Nordic Council of Ministers

Nordic Ceramics Industry

Best Available Technique (BAT)

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Esa Salminen, Johan Mjöberg and Juhani Anhava

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Preface

The Nordic Council of Ministers and the BAT Group under the Working Group for sustainable consumption and production (also called HKP) has requested a Nordic expert team led by Vahanen Environment Oy to prepare a Best Available Techniques (BAT) project on the manufacture of ceramics (CER) in the Nordic countries.

The project will serve as a Nordic contribution to the coming EU process in which BAT conclusions for the ceramic sector will be revised according to the industrial emission directive (IED 2010/75/EU). The work will also help in the national preparation for the upcoming process in the Nordic countries.

Potential BAT candidates and emerging techniques are included in the report, which addresses measures to reduce air emissions, waste, energy consumption/CO_2 emissions and wastewater, and replace some of the raw materials with recycled materials in the manufacture of ceramics.

The following consultants have contributed to the report:

Core team:

- Esa Salminen, Vahanen Environment Oy (Project Manager)
- Johan Mjöberg, Foritec AB
- Juhani Anhava, Anhava & Partnerts Oy

Support team:

- Hannu Pyy, Vahanen Rakennusfysiikka Oy

The BAT project has been observed and commented on by the Nordic BAT Group. The members of the BAT Group are:

- Anne Kathrine Arnesen, the Norwegian Environment Agency, Norway
- Kaj Forsius, Finnish Environment Institute
- Lena Ziskason, Environment Agency of the Faroe Islands
- Einar Halldorsson, Environment Agency of Iceland
- Mikael Stjärnfelt, Environmental and Health Protection Agency of the Aland Islands
- Birgitte Holm Christensen and Mette Lumbye Sørensen, Danish Environmental Protection Agency
- Elin Sieurin, Swedish Environment Agency

Summary

The BAT Group of the Nordic Council of Ministers has decided to conduct a project on Best Available Techniques (BAT) in the manufacture of ceramics (CER) in the Nordic countries. The objectives of the project have been to:

- review and describe the ceramics manufacturing industry in the Nordic countries;
- review and describe the techniques used in the Nordic countries;
- identify and describe the main environmental indicators from the Nordic perspective;
- identify and describe techniques that will be included in considerations in representing BAT in the manufacture of ceramics.

The project will serve as a Nordic contribution to the coming EU process in which BAT conclusions for the ceramic sector will be revised according to the industrial emission directive (IED 2010/75/EU). The work will also help in the national preparation for the upcoming process in the Nordic countries. The findings of the report are also applicable to plants with a smaller capacity than the IED. The report can also be directly used by environmental permitting and supervisory authorities, as well as industry itself, in considering the application of BAT for ceramic manufacturing.

The term "ceramics" refers to various types of product made of mostly inorganic and non-metallic materials by a firing process. The main raw material has traditionally been clay, whereas today ceramics include a multitude of products with only a small fraction of clay or none at all. Ceramics can be glazed or unglazed, porous or vitrified. Typical properties of ceramic products include high strength, wear resistance, long service life, chemical inertness and non-toxicity, resistance to heat and fire, (usually) electrical resistance and sometimes also a specific porosity.

The scope of the project covers the manufacture of the following product groups, which can further be divided into coarse ceramics and fine ceramics as follows:

Coarse ceramics:

- expanded clay aggregates
- vitrified clay pipes
- bricks and roof tiles
- refractory products

Fine ceramics:

- wall and floor tiles
- household ceramics
- sanitary ware
- technical ceramics
- inorganic bonded abrasives

The project also covers the Nordic ceramics manufacturing plants below the IED capacity threshold: that is, plants with an environmental permit.

The manufacture of ceramics has a long tradition and has been a large industry in the past, with a few hundred plants in the Nordic countries. Today, there are a relatively small number of manufacturing plants left in the Nordic countries, comprising a few percent of total EU ceramics manufacture. Many of the manufacturing plants in the Nordic countries belong to larger international industrial groups, which manufacture ceramics at many plants in the Nordic countries and elsewhere.

The main environmental indicators in the scope of this study are (in non-prioritized order):

- Raw materials, additives/chemicals and fuels
- Emissions to air
- Emissions to water
- Process losses/generated waste
- Energy consumption / CO_2 emissions

The sector covers very different types of product, manufactured from various raw materials in various types and sizes of installation. The technical and economic feasibility, as well as the environmental impacts, of BAT varies significantly, being very much case-dependent largely because of the considerable variations in production technology such as for coarse ceramics, fine ceramics, and expanded clay aggregates. In the Nordic countries, there are only a few plants of each kind of production, with the exception of brick production, of which there are more than 15 plants with the majority in Denmark. In addition, the location of the plant and local conditions have influenced the environmental permits.

Presented BAT candidates are listed in Table 1: BAT Candidates.

Table 1: BAT Candidates

		Coarse ceramics plants	Fine ceramics plants
1	Re-use of process waste.	The re-use potential of on-site process waste at own plant is high.	The re-use potential of on-site process waste at own plant is limited. Recycling of process waste from fine ceramics manufacture limited to early process stages of sanitary ware. In household ceramics, recycling of process waste is in practice not applicable due to the more complex technology at the beginning of the production process.
2	Wastewater recycling and treatment.	Recycling of wastewater is relatively easy.	Most wastewater cannot be re-used, and it must be discharged to an efficient wastewater treatment plant to remove mainly inorganic solids and dissolved metals, usually by chemical precipitation and, optionally, by sand filtration. Exceptionally, adsorption or ion exchange in case fluoride or boron needs to be removed.
3	Replacing some raw materials with recycled materials.	Usually possible to some extent, e.g. various by-products and waste from other industries are used as materials in brick manufacturing and expanded clay aggregates production. Economics and applicability to be determined case-by-case.	Limited possibilities.
4	Use of modern automised process technology in casting of products to save energy and reduce waste.	Not applicable.	High-pressure casting reduces both the use of plaster molds in the factory and energy consumption.
5	Renewable energy.	Possibilities exist e.g. of using biogas or other renewable fuels as supplementary fuel. The feasibility and applicability of alternative renewable fuels is very case-specific.	Possibilities exist e.g. of using biogas or other renewable fuels as supplementary fuel. The feasibility and applicability of alternative renewable fuels is very case-specific.
6	Air emissions abatement by selection of raw materials and fuels.	Hydrogen fluoride emissions can be reduced by using low-fluorine raw materials. Sulfur dioxide emissions can be reduced by using low-sulfur raw material and fuel.	Hydrogen fluoride emissions can be reduced by using low-fluorine raw materials. Sulfur dioxide emissions can be reduced by using low-sulfur raw material and fuel.
7	Air emissions abatement by end-of-pipe treatment.	Fliters to reduce particulate emissions. Other measures are usually not economically feasible.	Textile fliters or electrostatic precipitators to reduce particulate emissions. Sometimes also removal of HF and HCl by lime scrubber, optionally wet alkaline scrubbers.
8	Energy efficiency of processes.	Tunnel kilns of sufficient lengths. Large numbers of well-controlled burners to allow optimizing of the temperature curve of the firing process. Heat exchangers for hot flue gases from kiln against air for drying and for heating of premises. Cooling air added after burning to be used in dryers. Good production planning to achieve operation with high load and to avoid losses.	Tunnel kilns of sufficient lengths. Large numbers of well-controlled burners to allow optimizing of the temperature curve of the firing process. Heat exchangers for hot flue gases from kiln against air for drying and for heating of premises. Cooling air added after burning to be used in dryers. Good production planning to achieve operation with high load and to avoid losses.
9	Operate an Environmental Management System (EMS).	Operate an Environmental Management System (EMS), including all its vital elements.	Operate an Environmental Management System (EMS), including all its vital elements.
10	Emissions monitoring.	At least twice a year for flue gas particulates, fluoride (HF), chloride (HCl), and Sulfur dioxide (SO_2). One measurement per year may be sufficient if the emissions are stable.	At least twice a year for flue gas particulates, HF, HCl, and SO_2. For effluent after treatment, suspended matter, biological and chemical oxygen demand (BOD and COD). One measurement per year may be sufficient if the emissions are stable. For plants with effluent treatment, required frequency of measurements depends on the characteristics of the plant.

Emerging techniques are BAT not yet fully developed or in use in the industry, although they may be relevant as BAT candidates in the future. The last chapter discusses areas of research and development in ceramic materials and their manufacturing techniques. Energy and resource efficiency are important topics of research and development in the industrial sector.

List of abbreviations

BAT Group	BAT Group is a sub-group of the Working Group for Sustainable Consumption and Production
BAT	Best Available Techniques
BREF document	Best Available Technology Reference Document
CER	Ceramic Manufacturing Industry
EMS	Environmental management systems
IED	The Industrial Emissions Directive (2010/75/EU)
LNG	Liquefied natural gas

1. Introduction

1.1 Background and objective

The BAT Group of the Nordic Council of Ministers has decided to conduct a project on Best Available Techniques (BAT) for the manufacture of ceramics (CER) in the Nordic countries.

The objectives of the project have been to:

- review and describe the ceramics manufacturing industry in the Nordic countries
- review and describe the techniques used in the Nordic countries
- identify and describe the main environmental indicators from the Nordic perspective
- identify and describe techniques to be included in the considerations in representing BAT in the manufacture of ceramics

The scope of the project covers the manufacture of the following product groups, which can further be divided into coarse ceramics and fine ceramics as follows:

Coarse ceramics:

- expanded clay aggregates
- vitrified clay pipes
- bricks and roof tiles
- refractory products

Fine ceramics:

- wall and floor tiles
- household ceramics
- sanitary ware
- technical ceramics
- inorganic bonded abrasives

The project covers the Nordic ceramics manufacturing plants with an environmental permit. These plants mainly include plants subject to the industrial emission directive (IED 2010/75/EU) but also a few smaller plants not meeting the IED definition. The project will serve as a Nordic contribution to the coming EU process in which BAT conclusions for the ceramics sector will be revised according to the industrial emission directive (IED 2010/75/EU). The work will also help in the national preparation for the upcoming process in the Nordic countries.

1.2 Approach and methodology

Information and data on the manufacture of ceramics, techniques used, and emissions were collected Nordic-wide from documents and contacts, supplemented by visits to several manufacturing plants. Plants of different types and sizes, using different types of equipment and manufacturing different types of products, were contacted and visited to establish the broadest possible project coverage. Industrial associations were also contacted.

In identifying the BAT candidates, a longlist of them was first developed. The shortlist of BAT candidates was then prioritized from the longlist according to the following priorities:

- BAT addressing the identified main environmental indicators
- BAT assessed to significantly reduce emission and impacts
- BAT which are economically and technically viable considering cost and advantages
- BAT primarily developed or originating in the Nordic countries

1.3 Team of consultants

The following consultants have contributed to the report:

Core team:

- Esa Salminen, Vahanen Environment Oy (Project Manager)
- Johan Mjöberg, Foritec AB
- Juhani Anhava, Anhava & Partnerts Oy

Support team:

- Hannu Pyy, Vahanen Rakennusfysiikka Oy

1.4 BAT Group

The BAT project has been observed and commented on by the Nordic BAT Group. The members of the BAT Group are:

- Anne Kathrine Arnesen, The Norwegian Environment Agency, Norway
- Kaj Forsius, Finnish Environment Institute
- Lena Ziskason, Environment Agency of the Faroe Islands
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- Mikael Stjärnfelt, Environmental and Health Protection Agency of the Aland Islands
- Birgitte Holm Christensen and Mette Lumbye Sørensen, Danish Environmental Protection Agency
- Elin Sieurin, Swedish Environment Agency

2. The manufacture of ceramics in the Nordic countries and the techniques used

2.1 The ceramics industry

The term ceramics refers to various types of product made of mostly inorganic and non-metallic materials by a firing process. The main raw material has traditionally been clay, whereas today ceramics also include a multitude of products with only a small fraction of clay or none at all. Ceramics can be glazed or unglazed, porous or vitrified. Typical properties of ceramic products include high strength, wear resistance, long service life, chemical inertness and non-toxicity, resistance to heat and fire, (usually) high electrical resistance and sometimes a specific porosity (European Commission 2007).

