392.6</b>

**Table 44. Apparent consumption of furnace burners for liquid fuel by Member State, 2008**

<b>Country</b>	<b>Volume (number of units)</b>
Austria	-
Belgium	-
Bulgaria	-
Croatia	0
Czech Republic	-
Denmark	17,306
Estonia	362
Finland	11,388
France	-
Germany	84,181
Greece	90,281
Hungary	17,122
Iceland	0
Ireland	-
Italy	140,374
Latvia	11,450
Lithuania	391
Luxemburg	1,983
Malta	18
Netherlands	-
Norway	0
Poland	-
Portugal	82,408
Romania	8,033
Slovakia	1,479
Slovenia	4,338
Spain	511,252
Sweden	-
UK	103,292
<b>EU-27 total</b>	<b>691,094</b>

**Table 45. Production of furnace burners for solid fuel or gas (including combination burners) by Member State, 2008**

Country	Volume (number of units)	Value (€m)
Austria	n/a	n/a
Belgium	n/a	n/a
Bulgaria	n/a	n/a
Croatia	0	0.0
Czech Republic	2,838	8.1
Denmark	0	0.0
Estonia	0	0.0
Finland	2,026	15.7
France	n/a	n/a
Germany	95,735	224.8
Greece	0	0.0
Hungary	n/a	n/a
Iceland	0	0.0
Ireland	n/a	n/a
Italy	53,480,833	186.6
Latvia	0	0.0
Lithuania	414	0.0
Luxemburg	0	0.0
Malta	0	0.0
Netherlands	n/a	85.5
Norway	0	0.0
Poland	137,757	2.3
Portugal	3,610	2.5
Romania	n/a	n/a
Slovakia	n/a	n/a
Slovenia	0	0.0
Spain	1,767	14.1
Sweden	2,997	7.9
UK	26,933	72.4
<b>EU-27 total</b>	<b>53,962,732</b>	<b>705.5</b>

**Table 46. Production of electric bakery and biscuit ovens by Member State, 2008**

Country	Volume (number of units)	Value (€m)
Austria	n/a	n/a
Belgium	0	0.0
Bulgaria	n/a	1.0
Croatia	n/a	n/a
Czech Republic	n/a	n/a
Denmark	0	0.0
Estonia	n/a	n/a
Finland	0	0.0
France	3,980	25.8
Germany	22,410	85.6
Greece	n/a	n/a
Hungary	0	0.0
Iceland	0	0.0
Ireland	0	0.0
Italy	69,388	57.3
Latvia	0	0.0
Lithuania	0	0.0
Luxemburg	0	0.0
Malta	0	0.0
Netherlands	0	0.0
Norway	n/a	n/a
Poland	n/a	0.6
Portugal	n/a	n/a
Romania	0	0.0
Slovakia	0	0.0
Slovenia	0	0.0
Spain	12,619	38.4
Sweden	2,279	16.8
UK	0	0.0
<b>EU-25 total</b>	<b>112,718</b>	<b>241.3</b>
<b>EU-27 total</b>	<b>113,118</b>	<b>242.3</b>

**Table 47. Production of non-electric bakery and biscuit ovens by Member State, 2008**

Country	Volume (number of units)	Value (€m)
Austria	0	0.0
Belgium	0	0.0
Bulgaria	12	0.9
Croatia	n/a	n/a
Czech Republic	n/a	n/a
Denmark	393	1.7
Estonia	0	0.0
Finland	0	0.0
France	4,601	39.6
Germany	n/a	n/a
Greece	n/a	n/a
Hungary	n/a	n/a
Iceland	0	0.0
Ireland	0	0.0
Italy	15,880	99.1
Latvia	0	0.0
Lithuania	0	0.0
Luxemburg	0	0.0
Malta	0	0.0
Netherlands	n/a	n/a
Norway	0	0.0
Poland	n/a	n/a
Portugal	453	5.5
Romania	0	0.0
Slovakia	0	0.0
Slovenia	n/a	n/a
Spain	4,405	17.3
Sweden	n/a	n/a
UK	95	9.8
<b>EU-25 total</b>	<b>28,290</b>	<b>266.4</b>
<b>EU-27 total</b>	<b>28,302</b>	<b>267.3</b>