The scope of the project covers the manufacture of the following product groups divided into coarse ceramics and fine ceramics as follows:

Coarse Ceramics

- *Expanded clay aggregates* are porous ceramic products with a uniform pore structure of fine, closed cells and with a densely sintered, firm external skin. They are used as loose or cement bound material for the construction industry (e.g. loose fillings, lightweight concrete, blocks and other prefabricated lightweight concrete components, structural lightweight concrete for on-site processing) and loose material in garden and landscape design (e.g. embankment fillings in road construction, substrates for green roofs, filter and drainage fillings).
- *Vitrified clay pipes* and fittings are used for drains and sewers, as well as tanks for acids and products for stables.
- *Bricks and roof tiles* include, e.g. building bricks (e.g. clay blocks, facing bricks, engineering bricks ("klinker bricks") and lightweight bricks), roof tiles (e.g. extruded tiles, pressed tiles), paving bricks and chimney bricks (e.g. chimney pipes).
- *Refractory products* include ceramic materials capable of withstanding temperatures above 1,500 °C used in many industrial applications.

- *Wall and floor tiles* are thin slabs generally used as coverings for floors and walls.
- *Household ceramics* include tableware, artificial and fancy goods made of porcelain, earthenware and fine stoneware, e.g. plates, dishes, cups, bowls, jugs and vases.
- *Sanitary ware* includes lavatory bowls, bidets, wash basins, cisterns and drinking fountains.
- *Technical ceramics* include a diversity of products, e.g. electrical insulators, elements for the aerospace and automotive industries (engine parts, catalyst carriers), electronics (capacitors, piezo-electrics), biomedical products (bone replacement), environment protection (special filters).
- *Inorganic bonded abrasives* include tools used in working every kind of material: not only grinding, but also cutting-off, polishing, dressing, sharpening, etc. for metals, plastics, wood, glass, stones etc.

Table 2 shows the the production value of the members of the European Ceramic Industry Association, Cerame-Unie in 2017 (Source: Cerame unie, 2018, orig. Eurostat) and the European production of expanded clay aggregates in 2015 (the production of the members of the European Expanded Clay Association, EXCA).

Table 2: The European production of ceramics

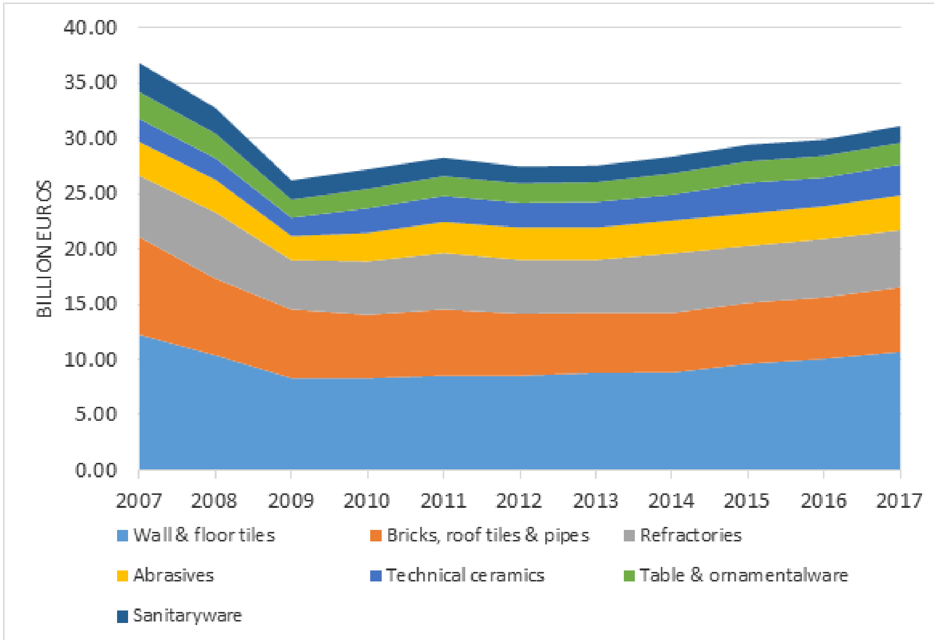
	Total EU production (billion, EUR) in 2017*
Wall and floor tiles	10.7
Bricks, roof tiles and pipes	5.8
Refractories	5.2
Abrasives	3.2
Technical ceramics	2.8
Table & ornamentalware	2.0
Sanitaryware	1.5
Expanded clay aggregates	0.14 in 2015**

Source: * Cerame unie, 2018, orig. Eurostat.

** European Expanded Clay Association (EXCA).

Figure 1 illustrates the production value of the members of the European Ceramic Industry Association, Cerame-Unie in 2007–2017. Expanded clay aggregates are not included in these figures. According to information obtained from the (EXCA), the production value of the European expanded clay aggregates industry has ranged between EUR 140 and EUR 180 million per year in recent years. Figure 2 illustrates the percentage of production value by European country in 2011. The Nordic countries comprise a few percent of total manufacture of ceramics in the EU, whereas the major producing countries in the EU are Italy, Germany, Spain, France, the UK, Poland, Portugal and Austria.

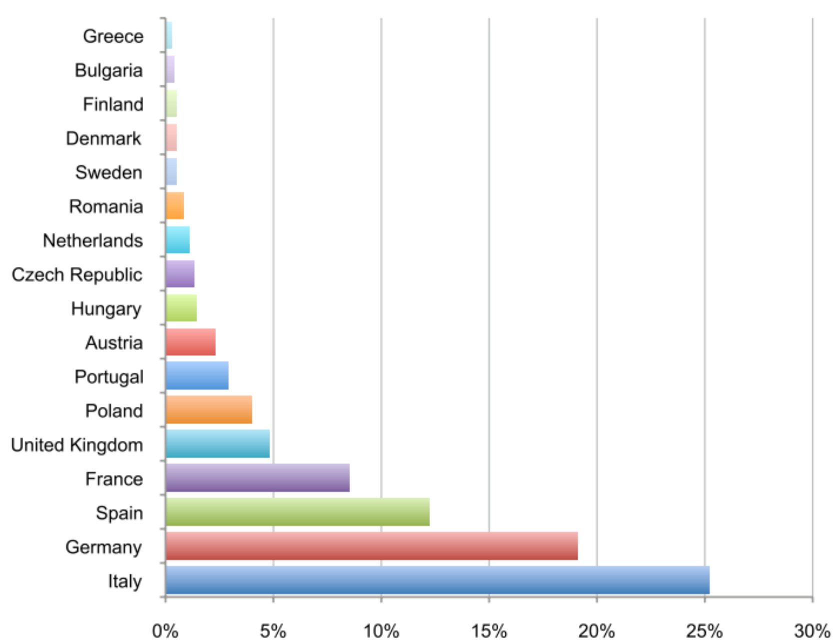
Figure 1: The production value in 2007–2017



Note: Expanded clay aggregates are not included in these figures.

Source: (Cerame unie, 2018, orig, Prodcom, Eurostat).

Figure 2: Percentage of production value of the members of the European Ceramic Industry Association, Cerame-Unie, in 2011



Note: Expanded clay aggregates are not included in these figures.

Source: (Cerame unie, 2018, orig, Prodcom, Eurostat).

2.2 The manufacture of ceramics in the Nordic countries

The manufacture of ceramics has a long tradition and has been a large industry in the past, with a few hundred plants in the Nordic countries. Today, there is a relatively small number of manufacturing plants left in the Nordic countries. Many of them belong to larger international industrial groups. Some companies still retain a brand, but these no longer manufacture ceramics in the Nordic countries.

This chapter briefly describes the industry sector in the different Nordic countries country by country. The number of permitted and IED plants in each country is given based on the available information.

2.2.1 Finland

In recent decades, the sector has concentrated. Many of the companies belong to larger international industrial groups, and many plants have ended their production in Finland.

IDO Kylpyhuone Oy Ab, producing sanitary ware in Raasepori, belongs to the Geberit group, and Leca Finland Oy, producing lightweight aggregate in Kouvola, belongs to the Saint-Gobain Weber group. Wienerberger Oy Ab produces bricks in Koria. Tiileri produces bricks and tiles at the Keramia Oy plant in Kemiönsaari and the Ylivieskan Tiili Oy plant in Ylivieska. Raikkonen Oy produces bricks in Loimaa. Based on the available information, these plants are all subject to the IED definition based on their permitted production capacity, but the current production of Ylivieskan Tiili Oy is less than the IED definition.

There was no readily available information on the permitted or current manufacturing of technical ceramics by Outotec Oyj in Turku.

Other ceramics manufacturers in Finland are small and do not require an environmental permit for their operations. The largest fine ceramics manufacturers in Finland are Pentik Oy in Posio and Vaja Finland Oy in Porvoo, although their production volumes do not exceed the environmental permit limits. Bet-ker Oy manufactures technical ceramics on a small scale. Turun Uunisepät Oy produces ceramic tiles on a small scale.

Some companies in the sector still retain a brand remaining, but these no longer manufacture ceramics in the Nordic countries, e.g. Pukkila Oy and Fiskars Oyj.

2.2.2 Sweden

In Sweden, the largest ceramics plant is the IFÖ complex at Bromölla. After 2000, this complex was divided into four different companies, where IFÖ Sanitary, now part of the Geberit Group. is the largest unit. The other three units make electric insulators (IFÖ

Ceramics, part of PPC Insulators, to be closed by the end of 2018), various products for electric applications, and various specialty ceramic products.
In Sweden, there is also one plant for the manufacture of roof tiling (Monier) at Vittinge and one for building bricks (Wienerberger) close to Enköping. Finally, there is one plant (Höganäs Bjuf) at Bjuv making refractory products.

Another two small plants (Horn's brick plant and the Bältarbo brick plant) produce bricks in a few batches per year, but are not subject to any environmental permits for the production.

In summary, the following list shows all the current Swedish ceramics plants where IFÖ Electric and Bromölla Specialkeramik are below the IED limits:

- IFÖ Sanitary, Bromölla, part of the Swiss Geberit Group
- IFÖ Electric AB, Bromölla (non-IED)
- Bromölla Specialkeramik AB, Bromölla (non-IED)
- Monier Roofing AB, Vittinge
- Wienerberger AB Haga Tegelbruk, Enköping
- Höganäs Bjuf AB, Bjuv, part of the Borgestad Group in Norway

2.2.3 Denmark

In Denmark, there is still a fairly large number of brick plants due to the abundance of suitable clay raw material in the ground. In total, there are 14 brick and roof-tiling plants, although the number was almost double this 15 years ago. The international groups Monier and Wienerberger run three plants, but the two Danish groups Egernsund and Randers operate 9 plants in total and there are two independent plants.

In Denmark, there is also a Leca plant for lightweight aggregates (part of the Saint-Gobain Weber group), Hasle Refractories and Landson Emission Technologies, a producer of specialized particulate filters made from silicon carbide (SiC) mainly for diesel exhaust-gas cleaning.

In summary, the following list shows all the current Danish ceramics plants, which are all subject to the IED definition based on the available information:

- Carl Matzens Teglværk, Egernsund
- Gandrup Teglværk, Randers
- Gråsten Teglværk, Egernsund
- Hammershøj Teglværk, Randers
- Hasle Refractories
- Hellingsø Teglværk, Egernsund
- Højslev Teglværk, Randers
- Pedershvile Teglværk, Wienergberger
- Petersen Tegl, Egernsund

- Petersminde Teglværk, Wienerberger
- Vedstaarup Teglværk, Strøjer
- Vesterled Teglværk, Egernsund
- Villemoes Teglværk, Gørding Klinker
- Vindø Teglværk, Randers Tegl
- Volstrup Teglværk, Monier
- Leca Danmark, Saint-Gobain Weber
- Landson Emission Technologies