**Table 48. Volume and value of exports, imports and production of non-electric industrial or laboratory furnaces and ovens by Member State, 2008**

Country	Exports		Imports		Production	
	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)
Austria	1,611	8.1	3,054	16.4	n/a	n/a
Belgium	667	5.4	1,711	12.8	0	0.0
Bulgaria	0	0.0	932	5.5	94	0.4
Croatia	n/a	n/a	n/a	n/a	n/a	n/a
Czech Republic	1,740	11.0	863	8.4	832	8.0
Denmark	785	13.2	1,671	1.9	0	3.2
Estonia	2	0.0	95	0.7	7	0.0
Finland	1,786	19.3	196	2.6	0	0.0
France	3,251	37.5	1,810	14.6	9	172.7
Germany	8,419	96.2	2,014	17.9	n/a	n/a
Greece	42	0.2	372	3.1	n/a	n/a
Hungary	1,998	9.3	2,177	27.7	n/a	n/a
Iceland	n/a	n/a	n/a	n/a	0	0.0
Ireland	11	0.2	18	0.3	n/a	n/a
Italy	45,812	251.2	1,515	8.6	23,913	164.2
Latvia	172	0.7	199	1.0	0	0.0
Lithuania	25	0.2	53	0.7	0	n/a
Luxemburg	0	0.0	17	0.3	0	0.0
Malta	1	0.0	27	0.1	0	0.0
Netherlands	1,043	10.0	776	11.4	n/a	n/a
Norway	n/a	n/a	n/a	n/a	n/a	n/a
Poland	3,887	13.9	2,674	14.1	n/a	4.0
Portugal	794	2.8	746	18.4	341	1.4
Romania	84	0.3	3,158	18.3	n/a	n/a
Slovakia	10	0.1	128	0.9	0	0.0
Slovenia	348	3.8	100	1.0	n/a	n/a
Spain	4,232	18.6	3,757	24.4	4,021	24.1
Sweden	688	16.1	239	3.8	44,933	14.5
UK	3,760	28.5	1,363	9.6	n/a	29.0
<b>EU-25 total</b>	<b>58,908</b>	<b>390.1</b>	<b>4,730</b>	<b>33.5</b>	<b>145,122</b>	<b>742.7</b>
<b>EU-27 total</b>	<b>56,641</b>	<b>379.8</b>	<b>5,121</b>	<b>35.7</b>	<b>145,242</b>	<b>744.2</b>

**Table 49. Volume and value of exports, imports and production of resistance heated industrial or laboratory furnaces and ovens by Member State, 2008**

Country	Exports		Imports		Production	
	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)
Austria	913	34	340	10	n/a	n/a
Belgium	317	9	385	9	0	0
Bulgaria	53	0	72	2	n/a	n/a
Croatia	n/a	n/a	n/a	n/a	0	0
Czech Republic	1,147	14	275	4	428	11
Denmark	713	9	110	3	0	10
Estonia	19	0	28	1	0	0
Finland	154	3	310	6	n/a	0
France	349	13	1,321	22	572	60
Germany	10,349	349	1,505	32	13,385	463
Greece	18	0	44	1	0	0
Hungary	0	0	289	4	n/a	n/a
Iceland	n/a	n/a	n/a	n/a	0	0
Ireland	2	0	26	1	0	0
Italy	2,734	42	397	12	4,744	64
Latvia	5	0	8	0	0	0
Lithuania	322	4	25	1	304	4
Luxemburg	0	0	55	1	0	0
Malta	0	0	5	0	0	0
Netherlands	377	14	89	3	n/a	n/a
Norway	n/a	n/a	n/a	n/a	0	0
Poland	693	10	375	6	n/a	n/a
Portugal	40	0	69	1	12	1
Romania	275	1	404	6	n/a	n/a
Slovakia	3	3	33	2	0	0
Slovenia	188	2	169	3	n/a	n/a
Spain	807	11	706	13	458	14
Sweden	929	13	208	4	538	12
UK	610	18	788	13	n/a	19
<b>EU-25 total</b>	<b>13,406</b>	<b>390</b>	<b>3,054</b>	<b>51</b>	<b>31,781</b>	<b>810</b>
<b>EU-27 total</b>	<b>13,563</b>	<b>388</b>	<b>3,153</b>	<b>53</b>	<b>31,805</b>	<b>811</b>