2.2.4 Norway

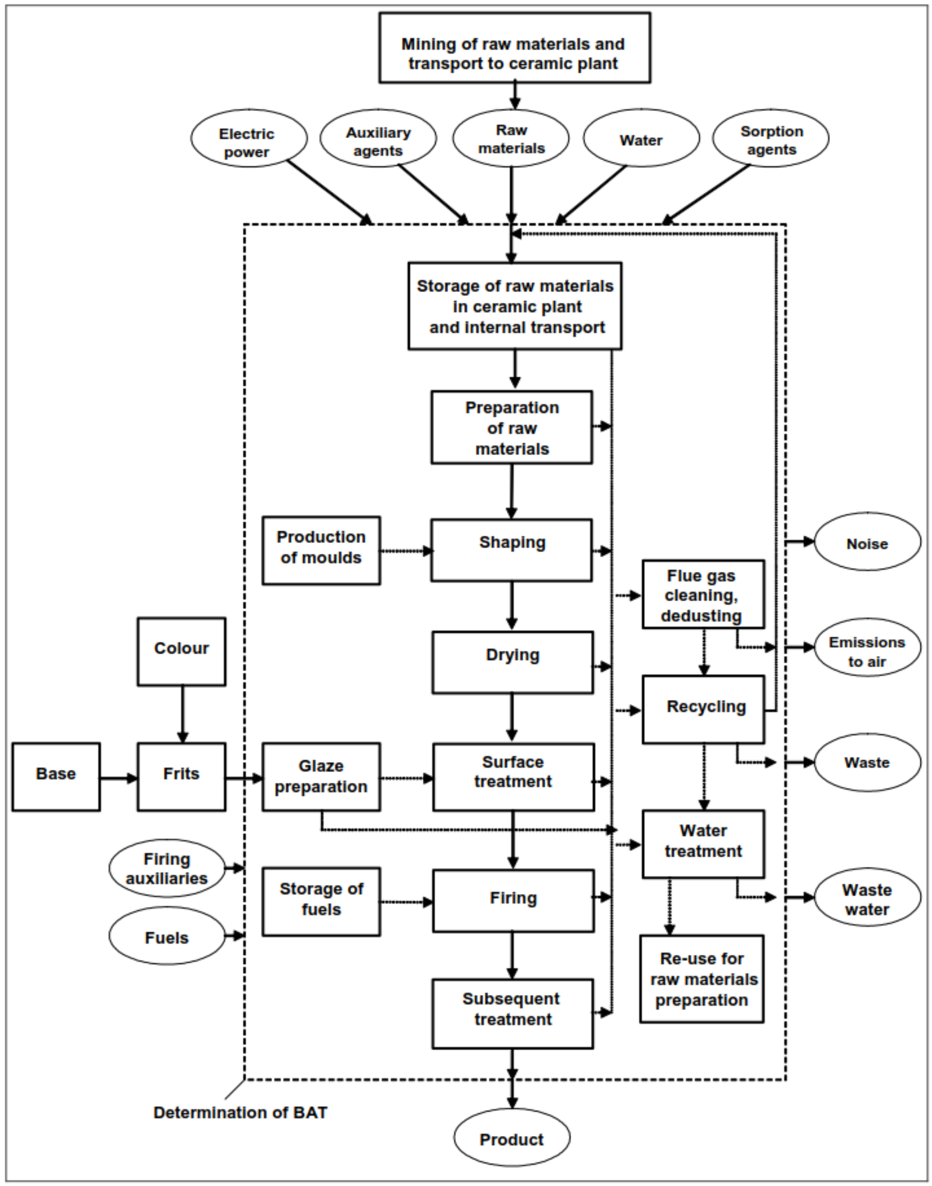
Norway has three installations: Figgjo, producing household ceramics; Leca Norge AS, producing lightweight aggregate; and Norsk Teknisk Porselen AS, producing insulators and ceramic components.

2.3 Commonly used techniques in the manufacture of ceramics

The following main steps apply generally to all ceramic products (see Figure 3):

- mining/quarrying of raw materials and transport to the ceramics plant (not included in the scope of this study)
- storage of raw materials
- preparation of raw materials
- shaping
- drying
- surface treatment
- firing
- cooling
- quality control and packaging of products

Figure 3: Schematic drawing of general ceramics manufacturing process



Source: (European Commission 2007)

Dry raw materials are stored at ceramics plants in open stockpiles, warehouses, large volume feeders or silos; liquid raw materials are stored in tanks or IBCs. Preparation of raw materials (e.g. pre-drying, pre-blending, weathering/souring, grinding and/or screening) and of frits and glazes can take place at the site.

Figure 4: Raw material silos at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

Figure 5: Raw material storage area at Wienerberger Oy Ab

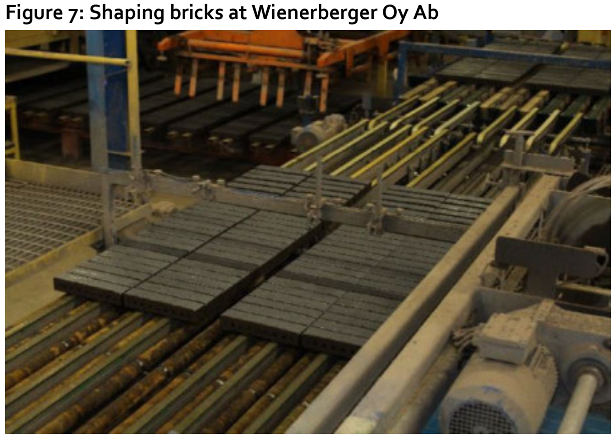
Source: (Photograph: Esa Salminen, 2018).

Figure 6: Feeding of raw material into the process at Wienerberger Oy Ab

Source: (Photograph: Esa Salminen, 2018).

In the process, raw materials are mixed (batch or continuous) and cast, pressed or extruded into shape (various techniques are in use, e.g. slip casting, molding, mechanical or hydraulic pressing and extrusion). Water used in mixing and shaping evaporates in drying (various forms of dryers are in use, e.g. chamber and tunnel dryers).

Figure 7: Shaping bricks at Wienerberger Oy Ab



Source: (Photograph: Esa Salminen, 2018).

Figure 8: Sanitary ware before drying at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

Figure 9: Dried bricks at Wienerberger Oy Ab

Source: (Photograph: Esa Salminen, 2018).

Surface treatment and decoration of ceramic products then takes place, e.g. glazing (see Figure 10).

Figure 10: Surface treatment at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

Firing controls many important properties of the finished product. Various techniques are in use, e.g. chamber, tunnel and rotary kilns. (The rotary kilns are used for the production of expanded clay aggregates.) The heat needed for the kiln is related to the process temperature required for the particular production (further details are in Chapter 4.5). The required firing temperature is typically created by burning natural gas, propane or fuel oil.

Figure 11: Firing of sanitary ware at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

Figure 12: Modern tunnel kiln with a large number of pulse burners

Source: (Photograph: Johan Mjöberg, 2018).

Subsequent treatment may include machining (grinding, drilling and/or sawing), polishing or carbon enrichment (refractory products). Finally, the addition of auxiliary materials and final assembly, sorting, packaging and storage takes place before the delivery of the products.

Figure 13: Final assembly of products at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

The technology for the manufacture of expanded clay aggregates differs substantially from other ceramics industries and is actually more closely resembles the cement industry than other ceramics industries, at least with respect to the kiln design. For expanded clay production the kiln is of a rotary type, with the burner located at the lower end of the inclined kiln.

Figure 14: During the expanded clay aggregates manufacturing process at Leca Finland Oy, the prepared raw material is first dried and then fired when passing through a rotary kiln

Source: (Photograph: Esa Salminen, 2018).

3. Brief regulatory review

The European Commission's BREF document on the Ceramic Manufacturing Industry (CES) is to be revised according to the IED 2010/75/EU. The current BREF is from 2007, and its review starts in 2019.

Annex I (Section 3.5) of the IED states threshold values for the directive as follows: Installations for the "manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day, and/or with a kiln capacity exceeding 4 m^3 and with a setting density per kiln exceeding 300 kg/m^3".

Other relevant EU legislation applying to some of the installations in the sector includes:

- The Medium Combustion Plant (MCP) Directive (2015/2193)
- The EU Emissions Trading System (EU ETS)

3.1 Finland

The IED is implemented in Finland as part of the renewed Environmental Protection Act (527/2014) and Decree (713/2014, amended 584/2017). According to the Decree, the Regional State Administrative Agencies (AVI) in Finland license ceramics manufacturing plants with production capacity exceeding the IED limits. The permitting authority is the municipality for installations for:

- ceramics or porcelain production with a capacity exceeding 200 tonnes per year
- lightweight bricks production with a capacity exceeding 3,000 tonnes per year

The Centres for Economic Development, Transport and the Environment (ELY Centres) supervise adherence to the environmental and water permits granted by AVI. Municipalities supervise the environmental permits they grant.

3.2 Åland Islands

Åland has its own provincial laws in a number of important areas based on its autonomous position. The environmental licensing for industrial plants is outlined in the Provincial law on environmental protection (ÅFS 2008:124, ändrad ÅFS 2015:14) and decree (ÅFS 2008:130, ändrad ÅFS 2015:15). A license is required for ceramics manufacturing plants with a production capacity exceeding the IED limits. The permitting authority is the environmental and health protection agency of Åland (ÅMHM).

3.3 Denmark

Industrial activities in Denmark are subject to Environmental Protection Law (LBK nr966 af 23/06/2017). The environmental IED is implemented in Denmark and included in the Executive Order for environmental permitting of companies (BEK nr1458 af 12/12/2017). Environmental permits for IED companies are reviewed case by case and must fulfill the BAT conclusions under the IED.

Supervisory responsibilities and functions are presented and defined in a recent Executive Order (BEK nr1476 af 12/12/2017).

The Executive Order for the environmental permitting of companies (BEK no. 514 from 27/05/2016) is part of the new environmental regulatory system, based on a digitalisation regime.

The discharge of wastewater and stormwater is covered by the permit when directly discharged into the recipient. The discharge is subject to a discharge permit (BEK nr1469 af 12/12/2017) when discharged into the public sewer system.

3.4 Norway

Industrial activities in Norway are subject to the Act 13 of March 1981 no. 6 relating to protection against pollution and relating to waste. The IED is implemented in Norwegian legislation by the Pollution Regulation and the Waste Regulation. Environmental permits for IED companies are reviewed case by case and must fulfill the BAT conclusions under the IED. The permitting authority for plants subject to the IED is the Norwegian Environment Agency (Miljødirektoratet). Permits for smaller plants, not subject to the IED, are issued by the County Governor.

3.5 Sweden

The overall environmental legal framework in Sweden is based on the Environmental Code (1998:808). The regulations of the IED are implemented in Swedish law by generally binding rules, mainly in the Ordinance on Industrial Emissions (2013:250). The Ordinance on Environmental Permitting (2013:251) defines conditions and considerations for the granting of environmental permits. The licensing process in the Swedish Environmental Code is not changed by the implementation of the IED. BAT conclusions are implemented as a parallel system through generally binding rules which are currently being updated with the publication of new BAT conclusions.

The environmental licensing for industrial plants is outlined in the Swedish Environmental Code (2013:51) and is based on case-by-case assessments of environmentally hazardous activities and considering local conditions. Permits for plants are issued by the County administrative boards.

The supervision of larger industrial operations is undertaken by the County administrative boards, while the local municipal and environmental committee may be responsible for the supervision of smaller industrial operations.

3.6 Iceland

Industrial activities in Iceland are subject to the Act no. 7/1998 on hygenic and pollution control. The IED was implemented in the act as of 1 June 2017. The permitting authority is The Environment Agency of Iceland for plants subject to the IED. Each permit is reviewed case by case and must fulfill the BAT conclusions under the IED. For smaller plants, not subject to the IED, the Board of Public Health in the relevant municipal control district issues the permit.

3.7 Faroe Islands

The Faroe Islands have their own laws in a number of important areas based on their autonomous position. The environmental legislation for industrial plants is outlined in the Act on Environmental Protection from 1988.

4. Environmental impacts from the manufacture of ceramics and main environmental indicators

The main environmetal indicators in the scope of this study are (in non-prioritized order):

- Raw materials, additives/chemicals and fuels
- Emissions to air
- Emissions to water
- Process losses/generated waste
- Energy consumption /CO2 emissions

In Chapter 5, BAT candidates are described within each of the listed main environmetal indicators.

In addition, noise and odor and soil contamination risks are briefly discussed. These environmental impacts do not differ significantly from other industries: c.f. the other general BAT candidates in Chapter 6.

4.1 Raw materials, additives/chemicals and fuels

Raw materials include the main body forming materials of ceramics, as well as various additives, binders and decorative surface-applied materials used in smaller quantities. Traditionally, the main raw material for ceramics has been clay, whereas today a diversity of raw materials, mostly inorganic, non-metallic materials is used (e.g. sand in defined particles range). The porosity of the product is created by adding fine organic material like sawdust to the mix, which is burnt in the kiln leaving a porous structure. For sanitary ceramics, glazing is used to include zinc as oxide (ZnO), which is an accumulating element. Today, these plants have changed to glazing containing non-accumulating strontium as carbonate ($SrCO_3$). In addition, due to environmental concerns, the two Nordic plants for sanitary ceramics have ceased using colouring materials, and all their products are now white.

Process loss from production before surface treatment can be recycled as raw material. By-products and waste from other industries can be used in varying amounts as raw material (for further details see Chapters 5.1 and 5.3)

The raw materials and fuels significantly affect the composition of air emissions (for further details, see Chapters 4.3 and 5.6).

Figure 15: Good housekeeping of non-bulk chemicals in storage of chemicals at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

Figure 16: Fuel tank for forklifts at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

4.2 Emissions to water

The amount of water used in production varies greatly between sectors and processes. The water added to the raw material evaporates into the air during the drying and firing stages, whereas wastewater is generated e.g. in processing, equipment cleaning and in wet scrubbers for off-gases. In general, in coarse ceramics manufacturing, all wastewater can be recycled into a raw material mixture, whereas in fine ceramics, there are limited possibilities for this, and in general, more water is used in fine ceramics production. Many brick plants basically have no water discharge at all except for sanitary wastewater.

Good quality water is essential for (BAT Guidance note on Best Available Technique for the manufacture of Ceramic Products and Industrial Diamonds, Irish Environmental Protection Agency 2008):

- the preparation of clays and glaze slips
- clay bodies for extrusion and ”muds” for molding
- the preparation of spray dried powders
- wet grinding / milling
- washing operations

The use of water can be reduced, e.g. by automatic valves or a high-pressure system for cleaning purposes (BAT Guidance note on Best Available Technique for the manufacture of Ceramic Products and Industrial Diamonds, Irish Environmental Protection Agency 2008).

After clarifying, water can often be re-used or recirculated before the excess water is discharged for wastewater treatment (for further details see Chapter 5.2).

Typical pollutants released from the wastewater are:

- suspended solids, e.g. clays, frits and insoluble silicates
- sulphates and carbonates and other dissolved anions
- suspended and dissolved heavy metals, e.g. lead and zinc
- boron in small quantities
- traces of organic matter (oil and grease, polymeric additives)

Wastewater re-use and treatment options are discussed in Chapter 5.2.

4.3 Emissions to the atmosphere

Air emissions from ceramics manufacturing include dust (particulate matter) and gaseous emissions.

Dust (particulate matter) is formed in the processing of clays and other dry raw materials, during decorating and firing of the ware and during machining (grinding, drilling and sawing) or finishing operations on fired ware. Fuels also contribute to these emissions to the air.

Gaseous emissions are released during drying, calcining and firing and are derived from the raw materials, as well as from fuels. Carbon dioxide is, of course, generated by all fuels, but carbon monoxide may be released due to non-optimal combustion conditions. Fluori~~n~~de compounds represent one of the typical principal pollutants from ceramics processes because of the presence of fluorides in the clays. Other gaseous emissions include sulfur dioxide and nitrogen oxides, hydrogen chloride and metals and their compounds. Sulfur dioxide emissions are related to the sulfur content of the raw material and of the fuel. For instance, the raw material for yellow bricks contains considerably more sulfur than the material for red bricks. Nitrogen compounds are present in fuels or in organic additives, and originates from the nitrogen in the air. Chloride compounds are derived from clays or additives. Metals and their compounds are released due to the use of substances for decorative purposes which may contain heavy metals, or due to the usage of heavy oil as fuel.

Figure 17: Lime scrubber at IFÖ Sanitary (Geberit) (behind the horizontal pipelines)

Source: (Photograph: Johan Mjöberg, 2018).

4.4 Process losses/generated waste

Process losses/waste include:

- different kinds of sludges
- broken material/products
- dust from flue-gas cleaning
- used molds
- used sorption agents
- packaging waste
- ashes and other solid residues

Figure 18: Wastewater sludge at IDO Kylpyhuone Oy Ab

Source: (Photograph: Esa Salminen, 2018).

Figure 19: Broken material/products at IDO Kylpyhuone Oy Ab

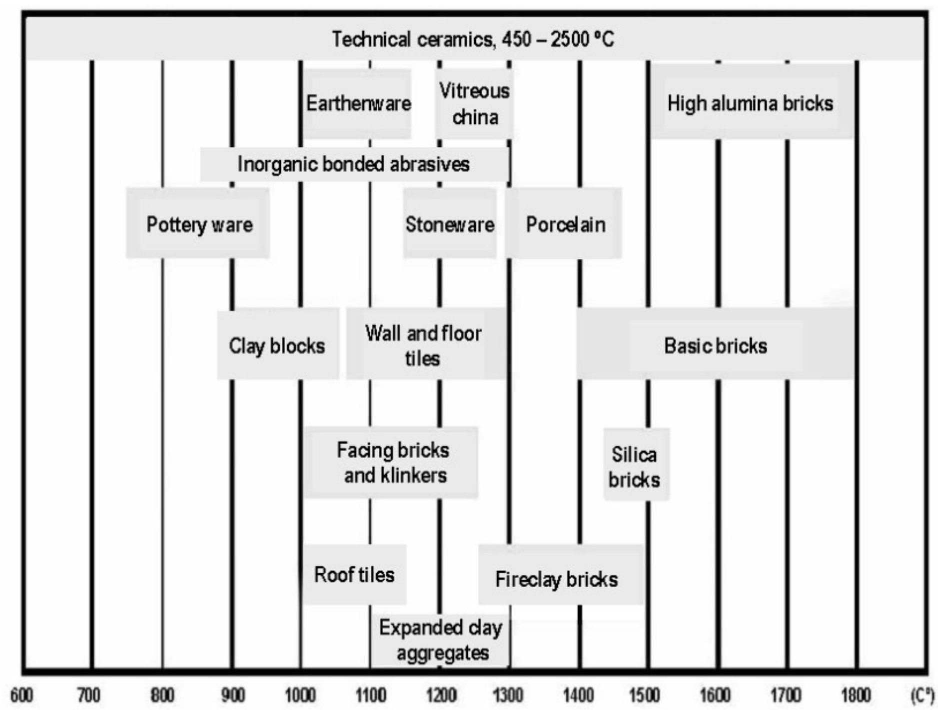
Source: (Photograph: Esa Salminen, 2018).

4.5 Energy consumption / CO2 emissions

Burning is an essential part of ceramics manufacturing and controls many important properties of the finished product. The heat needed for the kiln is related to the process temperature required for the particular production. Building materials (bricks, roof tilings) typically require a kiln temperature of between 750 and 1,050 °C, depending on clay quality and product demands. Refractory materials are burnt at higher temperatures, for example, between 1,350 and 1,600 °C, depending on materials and product demands and thus requiring more heat (fuel).

Different clays have different properties and the burning temperature is always optimized to local demands.

Figure 20: Ranges of industrial maturing temperatures for different product groups



Source: (European Commission 2007).

Energy for the processes is generated by the combustion of natural gas, propane or fuel oil. In the late 1960s, many brickworks in the Nordic countries used coal or oil as fuel for firing. Today, natural gas is the fuel for almost all brick production in the Nordic countries. In Denmark, it has been estimated that this change has reduced CO_2 discharges by approximately 40–50%. Combined with the energy savings made in the production process, the Danish brick industry has estimated that the total CO_2 discharges from the brick industry have been reduced by more than 75% over the last 20 years (The European Ceramic Industry Association, 2018). When natural gas is not available, the Nordic plants use propane (or LPG, liquefied petroleum gas), with similar benefits to using natural gas.

Correspondingly, because of the change from coal and oil to natural gas or propane as fuel, the industry's sulfur dioxide emissions have also been reduced significantly.

Basically all the heat for a ceramics plant is generated for the kiln, while the remaining heat in the flue gases from the kiln and in the materials produced is used for all other purposes in the plants, primarily the drying of materials before kilning and for general heating purposes.

The ceramics industry is continuing to improve its energy efficiency whenever economically viable. A crucial issue for energy consumption is the process load and interruptions in the kiln. In all process industries, high load and no interruptions result in lower energy consumption due to fewer losses. Thus, for instance, a continuous kiln (tunnel or fast-fire roller kiln) is advantageous to batch furnaces because the batch plants will need to be re-heated for each new cycle. Significant reductions in energy consumption have also been made, for example, through better kiln design, more efficient firing and better control.

It is noteworthy that the sector is capital intensive with long investment cycles. Kilns for ceramics production representing a principal investment can last more than 40 years.

The electricity needed for motors, fans, light, etc. in terms of energy corresponds to typically about 10% of the heat demands on average. It is also important for electricity consumption to avoid interruptions or disturbances in the production.

4.6 Noise and odor

Noise limits correspond to general industrial requirements. Typically, there are different noise limits for day (e.g. 55 dB 7:00–22:00) and night (e.g. 50 dB 22:00–7:00), measured at points outside the plant area. The surrounding land use can also affect the noise limits set. Noise limits in the different Nordic countries and the different possibilities of mitigating noise were recently discussed in more detail in the publication "Best Available Technique: Buller från bergtäkter" (2013).

Noise can be reduced by:

- enclosure of units
- vibration insulation of units
- using silencers and slow rotating fans
- situating windows, gates and noisy units away from neighbors
- sound insulation of windows and walls
- closing windows and gates
- carrying out noisy (outdoor) activities only during the day
- good plant maintenance
- avoiding noisy internal transports by using electrically driven loaders and lifters

Some raw material components may cause odors in firing, but in general, odor has a minor environmental impact for this industrial sector.

4.7 Soil contamination risks

Storage and handling of raw materials, fuels, additives and other chemicals poses a potential soil contamination risk. If some raw materials are replaced with recycled materials, there is a larger soil contamination risk than when natural clay materials are used.

5. BAT Candidates

When identifying the BAT candidates, a longlist was first developed. The shortlist of BAT candidates was then prioritized from the longlist according to the following priorities:

- BAT addressing the identified main environmental indicators
- BAT assessed to have a significant reduction in emission and impacts
- BAT which is economically and technically viable considering the cost and advantages
- BAT which is primarily developed or originates in the Nordic countries

The sector covers very different types of products, manufactured from various raw materials in various types and sizes of installation. The technical and economic feasibility, as well as the environmental impacts, of BAT varies greatly, being very much case-dependent largely because of the considerable variations in production technology, such as for coarse ceramics, fine ceramics and expanded clay aggregates. In the Nordic countries, there are only a few plants of each kind of production, with the exception of bricks production, where there are more than 15 plants, with the majority in Denmark. In addition, the location of the plant and local conditions have influenced the environmental permits.

This chapter refers primarily to the European Commission BREF document from August 2007. In many respects, this document is still valid for the Nordic ceramics industry, which is not undergoing strong technical development: many measures environmentally relevant in 2007 are still valid and applicable. Emission levels are also compared to the recent reports by Umweltbundesamt (2018) and Ricardo Energy & Environment (2018), which describe the state of the art / BAT in installations for the manufacture of ceramics production, mainly with reference to Austrian and German installations.

Presented BAT candidates are listed in Table 3.

Table 3: BAT Candidates

		Coarse ceramics plants	Fine ceramics plants
1	Re-use of process waste.	The re-use potential of on-site process waste at own plant is high.	The re-use potential of on-site process waste at own plant is limited. Recycling of process waste from fine ceramics manufacturing is limited to early process stages of sanitary ware. In household ceramics recycling of process waste is in practice not applicable, due to more complex technology at the beginning of the production process.
2	Wastewater recycling and treatment.	Recycling of wastewater is relatively easy.	Most wastewater cannot be re-used and has to be discharged to an efficient wastewater treatment plant to remove mainly inorganic solids and dissolved metals, usually with chemical precipitation and optionally with sand filtration. Exceptionally, adsorption or ion exchange is used in case fluoride or boron has to be removed.
3	Replacing part of raw materials with recycled materials.	Usually possible to some extent, e.g. various by-products and waste from other industries are used as materials in brick manufacturing and expanded clay aggregates production. Economics and applicability is to be determined case by case.	Limited possibilities
4	Use of modern automised process technology in casting of products to save energy and reduce waste.	Not applicable.	High-pressure casting reduces both the use of plaster molds in the factory and energy consumption.
5	Renewable energy.	Possibilities exist e.g. to use biogas or other renewable fuels as supplementary fuel. The feasibility and applicability of alternative renewable fuels is very case-specific.	Possibilities exist e.g. to use biogas or other renewable fuels as supplementary fuel. The feasibility and applicability of alternative renewable fuels is very case-specific.
6	Air emissions abatement by selection of raw materials and fuels.	Hydrogen fluoride emissions can be reduced by using low-fluorine raw materials. Sulfur dioxide emissions can be reduced by using low-sulfur raw material and fuel.	Hydrogen fluoride emissions can be reduced by using low-fluorine raw materials. Sulfur dioxide emissions can be reduced by using low-sulfur raw material and fuel.
7	Air emissions abatement by end-of-pipe treatment.	Fliters to reduce particulate emissions. Other measures are usually not economically feasible.	Textile fliters or electrostatic precipitators to reduce particulate emissions. Sometimes also removal of HF and HCl by lime scrubber, optionally wet alkaline scrubbers.
8	Energy efficiency of processes.	Tunnel kilns of sufficient lengths. Large numbers of well-controlled burners to optimize temperature curve of the firing process. Heat exchangers for hot flue gases from the kiln against air for drying and for heating of premises. Cooling air added after burning to be used in dryers. Good production planning to achieve operation with high load and to avoid losses.	Tunnel kilns of sufficient lengths. Large numbers of well-controlled burners to optimize temperature curve of the firing process. Heat exchangers for hot flue gases from the kiln against air for drying and for heating of premises. Cooling air added after burning to be used in dryers. Good production planning to achieve operation with high load and to avoid losses.
9	Operate an Environmental Management System (EMS).	Operate an Environmental Management System (EMS), including all its vital elements.	Operate an Environmental Management System (EMS), including all its vital elements.
10	Emissions monitoring.	At least twice a year for flue gas particulates, fluoride (HF), chloride (HCl), and sulfur dioxide (SO_2). One measurement per year may be sufficient if the emissions are stable.	At least twice a year for flue gas particulates, HF, HCl, and SO_2. For effluent after treatment, suspended matter, biological and chemical oxygen demand (BOD and COD). One measurement per year may be sufficient if the emissions are stable. For plants with effluent treatment, required frequency of measurements depends on the characteristics of the plant.