**Table 50. Volume and value of exports, imports and production of electrical induction industrial or laboratory furnaces and ovens by Member State, 2008**

Country	Exports		Imports		Production	
	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)
Austria	35.5	1.3	289.6	6.1	0.0	0.0
Belgium	26.0	0.2	119.3	1.5	n/a	n/a
Bulgaria	25.9	0.5	12.9	0.1	0.0	0.0
Croatia	n/a	n/a	n/a	n/a	0.0	0.0
Czech Republic	158.9	1.7	292.3	3.3	641.6	7.1
Denmark	12.6	0.2	3.2	0.1	0.0	0.0
Estonia	4.7	0.0	2.2	0.0	0.0	0.0
Finland	19.4	0.4	63.2	2.9	0.0	0.0
France	163.4	8.3	540.5	8.8	n/a	n/a
Germany	3,671.5	69.2	377.4	8.8	5,851.2	124.9
Greece	0.0	0.0	9.9	0.2	0.0	0.0
Hungary	0.0	0.0	23.5	0.8	0.0	0.0
Iceland	n/a	n/a	n/a	n/a	0.0	0.0
Ireland	1.5	0.0	5.6	0.2	0.0	0.0
Italy	1,232.8	33.9	533.1	6.5	1,879.4	48.5
Latvia	0.0	0.0	3.3	0.1	0.0	0.0
Lithuania	0.8	0.1	2.0	0.1	1.0	0.0
Luxemburg	0.0	0.0	0.0	0.0	0.0	0.0
Malta	0.0	0.0	0.9	0.0	0.0	0.0
Netherlands	35.1	3.0	6.3	1.1	0.0	0.0
Norway	n/a	n/a	n/a	n/a	0.0	0.0
Poland	2.1	0.0	486.1	7.3	311.0	3.3
Portugal	0.0	0.0	8.2	0.4	0.6	0.1
Romania	24.0	0.5	61.2	1.7	0.0	0.0
Slovakia	83.7	1.2	10.3	0.8	0.0	0.0
Slovenia	134.6	1.8	65.7	1.1	0.0	0.0
Spain	198.7	3.7	85.2	2.2	192.9	10.3
Sweden	326.3	8.3	34.8	1.5	0.0	0.0
UK	2,360.9	34.3	62.6	1.6	n/a	n/a
<b>EU-25 total</b>	<b>5,684.1</b>	<b>104.2</b>	<b>644.8</b>	<b>10.4</b>	<b>10,189.4</b>	<b>255.4</b>
<b>EU-27 total</b>	<b>5,495.3</b>	<b>99.9</b>	<b>649.5</b>	<b>10.7</b>	<b>10,189.4</b>	<b>255.4</b>

**Table 51. Volume and value of exports, imports and production of electrical industrial/laboratory furnaces/ovens, induction/dielectric heating equipment by Member State, 2008**

Country	Exports		Imports		Production	
	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)
Austria	1,150.2	29.8	467.4	12.4	n/a	n/a
Belgium	688.9	13.9	632.7	14.4	0.0	0.0
Bulgaria	42.6	0.8	113.9	1.1	0.0	0.0
Croatia	n/a	n/a	n/a	n/a	n/a	n/a
Czech Republic	153.6	2.9	327.9	15.4	1,001.4	6.5
Denmark	418.0	5.3	199.4	7.0	0.1	1.9
Estonia	31.5	0.5	17.9	0.4	112.7	2.1
Finland	25.3	1.3	473.7	9.4	n/a	1.5
France	1,077.3	31.6	870.0	20.4	6.1	23.8
Germany	6,106.0	216.5	1,990.3	50.0	5,735.3	193.8
Greece	32.5	0.1	80.5	1.8	0.0	0.0
Hungary	51.7	0.1	151.1	3.5	0.0	0.0
Iceland	n/a	n/a	n/a	n/a	0.0	0.0
Ireland	39.0	3.5	36.0	1.4	0.0	0.0
Italy	3,859.2	62.3	1,268.9	27.6	9,476.1	76.7
Latvia	4.8	0.2	24.1	0.7	0.0	0.0
Lithuania	24.8	0.6	69.7	1.0	0.0	0.0
Luxemburg	4.3	0.2	12.0	0.1	0.0	0.0
Malta	0.8	0.1	12.0	0.1	0.0	0.0
Netherlands	644.1	20.7	460.9	14.6	n/a	n/a
Norway	n/a	n/a	n/a	n/a	0.0	0.0
Poland	1,734.9	23.8	431.8	11.3	4,364.0	54.8
Portugal	91.1	1.0	131.9	2.5	1,358.9	3.4
Romania	28.8	0.2	314.0	6.5	0.0	0.0
Slovakia	13.7	0.2	33.9	0.9	0.0	0.0
Slovenia	14.8	0.7	555.2	7.7	n/a	n/a
Spain	1,659.3	17.7	739.8	17.6	n/a	n/a
Sweden	103.1	5.3	529.5	15.4	n/a	n/a
UK	1,917.1	52.7	2,705.7	28.4	n/a	25.0
<b>EU-25 total</b>	<b>12,952.5</b>	<b>309.1</b>	<b>6,209.0</b>	<b>103.8</b>	<b>27,149.4</b>	<b>480.0</b>
<b>EU-27 total</b>	<b>12,792.4</b>	<b>305.5</b>	<b>6,276.1</b>	<b>103.8</b>	<b>27,149.4</b>	<b>480.0</b>

**Table 52. Volume and value of exports, imports and production of electric infra-red radiation ovens by Member State, 2008**

Country	Exports		Imports		Production	
	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)	Volume (tonnes)	Value (€m)
Austria	0.5	0.0	1.9	0.1	0.0	0.0
Belgium	3.4	0.2	47.2	0.2	0.0	0.0
Bulgaria	31.7	0.5	0.5	0.0	0.0	0.0
Croatia	n/a	n/a	n/a	n/a	0.0	0.0
Czech Republic	0.0	0.0	4.9	0.2	0.0	0.0
Denmark	0.6	0.0	0.0	0.0	0.0	0.0
Estonia	0.1	0.0	0.3	0.0	0.0	0.0
Finland	1.3	0.1	2.5	0.2	0.0	0.0
France	15.7	2.0	223.9	2.3	n/a	3.1
Germany	39.1	5.0	46.2	1.4	n/a	n/a
Greece	0.0	0.0	30.0	1.9	n/a	n/a
Hungary	0.0	0.0	3.1	0.0	0.0	0.0
Iceland	n/a	n/a	n/a	n/a	0.0	0.0
Ireland	0.1	0.0	1.8	0.1	0.0	0.0
Italy	107.9	1.5	8.4	0.5	445.6	4.7
Latvia	0.3	0.0	12.0	0.1	0.0	0.0
Lithuania	7.1	0.1	0.8	0.0	0.0	0.0
Luxembourg	0.0	0.0	7.0	0.1	0.0	0.0
Malta	n/a	n/a	n/a	n/a	0.0	0.0
Netherlands	22.2	0.8	57.5	1.7	n/a	n/a
Norway	n/a	n/a	n/a	n/a	0.0	0.0
Poland	0.9	0.0	41.9	0.5	0.0	0.0
Portugal	0.1	0.0	18.3	0.3	0.0	0.0
Romania	0.0	0.0	39.3	0.5	0.0	0.0
Slovakia	0.1	0.0	0.0	0.0	0.0	0.0
Slovenia	0.4	0.0	1.6	0.0	0.0	0.0
Spain	41.6	0.5	106.5	0.8	n/a	n/a
Sweden	3.6	0.4	6.7	0.1	0.0	0.0
UK	274.5	1.6	75.2	1.2	0.0	0.0
<b>EU-25 total</b>	<b>434.9</b>	<b>7.7</b>	<b>156.4</b>	<b>4.6</b>	<b>1,000.0</b>	<b>16.3</b>
<b>EU-27 total</b>	<b>434.2</b>	<b>7.6</b>	<b>157.4</b>	<b>4.7</b>	<b>1,000.0</b>	<b>16.3</b>