5.1 BAT Candidate no. 1 – Re-use of process waste

5.1.1 Introduction

Process waste is usually generated in all process stages of ceramics production, and its amount varies considerably, depending on the type of production and the process technology applied. The moisture content of process waste is higher in the early stages of production and decreases significantly in drying and firing. "Process waste" here means mainly rejected materials from the main product material flow but also – to a minor extent – used plaster molds from casting.

The requirements for raw materials depend on what kind of material can be accepted in the recipes of different products, how homogenous they need to be, what kind of casting and shaping is applied etc.

The requirements for raw materials are generally higher with fine ceramics compared to coarse ceramics. Process waste of coarse ceramics can often be recycled in a plant's own production to some extent only before glazing, drying and firing. In fine ceramics production, recycling is often impossible in practice due to the more complex first stages of the process than is the case in coarse ceramics production.

In coarse ceramics manufacturing, most of the process waste is usually reusable in raw material preparation in a plant's own production.

In several environmental permits, there is a general obligation to reduce the generation of waste, and this encourages the plants to seek different ways to re-use process waste (Environmental permits of Geberit / IDO, Finland 2007 and Saint Gobain / LECA Finland 2017).

5.1.2 Applied processes and techniques

The recycling of dust from the grinding and milling of raw materials requires collection and removal of dust from exhaust air and the transfer of the recovered dust back to the starting point of the process, mixing of raw materials.

The recycling of wet process material from casting requires the recovery of rejected products or pieces followed by shredding of the wet material and mixing with water to form a slurry which can be pumped back to mixing of raw materials.

The recycling of dry process waste after drying and firing stages in the process requires the grinding and sorting of the waste if the type of material can be accepted as new raw material.

The recycling of used plaster molds from casting can take place only externally. Used plaster molds made of gypsum can in principle be re-used as raw material in the gypsum board industry when such plants are within a reasonable distance of the ceramics production plant. However, these circumstances are rare and usually the gypsum molds end up in landfills. Today, in the Nordic ceramics industries, gypsum molds are only used to a small extent at Geberit's two plants (IDO and IFÖ), since most of the moulds are now made of polymers with much longer life time.

The recycling of process waste from fine ceramics manufacturing may be possible only externally, e.g. in brick manufacturing.

Solid residues from burnt bricks may also be used for various filling purposes, especially on roads. Some residues can be used after grinding on certain tennis courts, giving the top layer of the court its characteristic red colour.

5.1.3 Emission and consumption figures

The recycling and re-using of dust from milling, screening or other dry processing of waste from the later stages of production require filters or similar equipment designed for dust removal to limit air emissions. With modern dust control equipment, dust can be removed with very high efficiency from the exhaust gases, and the remaining dust (particulates) concentration can be reduced to 1 … 10 mg/Nm^3.

5.1.4 Applicability

The re-use potential of on-site process waste at the same plant is high (a minimum of 50% and up to 90 – 100%) in the production of bricks and expanded clay products. It has been required as an important general objective in the environmental permit of Saint Gobain LECA Finland, but no specific percentage has been demanded, because this percentage depends on the specifications of final products.

In the fine ceramics industry, the re-use potential of on-site process waste at the same plant is considerably more limited due to the higher requirements for raw materials than in coarse ceramics plants. The recycling potential of process losses from fine ceramics manufacturing is very case-specific.

5.1.5 Cross-media effect

The re-use of wet process waste reduces the solid material discharge to wastewater treatment and the amount of sludge generated in the wastewater treatment plant.

The re-use of dry process waste somewhat increases the energy consumption, due to the grinding and milling of process waste before re-use. It also increases the emissions to air, but utilizing proper pollution control equipment, like filters and scrubbers, no significant increase of dust or other air pollutants is likely to take place.

5.1.6 Economics

The economics of this BAT can be discussed on a general level, as the costs depend on the type of production technology. The re-use of process waste can at best slightly decrease the raw material costs. In addition, it may somewhat decrease the waste disposal costs and waste taxes associated with the total amount of waste produced.

The costs depend on the type of ceramics production. For the reasons mentioned earlier in this section, the recycling costs of process waste has a larger influence on savings in production cost of coarse ceramics than in fine ceramics.

5.1.7 References

Finnish Environment Institute, 2004

Environmental permits of Geberit / IDO, Finland, 2007 and Saint Gobain / LECA Finland, 2017, visit to Geberit IDO plant in Finland in 2018.

5.2 BAT Candidate no. 2 – Wastewater recycling and treatment

5.2.1 Introduction

The ceramics industry does not generally use large amounts of water, and water can often be re-used or recirculated before excess water is discharged to wastewater treatment.

Process water occurs in small quantities in the manufacture of *coarse ceramics* in the forming stage and in the cleaning of process equipment. The recycling of wastewater is relatively easy because less wastewater is produced than the amounts evaporated in the drying and firing of products.

In the *fine ceramics* industry, water is needed mainly to prepare raw materials for slurries, cleaning, grinding, exhaust gas scrubbers and sealing of pumps. Water is also needed for cooling in heat exchangers and since cooling water remains clean it can be repurpoused or collected and discharged to rainwater drainage.

Wastewaters are generated from the flushing and cleaning of process equipment, pipes and tanks on a discontinuous basis. Waters from equipment flushing from the first stages before glazing can sometimes be collected in a tank and recirculated to the previous stages of wet processes to reduce the need for fresh water to be used in slurry preparation. The dry solids (DS) content of slurries is typically 30–40%. However, raw materials are often fed to the molds at high solid content (95–98% DS), and hence much less water is required for raw material preparation, and there is much less room for recycling in the water balance.

However, when wastewater cannot be re-used, it must be discharged to an efficient wastewater treatment plant. Equipment cleaning waters after glazing contains glazing material, and floor cleaning waters contain substances such as sand, pieces of intermediate products and sometimes oil residues leaked from lubrification, gearboxes and similar mechanical equipment. These wastewaters cannot be recycled and must be discharged to wastewater treatment. During the start-ups and shut-downs of the process, the recovery of all water may also be limited by the size of collection tanks, and in these cases, some process water will also be discharged to a wastewater treatment plant.

With plants producing more wastewater than can be recycled, a separate wastewater treatment plant is needed at the plant. The treated excess wastewater is then discharged to a recipient or to a municipal sewer. Wastewater treatment is designed to remove mainly inorganic solids and dissolved metals ions, usually by chemical precipitation and optionally by adsorption or ion exchange if fluoride or boron needs to be removed.

5.2.2 Applied processes and techniques

In the *Coarse Ceramics Sector* – production of bricks or expanded products – the generation of wastewater is very small and all wastewater can be recycled back to the beginning of the process where materials are mixed prior to casting. Wastewater contains mainly suspended solids, which are released from the different stages of the production line during the cleaning and flushing of equipment. These waters are collected in a tank or basin below the floor level of the production area and pumped back to the raw material treatment area. Larger pieces of process rejects are separated from circulating water by screening, and screened material can be ground with the grinding or milling of dry process waste and then re-used as raw material.

Wastewater can also be produced from flue gas cleaning. If sorted waste is used to replace fossil fuels, wet scrubber must be used for flue-gas cleaning, and this produces wastewater which cannot be recycled. This wastewater typically contains 30–45 mg/l of suspended solids and 0.03–1.5 mg/l of various heavy metals such as mercury (0.03 mg/l) and zinc (1.5 mg/l), which cannot be recycled but must be neutralized to a pH of 6–9 (according to Environmental permits of Saint Gobain / LECA Finland [2017] and Norway [2004]). Limit values for heavy metals are set in a range of 0.03 mg/l (mercury) to 1.5 mg/l (zinc) according to the Environmental permit of Saint Gobain / LECA Finland (2017). In LECA Finland, the scrubber is currently not used (because the heat recovery cannot be re-used) and has been replaced by an electrostatic filter followed by a fiber filter in air emissions treatment.

In the *Fine Ceramics Sector*, the water balance calculations and practical experience from different plants show that more water must be discharged than can be recycled. A modern treatment plant for such surplus water consists of the following unit processes. A buffer tank is usually needed as the first stage of treatment to ensure as even a flow as possible to the next stages. Sometimes the wastewater can contain oil, which first has to be removed with standard oil separation equipment using compressed air or lamella plates in the separator. The main wastewater treatment stage is chemical precipitation, followed by the settling of suspended solids in a clarifier. Clarifiers are circular or rectangular basins and the settling of solids can be enhanced with lamella plates inside the clarifier. From the bottom of the clarifier a slurry of suspended solids with 2–5% concentration is pumped and dewatered with centrifuges to 25–30% dry solids content. This sludge can then be transported for re-use in the brick and cement industries, the capping of landfills or other beneficial use. Otherwise the sludge can be disposed of in standard landfills.

When environmental permits or other guidelines states high requirements for maximum allowed amounts of suspended solids in waste water sand filters may be required as the final stage of waste water treatment before discharge to recipient or municipal sewer.

5.2.3 Emission and consumption figures

In the mechanical and chemical treatment of wastewater, suspended solids can be removed to 95–99%, and residual suspended solid concentration can be reduced to 10–50 mg/l. The most common precipitation chemicals are polyaluminium chloride or ferric chloride, which should be used with a flocculation agent (a polyelectrolyte). The consumption of these chemicals depends on the suspended solids concentration of the incoming wastewater.

When, exceptionally, sand filters are used after chemical precipitation, the residual suspended solids concentration can be decreased to below 10 mg/l. No chemicals are required, and the washing water of the filters can be recycled to the previous stages of the treatment.

The BREF document from 2007 provides the BAT-associated emission levels shown in Table 4 below (European Commission 2007), which, however, are highly dependent on the production process, wastewater matrix, treatment and recycling onsite, as well as on the recipient of the treated wastewater, and should be considered on a site-specific basis.

Table 4: BAT-associated emission levels

Parameter	Wastewater pollutant level* mg/l
Suspended solids	50
AOX	0.1
Lead (Pb)	0.3
Zinc (Zn)	2.0
Cadmium (Cd)	0.07

Note: * If more than 50% of the process water is re-used in the manufacturing processes, higher concentrations of these pollutants may be allowed where the specific pollutant load per production unit (kg of processed raw material) is not higher than the pollutant load resulting from a water recycling rate of less than 50%.

Source: (European Commission 2007).

Recent reports (Umweltbundesamt, 2018 and Ricardo Energy & Environment, 2018) describe the state-of-the-art / BAT in installations for the manufacture of ceramics and proposes somewhat lower state-of-the-art emission levels when wastewater is discharged into the public sewer. The proposed state-of-the-art / BAT emission levels in sanitary ware manufacturing are <0.01–0.1 mg/l for lead and <0.001–0.01 mg/l for cadmium. The report Ricardo Energy & Environment (2018) also proposes state-of-the-art emission levels for other heavy metals. In the Nordic countries, the wastewater limits are generally agreed in an industrial wastewater discharge agreement between the industrial plant and the municipal water works. In the Nordic countries, there is hardly ever a limit for metals for plants discharging wastewater directly into a river, lake or the sea. It is therefore impossible to compare current emission levels with the state-of-the-art / BAT levels mentioned above.

5.2.4 Environmental benefits

Wastewater recycling can eliminate emissions to water from a unit process or from the entire ceramics plant. At the same time, it reduces the consumption of water in the process.

If wastewater is generated, wastewater treatment can very effectively reduce the discharge of suspended solids into the environment or to a municipal waste water treatment plant.

5.2.5 Applicability

Achieving the recycling of all wastewater is usually possible in brick manufacturing and in expanded clay products in the coarse ceramics sector. In technical ceramics, recycling is very limited, because of the high raw material and product quality requirements and often also the presence of organic compounds in the wastewater.

The recycling of wastewater in the fine ceramics sector is often very limited and can be in the range of 5–10% of total water consumption.