The following tables include Member State data for section 2.4.2

**Table 53. The evolution of electricity rates between mid-2007 and mid-2009 for customers (500-2000 MWh) in EU-27<sup>63</sup> (all taxes included)**

Member State	Rate [€/kWh]			
	2008S1	2008S2	2009S1	2009S2
Austria	0.1276	0.1286	:	:
Belgium	0.1293	:	0.1344	:
Bulgaria	0.0675	0.0782	0.0777	0.0767
Cyprus	0.1638	0.2075	0.1360	0.1715
Czech Republic	0.1318	0.1335	0.1271	0.1335
Denmark	0.2113	0.2240	0.2067	0.2136
Estonia	0.0669	0.0711	0.0759	0.0774
Finland	0.0781	0.0822	0.0841	0.0833
France	0.0778	0.0736	0.0865	0.0784
Germany	0.1410	0.1428	0.1505	0.1515
Greece	0.0941	0.1006	0.1037	0.1020
Hungary	0.1371	0.1461	0.1487	0.1554
Ireland	0.1489	0.1604	0.1364	0.1327
Italy	0.1584	0.1685	0.1824	0.1581
Latvia	0.0779	0.0940	0.1085	0.1082
Lithuania	0.0978	0.0990	0.1099	0.0954
Luxembourg	0.1035	0.1038	0.1227	0.1228
Malta	0.1282	0.1700	0.1581	0.1356
Netherlands	0.1180	0.1220	0.1340	0.1320
Poland	0.1075	0.1110	0.1100	0.1139
Portugal	0.0939	0.0946	0.0984	0.0989
Romania	0.1057	0.1134	0.0970	0.0990
Slovakia	0.1368	0.1534	0.1693	0.1670
Slovenia	0.1118	0.1182	0.1342	0.1155
Spain	0.1108	0.1238	0.1338	0.1299
Sweden	0.0866	0.0965	0.0832	0.0861
United Kingdom	0.1147	0.1279	0.1283	0.1164
<b>European Union 27</b>	<b>0.1194</b>	<b>0.1253</b>	<b>0.1305</b>	<b>0.1253</b>

<sup>63</sup> Eurostat (2010), "Electricity - industrial consumers - half-yearly prices - New methodology from 2007 onwards".

**Table 54. Electricity rates in the first semester of 2009 according to taxes breakdown in EU-27<sup>64</sup> for average industrial consumers (500 – 2000MWh)**

Member State	Rate [€/kWh]		
	Without taxes	Without VAT	All taxes included
Austria	:	:	:
Belgium	:	:	:
Bulgaria	0.0634	0.0639	0.0767
Czech Republic	0.1110	0.1122	0.1335
Denmark	0.0793	0.0927	0.2136
Germany	0.0958	0.1134	0.1515
Estonia	0.0575	0.0645	0.0774
Ireland	0.1170	0.1175	0.1327
Greece	0.0853	0.0936	0.1020
Spain	0.1066	0.1120	0.1299
France	0.0599	0.0656	0.0784
Italy	:	0.1370	0.1581
Cyprus	0.1472	0.1494	0.1715
Latvia	0.0893	0.0893	0.1082
Lithuania	0.0790	0.0790	0.0954
Luxembourg	0.1118	0.1158	0.1228
Hungary	0.1276	0.1297	0.1554
Malta	0.1291	0.1291	0.1356
Netherlands	0.0930	0.1110	0.1320
Poland	0.0886	0.0933	0.1139
Portugal	0.0932	0.0944	0.0989
Romania	0.0828	0.0828	0.0990
Slovenia	0.0921	0.0962	0.1155
Slovakia	0.1396	0.1403	0.1670
Finland	0.0656	0.0683	0.0833
Sweden	0.0684	0.0689	0.0861
United Kingdom	0.0973	0.1012	0.1164
<b>European Union 27</b>	<b>0.0913</b>	<b>0.1026</b>	<b>0.1253</b>

<sup>64</sup> Eurostat, <http://nui.epp.eurostat.ec.europa.eu/nui/submitViewTableAction.do>

**Table 55. Natural gas rates (including taxes) for consumers in the consumption band IC (1000-10000 GJ), between 2008 and 2009 in EU-27<sup>65</sup> (taxes included)**

Member States	Rate [€/GJ]			
	2008S1	2008S2	2009S1	2009S2
Austria	:	:	:	:
Belgium	11.0600	13.0400	10.9000	10.1400
Bulgaria	6.8565	8.9120	10.4919	7.1480
Czech Republic	10.5608	13.0291	11.0608	8.9957
Denmark	:	21.1262	19.2852	16.9414
Germany	14.7600	16.4300	14.2600	11.4400
Estonia	8.2263	10.3394	8.8481	7.6630
Ireland	12.4800	12.2000	10.2800	8.0800
Spain	8.8640	10.4800	10.0944	8.7328
France	10.9300	12.8440	11.8700	10.3400
Italy	10.2710	12.4510	12.1880	8.6160
Latvia	9.3343	12.9890	13.1531	9.3030
Lithuania	10.3688	14.3275	10.3029	9.0917
Luxembourg	11.1400	12.0400	11.9200	10.6500
Hungary	11.6241	14.0565	12.3662	9.7429
Netherlands	11.4400	12.6580	12.6610	12.3630
Poland	10.2049	11.3883	9.4335	10.1955
Portugal	9.1250	9.6740	10.3000	7.5851
Romania	9.2700	9.2396	7.7146	7.0551
Slovenia	12.1400	15.1900	14.5500	11.5400
Slovakia	10.6105	15.6186	13.4510	10.6020
Finland	9.7000	11.4000	10.4000	9.7000
Sweden	17.9508	18.3688	13.7191	15.7882
United Kingdom	9.0719	10.2074	9.5994	6.6988
<b>European Union 27</b>	<b>11.0670</b>	<b>12.8311</b>	<b>11.7462</b>	<b>9.6012</b>

<sup>65</sup> Eurostat (2009), "Environment and Energy, Data in focus, 49/2009".

**Table 56. Natural gas tax rates for consumers in the range 1000-10000 GJ, between 2008 and 2009 in EU-27<sup>66</sup>**

Member States	Rate [€/GJ]		
	Without taxes	Without VAT	All taxes included
Austria	:	:	:
Belgium	8.0700	8.5000	10.1400
Bulgaria	5.9566	5.9566	7.1480
Czech Republic	7.2294	7.5594	8.9957
Denmark	5.4546	13.5558	16.9414
Germany	8.4900	9.6100	11.4400
Estonia	5.7699	6.3861	7.6630
Ireland	7.3100	7.3100	8.0800
Spain	7.5283	7.5283	8.7328
France	8.5000	8.8000	10.3400
Italy	7.4080	7.8330	8.6160
Latvia	7.6863	7.6863	9.3030
Lithuania	7.5535	7.5535	9.0917
Luxembourg	9.9600	10.0300	10.6500
Hungary	7.5155	7.7943	9.7429
Netherlands	8.7680	10.3890	12.3630
Poland	8.3585	8.3585	10.1955
Portugal	7.2239	7.2239	7.5851
Romania	3.8725	5.9288	7.0551
Slovenia	8.8300	9.6100	11.5400
Slovakia	8.7260	8.9090	10.6020
Finland	7.4000	8.0000	9.7000
Sweden	10.8785	12.6113	15.7882
UK	5.5279	5.8206	6.6988
<b>European Union 27</b>	<b>7.5557</b>	<b>8.2166</b>	<b>9.6012</b>

<sup>66</sup> Eurostat (2009), "Environment and Energy, Data in focus, 49/2009".