In the production of sanitary ware, the re-use of waste water from the manufacturing process can be achieved to a ratio of 30–50% by applying a combination of process optimisation measures and process waste water treatment systems.

5.2.6 Cross-media effect

The main cross-media effect is the generation of inorganic sludge in the wastewater treatment. This cannot be re-used in the fine ceramics industry, but it can be used as a raw material in brick production.

5.2.7 Economics

The investment cost of waste water treatment in fine ceramics depend on the amount of waste water and the required quality of the final effluent. It has been estimated in this study to range typically between EUR 0.5–2 million whereas the cost of investment for neutralization of scrubber water in manufacturing of expanded clay aggregates, like LECA products, have been estimated to range from EUR 0.2–0.5 million.

5.2.8 References

Finnish Environment Institute, 2004

Umweltbundesamt, 2018

Ricardo Energy & Environment, 2018

European Commission,2007

Environmental permits of Figgjo AS Norway, 2011, LECA Norway, 2004, Geberit / IDO, Finland, 2007 and Saint Gobain / LECA Finland, 2017

5.3 BAT Candidate no. 3 – Replacing part of raw materials with recycled materials

5.3.1 Introduction

The objective of the EU Circular Economy emphasizes the use of by-products or waste as raw material for another process. The replacement of parts of the raw materials with recycled materials from other ceramics plants or ashes from energy production has been widely practiced in brick manufacturing. In other ceramic products, recycling is limited by the high requirements on raw material and product quality.

If a plant considers using secondary raw materials, there are other pre-conditions beyond economic savings to consider. One important aspect is the variation of the quality of the secodary raw material. A second important aspect is the supply ratio. A third is the quality and purity of the secondary raw materials so they do not contain any hazardous substances that can end up in the final product, waste water or air emissions.

When introducing new components in the manufacture of bricks, pavement tiles and similar products, the products need to be approved and eventually certified by comptetent authorities. This approval process takes time and incur costs, which stresses the importance of ensuring the supply of secondary raw materials for years.

New components may also require new types of pretreatment, storage and feeding systems.

Since the implementation of this BAT Candidate depends not only on the company that would be using secodary raw materials but also on their suppliers, this BAT can be considered only as a recommendation and not as mandatory for either of the parties (producing or re-using materials). This kind of recommendation is included, for example, in the environmental permit of Geberit / IDO in Finland.

5.3.2 Applied processes and techniques

Common secondary raw materials used as raw material in brick manufacturing are broken or off-spec products or other rejects of porcelain, other household ceramics or sanitary ware production. Ash or slags from power plants are also used. Sometimes, recycled materials from metal industries are used as well.

Examples of inorganic waste streams that can be recovered as raw material in the manufacture of expanded clay aggregates (LECA Denmark) are:

- Mineral wool
- Metal shavings or other mineral shards
- Ashes from power plants
- Ground glass, tile, porcelain etc.

Examples of organics that can be utilized and substituted for heavy fuel oil as an expansion agent in the manufacture of expanded clay aggregates (LECA Denmark) are:

- Oil/fat containing waste streams in many other varieties
- Sewage sludge

Depending on the type of waste products supplied by other plants, it usually must be treated to obtain smaller pieces or powder. Pretreatment techniques are i.e. crushing, shredding and milling. Stones and non-magnetic metals are sorted out while other metals are separated by using magnetic separators. Sorting is carried out with different techniques like vibrating screens, cyclones and other equipment classifying material according to particle size. Typical end-products of the processing secondary waste is a powder which is stored in a silo before feeding it into the production of bricks or other ceramic products.

Bottom ash from power plants requires the removal of magnetic and non-magnetic metals. If fly ash can be re-used, it requires only screening prior to being stored in ash silos.

5.3.3 Emission and consumption figures

The reuse of waste materials and the pretreatment of the material creates a lot of dust. Control of the emissions to air requires use of cyclones, bag filters or similar equipment designed for dust removal. With modern dust control equipment 90–99% of the dust can be removed.

5.3.4 Environmental benefits

The reduction of waste disposed of in landfills is the main environmental benefit of this type of solution.

5.3.5 Applicability

Applicability is limited to the production of bricks, expanded products and possibly to a few other coarse ceramic products like pavement tiles. The share of secondary raw materials can be 10–20% of the total amount of raw materials.

5.3.6 Cross-media effect

Crushing and screening generate a lot of dust, which must be collected with ducts and cleaned and recovered with appropriate exhaust gas cyclones and bag filters as described above.

5.3.7 Economics

The economics of this BAT can be discussed on a general level. This type of recycling can achieve some cost savings in the raw material procurement of brick production. The supplier of the raw material can benefit from savings in waste management costs.

Waste material can cause additional investment needs in the testing of material, permitting process, raw material storage and feeding equipment – (e.g. sheltered and roofed areas may be required to avoid the spread of waste into the environment).

5.3.8 References

Environmental permit of Geberit / IDO, Finland, 2007
Site visits to Danish and Finnish brick plants and LECA Denmark in 2018

5.4 BAT Candidate no. 4 – Use of modern process technology in casting of products

5.4.1 Introduction

There are a few casting technologies which have positive environmental impacts. These can be applied mainly in the fine ceramics sector.

5.4.2 Applied processes and techniques

High-pressure casting can be carried out automatically at very high pressure into a plastic mold. In conventional plaster molds, the driving force is the suction of the plaster mold, while in high-pressure casting it is the hydrostatic pressure exerted on the slip. High-pressure casting in plastic molds (which have a lifetime of several thousand times) reduces the use of the plaster molds in the factory (which can be used only 200–300 times).

The dry pressing of material in casting is carried out with a lower moisture content than the raw material's. This reduces the casting time, saves energy and reduces air emissions because pre-firing is not needed.

5.4.3 Emission and consumption figures

Emissions to water and air are the same in high-pressure casting as in conventional casting, but the generation of waste from used plastic molds is less than 5% of the waste generated by using plaster molds.

In dry pressing, water consumption in raw material dosing and mixing is less than 10% of that used when casting is made with slurries.

5.4.4 Environmental benefits

A reduction of plaster mold waste disposed of in landfills is the main environmental benefit of high-pressure casting.

A reduction of water consumption and the generation of wastewater is the main environmental benefit of dry pressing.

5.4.5 Applicability

The applicability is limited to the production of sanitary ware and household ceramics. These technologies are also much easier to apply in installing new product lines or when an existing production line is otherwise modernized.

5.4.6 Cross-media effect

There is a positive cross-media effect with these types of new technology because they reduce energy consumption as pre-firing is not needed.

5.4.7 Economics

The main economic benefit with these modern casting techniques is that they increase the productivity of casting. Casting can be carried out automatically and this accelerates this phase of the process.

5.4.8 References

Finnish Environment Institute, 2004

5.5 BAT Candidate no. 5 – Renewable energy

5.5.1 Introduction

A competitive low-carbon economy is one of the EU's key policy areas. The ceramics industry is an energy intensive industrial sector. CO_2 emissions of the industry's energy production can be reduced by replacing natural gas and oil in energy production with renewable fuels. Examples of renewable fuels are:

- Biogas to replace natural gas
- Any solid material that can be finely ground and can ignite and burn without creating low temperature melting ashes.
- Liquid fuels that can be sprayed into fine, easily combustible droplets

If a plant considers using alternative renewable fuels, several preconditions require consideration, as discussed in the following. The feasibility and applicability of alternative renewable fuels is therefore very case-specific.

Currently, there is no known ceramics industry plant in the Nordic countries using alternative fuels in significant amounts, whereas there are plans to start using renewable fuels in the manufacture of expanded clay aggregates at LECA Denmark.

It is noteworthy that CO_2 emissions are also caused by the breakdown of carbonates in clay raw materials, such as limestone, dolomite or magnesite, in the process, for example $CaCO_3 \rightarrow CaO + CO_2$. These emissions cannot be avoided.

5.5.2 Applied processes and techniques

Firing is the crucial stage of ceramics manufacturing and controls many important properties of the finished product. Sufficiently high temperatures must be reached to obtain sintering and other processes occurring in the clay materials. Thus, a temperature of 750 °C to 1,500 °C or more should be obtainable, depending on production. This means that the fuel must be of sufficient quality to generate these temperatures. Nevertheless, even if a substitution fuel is of low quality, it may be used as an addition to higher quality fuels with the aim of reducing carbon dioxide discharges.

Technologies for the production of biogas are well established by means of anaerobic digestion. Biogas can be used to replace natural gas or propane.

For the production of pyrolysis gas, there are different options, but these processes often show difficulties in terms of tar that must be carefully analysed, depending on the raw material for the gasification.

Liquid fuels other than fuel oil such as methanol or ethanol could well be used for the firing. Methanol and ethanol may be produced from biological material, thus being carbon dioxide neutral as fuels. These fuels are also free from sulfur compounds, so do not contribute to sulfur dioxide emissions. Methanol and ethanol are also easy to handle and store. Today, however, the current cost of energy from burning these alcohols is too high to make these fuels competitive as an option for the ceramics industry.

The electrification of kilns using "low-carbon" electricity may be an option for reducing fuel emissions. However, this option is currently not generally economically viable. One Swedish fine ceramics plant (IFÖ Ceramics, making electric insulators but closing by the end of 2018) uses electrical heating for batch-type furnaces at temperatures above 1,200 °C, thereby avoiding any generation of carbon dioxide and showing that this technology is feasible at least for certain kinds of ceramics production. For production of expanded clay aggregates, which is done in rotary kilns, electric heating cannot be considered.

The BREF Document from 2007 mentions microwave-assisted firing as an emerging technique for ceramics manufacturing. This would have similar benefits as the electrification of kilns, but no plant in the Nordic countries has made any such implementation and any progress in this development is unknown.

5.5.3 Emission and consumption figures

The main advantage for the ceramics industry of using alternative fuels would be a reduction of CO_2 emissions. Basically, a replacement of natural gas or propane with biogas will reduce CO_2 in proportion with the energy generation. The disadvantages are that other emissions may increase, in particular of sulfur dioxide, which implies needs for additional equipment for flue gas cleaning. The operation of such equipment, for example, wet scrubbers, will increase consumption of electric energy for pumps and fans and call for sufficient effluent treatment.

5.5.4 Environmental benefits

The environmental benefit of using biogas or other alternative fuels is mainly related to reduced emissions of carbon dioxide (CO_2), but other emissions may simultaneously increase. However, using liquid fuels such as methanol and ethanol produced from biological raw materials would reduce emissions of carbon dioxide without creating an increase of other emissions.

The electric heating of kilns would most likely be the most advantageous heating method from an environmental point of view, provided the electric power is generated with "low-carbon" electricity. However, the cost of electric energy is currently too high to make this option competitive, except in the manufacture of specialty products in smaller amounts.

5.5.5 Applicability

The feasibility and applicability of alternative renewable fuels is very case-specific. Continuous processes used in the ceramics industries require uninterrupted, secure and affordable fuel. Unplanned interruptions can cause severe kiln damage, resulting in shutdown and production loss for several months.

Currently, there is no known ceramics industry plant in the Nordic countries able to use only biogas as fuel. The biogas burner system differs from the natural gas burner system. Biogas is generally not readily transported, and the biogas plant must be located in the vicinity of the ceramics plant. Since biogas plants are mainly established close to population centers, there is limited potential to utilize such fuels in the ceramics industry.

Where pyrolysis gas is concerned, the investment in generating such gas would be too high for a brick plant and can only be realised with other nearby industries in need of such fuel.

Renewable fuels often bring additional legal requirements, such as increasing demands for the monitoring of air emissions etc. For example, the Leca facility in Hinge is classified as a co-incineration plant.

5.5.6 Cross-media effect

Replacing traditional fuels with alternative fuels may increase other emissions in addition to CO_2. For example, a disadvantage of using biogas is the content of hydrogen sulphide and ammonia in such a gas. The concentration of these substances is low, but would nevertheless increase the emission of sulfur dioxide and perhaps also of nitrogen oxides. In theory, the ammonia might contribute to a reductíon of nitrogen oxides through reduction processes, but it is unlikely that various conditions in the kilns are optimal for such a reduction process to occur.

5.5.7 Economics

Generally, the price of alternative fuels is higher compared to natural gas, propane and oil.

Biogas currently costs up to 2–3 times more than natural gas. The use of liquid fuels such as methanol or ethanol is also unviable because of cost, but might otherwise be of interest. Likewise, the use of electric heating would contribute to a reduction in emissions, but it is not competitive at current electric power costs.

Furthermore, alternative fuels can create additional investment needs in the testing of material, permitting process, fuel storage and feeding equipment. If a plant is classified as a waste incineration plant, the requirements and related costs for monitoring and treatment of air emissions may be high.

An emissions trading scheme may be an incentive to consider alternative fuels.

5.5.8 References

The European Ceramic Industry Association, Paving the way to 2050: The Ceramic Industry Roadmap 2018

5.6 BAT Candidate no. 6 – Air emissions abatement by raw materials and fuels selection

5.6.1 Introduction

Hydrogen fluoride, hydrogen chloride and sulfur dioxide emissions from ceramics manufacturing are generated when the ceramics are burnt at high temperature because of the presence of precursors of these pollutants (fluorides, chlorides and sulfur compounds) in the clay materials. Therefore, the selection of clay materials with low concentrations of these compounds is a potential way to reduce these emissions into the atmosphere.

Emissions of sulfur dioxide and nitrogen oxides, as well as the release of carbon dioxide, may also arise from the fuel, and nitrogen is of course a major component in air. Currently, most plants in the Nordic countries use natural gas or propane as fuel, neither of which contributes to sulfur dioxide emissions.

5.6.2 Applied processes and techniques

Ways to reduce these pollutants may be to select other raw material sources with lower amounts of the fluoride, chloride and sulfur precursors. There are, however, several preconditions to consider in the selection of raw materials, which limits the choices as further discussed in Chapter 5.6.5, "Applicability".

The addition of calcium-rich additives to the clay raw material helps to bind fluoride and chloride, as well as some sulfur, to the ceramic products, thus somewhat reducing the emissions.

To minimize fuel emissions, natural gas and propane are simply the best options, because they generate no sulfur dioxide.

5.6.3 Emission and consumption figures

The emissions of fluoride in the flue gases from ceramics plants may vary greatly, depending on the raw material. According to Table 3.2 in the BREF document (European Commission 2007), the emission of raw flue gases from the firing process of brick and roof tile manufacturing is in the range of 1–250 mg/Nm^3 as HF. Correspondingly, the emissions of hydrogen chloride are in the range of 1–270 mg/Nm^3 as HCl, and the emissions of sulfur dioxide in a range from below the detection limit to 3,485 mg/Nm^3.

The measured fluoride emissions of a Finnish brick factory are 0.5 and 21.2 mg/Nm^3 as HF for Finnish and imported clay, respectively.

Sulfur dioxide generated from clay raw material is highly dependent on the kind of product produced. For instance, the production of yellow bricks may generate 250–500 mg/Nm^3 of sulfur dioxide, while the production of red bricks generates only 5–10 mg/Nm^3. (Some clays may contain more than 0.25% sulfur, and most of this sulfur will inevitably be converted into sulfur dioxide.)

The BAT-associated emission levels given in the BREF document from 2007 are summarized in the next chapter on Air emissions abatement by flue gas treatment.

5.6.4 Environmental benefits

The benefits of these measures are that they reduce emissions of the characteristic pollutants from the ceramics industry. The raw materials do not significantly influence NO_x emissions or sulfur dioxide emissions, except in the manufacture of yellow bricks, which are made from sulfur-rich raw material.

5.6.5 Applicability

Feasibility in the selection of raw materials with low fluoride and chloride content is very case-specific in ceramics manufacturing.

Coarse ceramics manufacturing plants are normally obliged to collect the main part of their clay raw material from nearby land areas, and raw material costs would be higher if they had to obtain clay from other sources. However, imported clays are used for specific purposes, for example, because of the color of the bricks.

For fine ceramics manufacturing plants, the clay is often not collected locally, and these plants are thus freer to select raw material sources generating less pollutants. However, other clay properties in obtaining the correct end quality at a competitive cost level are normally decisive in the selection. The requirements of raw materials are generally higher with fine ceramics compared to coarse ceramics. The selection of raw materials with a low fluoride and chloride content can therefore be difficult for fine ceramics manufacturers. It should also be pointed out that all clay materials contain fluorides, and one cannot expect to completely eliminate the problem with hydrogen fluoride emissions by selecting other raw material sources.

Where the choice of fuels is concerned, the situation can be considered satisfactory in the Nordic plants because they all use natural gas or propane.

5.6.6 *Cross-media effect*

None identified.

5.6.7 *Economics*

Switching raw material suppliers requires no investment, but raw material and transport costs may change.

Concerning fuels, natural gas is the cheapest option, when available. Otherwise, propane (or LPG) is readily available but also requires some investment in local storage capacity.

5.6.8 *References*

Finnish Environment Institute, 2004
The European Ceramic Industry Association, 2018

5.7 BAT Candidate no. 7 – Air emissions abatement by flue gas treatment

5.7.1 *Introduction*

Air emissions from ceramics plants are generated in the material handling and in flue gases from the kiln(s). Dust emissions are the main concern in material handling. In the flue gases from the kiln, emissions include dust, hydrogen fluoride, hydrogen chloride, sulfur dioxide, nitrogen oxides and, possibly, volatile organic carbon compounds if organic additives are used e.g. to create pores in the clay matrix to improve the thermal insulation performance of clay blocks. Carbon dioxide is, of course, always formed in fuel combustion.

5.7.2 Applied processes and techniques

Dust from material handling stages is normally separated by filters. Other options may be wet scrubbers, cyclones and, possibly, electrostatic precipitators. Textile filters (bag filters) are the standard solution and considered as BAT.

When required, cleaning of flue gases in the ceramics industry is normally done with scrubbers filled with granular dry lime, which is considered as BAT. Wet scrubbers may also be used, especially if high sulfur dioxide emissions are of concern. Other techniques may also be applied.

5.7.3 Emission and consumption figures

Filters for dust removal have efficiencies of 95–99%, depending on the nature of the dust and the quality of the filter material. Electrostatic precipitators have efficiencies of 97–99% but are used for higher gas flows than those from clay material handling.

For flue gas cleaning, the main equipment in use in the ceramics industry is a lime scrubber filled with solid lime (CaO). Hydrogen fluoride (HF) has a very high reactivity and reacts with solid lime to form calcium fluorides on the lime surface. Removal efficiency is more than 90%. Hydrogen chloride is less reactive than HF, and the removal efficiency for hydrogen chloride is 80–90% with solid lime scrubbers. The removal of sulfur dioxide with this kind of scrubber is low, below 30%, since sulfur dioxide is less acidic.

To remove sulfur dioxide with higher efficiencies, wet alkaline scrubbers need to be installed. With wet scrubbers, removal efficiencies for sulfur dioxide of more than 90% are achieved. Wet scrubbers also remove dust, but the handling of the slurry from such a scrubber presents a secondary issue to consider.

The BREF document from 2007 provides the BAT-associated emission levels shown in Table 5 below (European Commission 2007), which, however, should always be considered on a site-specific basis. The data in this table should still be considered valid, since no major technical developments have taken place in these respects since 2007.

Table 5: BAT-associated emission levels

Process/Parameter	Emission level of discharges to air**** mg/Nm³ (18% O2)
Kiln Firing	
Particulates	1–50
Fluoride as HF	5–10
Chloride as HCl	1–30
NO_x	250–500
SO_x	< 500*****
VOC*	5–20
Spray Drying Processes	
Particulates**	1–50
Spray Glazing	
Particulates**	1–10
Hot Off Gases	
Particulates***	5–50
Channelled dust emissions from dusty operations	
Particulates	1–10

Note: *Refers to Brick and Roof Tiles, Refractory Products, Technical Ceramics and Inorganic Bonded Abrasives (industrial diamond) Sectors.

**Refers to Household Ceramics, Wall and Floor Tiles and Technical Ceramics Sector.

***Relates to hot off gases in the manufacture of expanded clay aggregates using electrostatic precipitation.

****The ranges depend on the content of the pollutant (precursor) in the raw material, i.e. for firing processes of ceramic products with a low content of the pollutant (precursor) in the raw materials, lower levels in the ranges are associated with BAT and for firing processes of ceramic products with a high content of pollutant (precursor) in the raw materials, higher levels within the ranges are associated with BAT.

*****Where the sulfur content in the raw material is greater than 0.25% this value may be increased to a maximum of 2,000mg/m3.

Source: (EPA of Ireland, 2008, orig. European Commission 2007).

Recent reports (Umweltbundesamt, 2018 and Ricardo Energy & Environment, 2018) describe the state-of-the-art / BAT in installations for the manufacture of ceramics and propose somewhat lower state-of-the-art emission levels for certain sectors and using certain control measures. The reports mainly refer to Austrian and German installations and emission levels derived from either national legislation (German TA Luft) or air emissions monitoring of the installations.

For example, the German TA Luft prescribes techniques and the following emission limit values for HF: 5 mg/Nm3 (17% O2) in general, 10 mg/Nm3 (17% O2) for discontinuous kilns (corresponding to 4 and 7.5 mg/Nm3 at 18% O2, respectively). The state-of-the-art / BAT emission level of HF based on Austrian installations is 2 mg/Nm3 (18% O2) for bricks manufacturing, refractory bricks, sanitary ware and technical ceramics manufacturing using either no or cascade-type packed lime absorbers. Ricardo Energy & Environment (2018) further reviews a study in Germany and provides emission levels derived from monitored emissions with HF below 1 or 4 mg/Nm3 (17% O2), depending on the abatement technique applied. The data is not analysed in further detail, since their applicability to Nordic installations would require in-depth analysis. It is also noteworthy that in Austria and Germany the sector is more significant than it is in the Nordic countries.

5.7.4 Environmental benefits

Hydrogen fluoride as well as hydrogen chloride are acids and contribute to acidification and corrosion when precipitating. This also applies to sulfur dioxide. The amounts of these substances emitted from the ceramics industries are limited, and demand for flue gas cleaning with lime scrubbers is mainly relevant for the largest units.

5.7.5 Applicability

Technologies using textile filters and lime scrubbers are common solutions in the ceramics industry and should be considered, depending on local needs. For example, for hydrogen fluoride, annual emissions above 25,000 kg/a should call for a lime scrubber, but annual amounts below this should be evaluated on a case-by-case basis.

Electrostatic precipitators (ESPs) are highly efficient and are widely used in the cement industry and in many boiler plants, but they are normally used for higher dust loads and capacities than are required in the ceramics industry.

Monitoring of emissions should always be carried out for plants meeting the IED production limts.

5.7.6 Economics

The investment cost for textile filters varies according to the size (m^2) of the filters. One may estimate the cost to be in the range of EUR 100,000 to EUR 1 million, depending on size, and operating costs for these filters are relatively low. Operating costs include electric power, textile elements ("bags") and general maintenance.

The investment cost for electrostatic precipitators is higher than for textile filters, and they require more electric power for operation. Maintenance costs are typically higher than for textile filters in baghouses.

Lime scrubbers require higher investment, from EUR 500,000 to EUR 3 million, depending on size. Operating costs are low, because lime is cheap and lime consumption is relatively low. Any filter or scrubber will require some electric power for fans, and scrubbers normally require higher flue gas temperatures, thereby somewhat increasing fuel consumption.

5.7.7 References

Finnish Environment Institute, 2004
Umweltbundesamt, 2018
Ricardo Energy & Environment, 2018
European Commission, 2007

5.8 BAT Candidate no. 8 – Energy efficiency

5.8.1 Introduction

Energy efficiency is crucial in all process industries to keep operating costs down and to minimize emissions from fuel burning. Efficiency is improved in a number of different ways, such as improved kilns with improved burning systems, reduced air leakage and improved insulation, high production load and recovery of heat for drying processes.

5.8.2 Applied processes and techniques

The switch to tunnel kilns is important in reducing energy consumption. Improved insulation of kilns helps to reduce energy losses. A large number of pulse burners with good temperature control helps to keep uniform conditions with minimum losses. Tunnel kilns with an adequate number of pulse burners represent BAT for burning. A high constant load of production i.e. high production efficiency is important to minimize losses that otherwise may occur. All heat in the flue gases and in goods produced should be utilized in the drying of wet goods and for the heating of plants. Drying is achieved with hot air that is heated in heat exchangers by the outgoing flue gases and/or heated by the hot products being cooled by air. The amount of excess air going into the kiln should be minimized to reduce losses of heat.

Kilns can also be heated with electric power, which is the most efficient way to reduce emissions. However, the higher cost of electric energy means this technology is currently not economically viable.

For expanded clay production, continuous fast-fire roller kilns represent BAT.

In summary, BAT includes:

- Tunnel kilns of sufficient lengths
- Large numbers of well-controlled burners to optimize the temperature curve of the firing process
- Heat exchangers for hot flue gases from the kiln against air for drying and for heating of premises, as well as using cooling air heated when passing through the cooling sections of the kilns
- Minimizing air leakage into kilns

5.8.3 Emission and consumption figures

High energy efficiencies help to minimize fuel consumption and thus, in particular, to reduce discharges of carbon dioxide. Other emissions may also be reduced, but not to the same extent. Carbon dioxide generation is basically proportional to fuel consumption.