**Table 57. Coal prices without VAT in 18 Member States, in June 2005<sup>67</sup>**

<b>State</b>	<b>Coal price (€/GJ)</b>
Austria	12.68
Belgium	N.A.
Czech Rep.	1.29
Denmark	20.80
Estonia	3.31
Finland	N.A.
France	15.03
Germany	9.23
Greece	N.A.
Hungary	3.88
Ireland	12.59
Latvia	1.75
Netherlands	N.A.
Poland	3.49
Portugal	N.A.
Slovakia	4.49
Spain	N.A.
Sweden	N.A.
<b>EU average</b>	<b>8.05</b>

<sup>67</sup> E. Alakangas et al. (2007) Biomass fuel trade in Europe, Summary Report. Eubionet II.

**Table 58. EU-27 interest rates<sup>68</sup>**

State	2006	2007	2008
Austria	3.79%	4.29%	4.27%
Belgium	3.81%	4.33%	4.42%
Bulgaria	4.18%	4.54%	5.38%
Cyprus	4.13%	4.48%	4.60%
Czech Republic	3.80%	4.30%	4.63%
Denmark	3.81%	4.29%	4.30%
Estonia	5.01%	6.09%	8.16%
Finland	3.78%	4.29%	4.30%
France	3.80%	4.30%	4.24%
Germany	3.76%	4.22%	4.00%
Greece	4.07%	4.50%	4.81%
Hungary	7.12%	6.74%	8.24%
Ireland	3.77%	4.31%	4.53%
Italy	4.05%	4.49%	4.69%
Latvia	4.13%	5.28%	6.43%
Lithuania	4.08%	4.55%	5.61%
Luxembourg	3.91%	4.56%	4.61%
Malta	4.32%	4.72%	4.81%
Netherlands	3.78%	4.29%	4.23%
Poland	5.23%	5.48%	6.07%
Portugal	3.91%	4.43%	4.53%
Romania	7.23%	7.13%	7.70%
Slovakia	4.41%	4.49%	4.72%
Slovenia	3.85%	4.53%	4.61%
Spain	3.78%	4.31%	4.37%
Sweden	3.70%	4.17%	3.90%
UK	4.38%	5.06%	4.51%
<b>EU 27</b>	<b>4.08%</b>	<b>4.57%</b>	<b>4.55%</b>

<sup>68</sup> Eurostat, Interest Rates, Long-term interest rates, Maastricht criterion interest rates, EMU convergence criterion series - Annual data, accessed 26 November 2009.

**Table 59. EU-27 annual inflation rates (%)<sup>69</sup>**

<b>State</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>
Austria	1.70	2.20	3.20
Belgium	2.30	1.80	4.50
Bulgaria	7.40	7.60	12.00
Cyprus	2.20	2.20	4.40
Czech Republic	2.10	3.00	6.30
Denmark	1.90	1.70	3.60
Estonia	4.40	6.70	10.60
Finland	1.30	1.60	3.90
France	1.90	1.60	3.20
Germany	1.80	2.30	2.80
Greece	3.30	3.00	4.20
Hungary	4.00	7.90	6.00
Ireland	2.70	2.90	3.10
Italy	2.20	2.00	3.50
Latvia	6.60	10.10	15.30
Lithuania	3.80	5.80	11.10
Luxembourg	3.00	2.70	4.10
Malta	2.60	0.70	4.70
Netherlands	1.70	1.60	2.20
Poland	1.30	2.60	4.20
Portugal	3.00	2.40	2.70
Romania	6.60	4.90	7.90
Slovakia	4.30	1.90	3.90
Slovenia	2.50	3.80	5.50
Spain	3.60	2.80	4.10
Sweden	1.50	1.70	3.30
UK	2.30	2.30	3.60
<b>EU 27</b>	<b>2.30</b>	<b>2.40</b>	<b>3.70</b>

<sup>69</sup> Eurostat, Prices, Harmonised indices of consumer prices (HICP), HICP (2005=100) - Annual Data (average index and rate of change), accessed 27 November 2009.

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