5.8.4 Environmental benefits

The environmental benefits of improved energy efficiency are primarily related to the reduced generation of carbon dioxide. According to estimates by the Danish industry, the overall energy used in the production of ceramic products has been reduced by around 50% per ton of product over the last 40 years. Simultaneously, the switch of fuels from coal and fuel oil to gas has reduced carbon dioxide discharges by more than 60% per ton of product over the same period.

5.8.5 Applicability

Energy efficiency measures can be applied by all industries as constantly ongoing programs. The implementation of different measures depends on the availability of funding and on a project's return on investment, but the long-term goal should be considered for any project.

5.8.6 Cross-media effect

Improved control of burning saves fuel and at the same time improves product uniformity and product quality. Burning fuels only for the kiln also avoids separate fuel supply systems for dryers and simplifies fuel supply to processes.

5.8.7 Economics

Improved energy efficiency is a broad concept. A new kiln is the largest single investment for the ceramics industry, with costs of at least EUR 5 million. Such investments can only be implemented when a kiln needs to be replaced. Other projects, such as the heating of dryers with heat from kiln flue gases or with cooling air from cooling of products, are easier to justify simply because of the rapid pay-back on such an investment.

Operating with a high load tends to avoid losses and mainly requires good production planning.

5.8.8 References

Finnish Environment Institute, 2004
European Commission, 2007
The European Ceramic Industry Association, 2018

5.9 BAT Candidate no. 9 – Operate an Environmental Management System (EMS)

5.9.1 Introduction

An Environmental Management System (EMS) is a tool operators can use to address design, construction, maintenance, operation and decommissioning issues in a systematic, demonstrable way.

The goals of an EMS are to increase compliance with legal standards and to reduce environmental impact.

An EMS includes the organizational structure, responsibilities, practices, procedures, processes and resources for developing, implementing, maintaining, reviewing and monitoring the environmental policy. An EMS is most efficient when it is integral to the overall management and operation of an installation.

The most widely used standard on which an EMS is based is the ISO 14001 standard, as defined by the International Organization for Standardization.

5.9.2 Applied processes and techniques

A number of environmental management techniques are determined as BAT. The scope (level of detail) and nature of an EMS (standardized or non-standardized) will generally be related to the nature, scale and complexity of the installation and the operation, and the range of environmental impacts they may have.

An environmental management system (EMS) for an IED installation should contain the following components:

- Defining of an environmental policy
- Planning and establishing objectives and targets
- Implementing and operating procedures
- Checking and corrective action
- Management review
- Preparing a regular environmental statement
- Validating by certification body or external EMS verifier
- Considering design for end-of-life plant decommissioning
- Development of cleaner technologies
- Benchmarking

5.9.3 Environmental benefits

An EMS assists with planning, controlling and monitoring policies in an organization. The benefits of an EMS are:

- Better organization of environmental work
- Improved documentation and facilitating of reporting to authorities
- Better records for communication with authorities
- Better basis for continuous improvements.

5.9.4 Applicability

Preferably, an EMS can be implemented for any industrial operation.

The model is continuous because an EMS is a process of continual improvement in which an organization is constantly reviewing and revising the system.

5.9.5 Cross-media effect

An EMS assists with planning, controlling and monitoring policies in an organization. It provides a tool to evaluate suppliers' products from an environmental perspective and it offers a means to define the environmental impact of the products delivered to the marketplace.

5.9.6 Economics

The implementation of an EMS will require some investment costs, mainly in human resources. When the system is in operation, there should be no extra costs for the plant.

An EMS systematizes operations and minimizes risks, and can in the best case result in cost savings.

5.9.7 References

European Commission, 2007

European Commission – EMAS Helpdesk (2011)

Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 2009 on the voluntary participation by organisations in an eco-management and audit scheme (EMAS)

5.10 BAT Candidate no. 10 – Emissions Monitoring

5.10.1 Introduction

Most of the Nordic ceramics plants that have no emissions control do not monitor emissions. All plants with filters for air emission reduction and with effluent treatment plants already monitor some emission parameters today. Monitoring is recommended as BAT because it represents a necessary stage in reducing emissions. Without measurements there is no clear way of benchmarking performance and making improvements.

5.10.2 Applied processes and techniques

For air emissions, monitoring is proposed for flue gases (at stack, after flue gas treatment, if any) with respect to particulates (TSP), CO, SO_2, NO_X, HF and HCl. Carbon dioxide, CO_2, discharges should be calculated

For water emissions, monitoring is proposed with respect to flow (volume), temperature, pH, suspended solids (TSS) and chemical oxygen demand (COD).

For plants with no measures for emissions control, monitoring for air emissions should be conducted twice a year. One measurement per year may be sufficient if the emissions are stable. For plants with effluent treatment, required frequency of measurements depends on the characteristics of the plant.

5.10.3 Environmental benefits

Emissions monitoring is necessary for understanding levels of discharges and environmental impact. Monitoring is also necessary as a benchmark for making improvements in reducing emissions.

5.10.4 Applicability

Monitoring is applicable to any ceramics plant.

Sampling of flue gases before or after the stack should normally be possible, but some modifications may be necessary to facilitate the obtaining of representative samples. Analyses may be carried out by accredited firms.

For water emissions, analyses of pH, temperature, suspended matter and COD are easy to undertake, while flow measurements require special arrangements.

5.10.5 Cross-media effect

Not applicable.

5.10.6 Economics

The cost of making the various BAT measurements are defined by accredited firms conducting such analyses. Some site-specific investments may be required to correctly take flue gas samples.

For the volumetric measurement of effluent, a device for flow measurement is needed. Standard devices are available at competitive costs.

5.10.7 References

European Commission, 2007

European Commission: "Integrated Pollution Prevention and Control (IPPC) – Reference Document on the General Principles of Monitoring", July 2003

European Commission: "TRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations", Industrial Emissions Directive 2010/75/EU – Integrated Pollution Prevention and Control, 2018

6. Other general BAT candidates

This chapter provides a longlist of other general BAT candidates to be considered in operations in the sector. These are general requirements that are not specific for this industrial sector.

BAT for noise emissions:

- Prioritize regular maintenance of fans, motors, etc.
- Use noise shields where possible
- Select low-speed fans where possible
- Keep doors and windows closed whenever possible
- Noise levels to be a criterion when purchasing new equipment
- Conduct noise measurement and identify significant noise sources and potential sensitive receptors in the vicinity, and reduce noise when necessary

BAT for chemicals handling and substitution:

- Control and optimized consumption of chemicals
- Use less harmful chemicals when possible
- Follow the duties of a downstream user of chemicals related to the safe handling and use of chemicals according to the provisions set in the safety data sheets.

General BAT for waste handling:

- Source separate different waste fractions and do not mix waste
- Re-use, recycle and recover waste when possible
- Waste should be delivered only to permitted vendors
- Store waste in designated, labelled containers in sheltered and roofed areas to avoid spread of waste into the environment, for example, leakage of chemicals into soil or spread of dust by wind
- Specific requirements apply for storage and handling of hazardous waste, including hydraulic oils etc.

BAT for reduction of risks and accidents:

- Appropriate risk management procedures and trained personnel should be in place
- An embankment of chemical storages should have the capacity to retain all chemicals in case of leakage or accident
- Adequate spill kits, fire extinguishers and other emergency provisions and procedures should be in place (for example, a valve to close sewer lines in case of emergency). There should also be a plan to ensure firewater does not get into the environment if there is a fire
- Inspect embankment and safety equipment regularly
- Follow fire and chemical regulations. Explosion-proof documents should be in place.

7. Emerging techniques

Emerging techniques are BAT not yet fully developed or in use in the industry, although they may be relevant as BAT candidates in the future.

This chapter briefly discusses areas of research and development in ceramic materials and their manufacturing techniques. It is noteworthy that some of the areas of research and development briefly discussed in this chapter do not fall within the scope of the BREF.

Energy and resource efficiency are important topics of research and development in the industrial sector. For example, several EU-funded projects are ongoing for these topics.

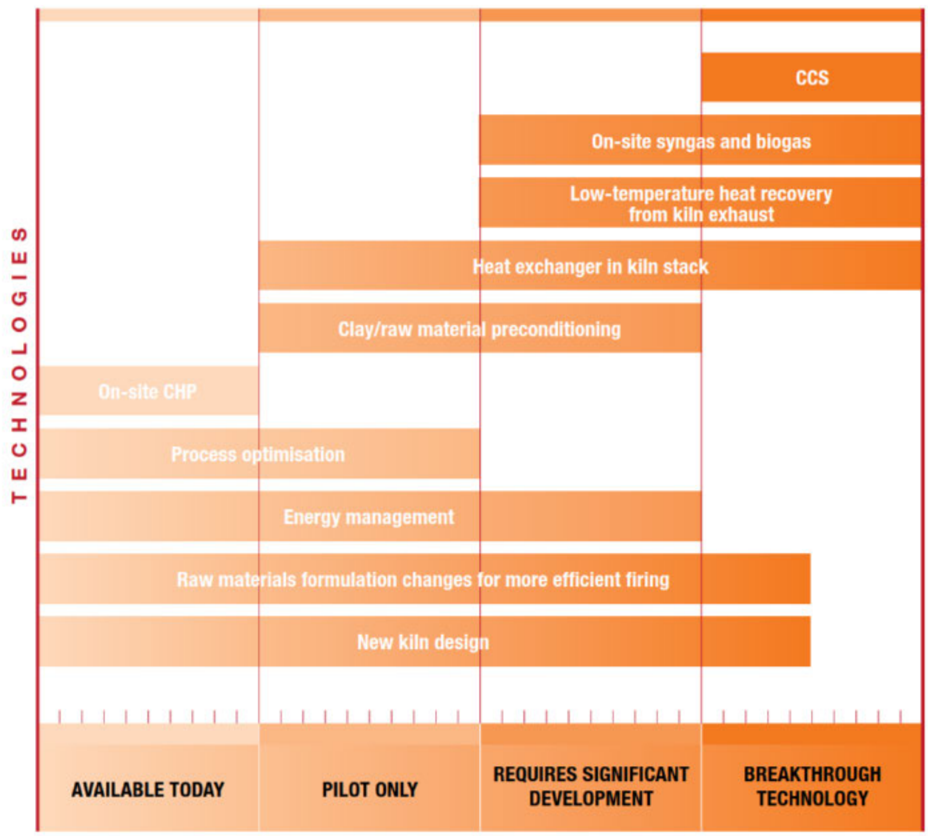
There is active research and development, for example, on:

- High energy efficiency and the reduction of fossil carbon emissions by means of waste heat recovery by two high temperature vapour compression heat pumps: a closed loop heat pump for air drying processes and an open loop heat pump for steam drying processes (DRYficiency project funded by HORIZON 2020, http://cordis.europa.eu/project/rcn/205646_en.html).
- Design, development and demonstration of improved architecture for ceramics industrial furnaces, characterized by optimized energy consumption, reduced emissions, and lower operating costs compared to currently available technological solutions, e.g. by substantially enhancing specific furnace parts (control system, refractories, emissions abatement system) and by adding new modules and subsystems (CHP unit, heat pipes) to the current furnace architecture (DREAM project funded by SPIRE, https://www.spire2030.eu/printpdf/projects/our-spire-project/1917).
- Improvement of the energy performance of energy intensive processes based on heat exchanger technology (HPHE), using heat pipes for thermal recovery (ETKINA project funded by EU, https://www.etekina.eu/).
- Development of a standard modularized solution for the flexible and adaptive integration of heat recovery and thermal storage capable of recovery and management of waste heat (Smartec project funded by SPIRE. https://www.spire2030.eu/printpdf/projects/our-spire-project/1969).
- Reduction of the natural gas consumption and the CO_2 emissions of existing state-of-the-art clay roof tiles or brick production units (HEART project funded by LIFE http://life-heart-terreal.com/en/project/objectives/).

- Reduction of the natural gas consumption and carbon dioxide (CO_2) emissions from the firing of ceramic materials in a factory producing bricks and roof tiles through an innovative method using calcium carbonate ($CaCO_3$) nanoparticles in raw materials, which enables the firing temperature to be reduced (LIFE NanoCeramiCO₂ project. http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=5076).
- Valorization of iron foundry sands and dust waste in the ceramic tile production process (LIFE Foundrytile project, http://foundrytile.eu/project/members/).
- Zero waste in ceramic tile manufacture by: (i) Developing a new type of ceramic tile for outdoor application (urban paving) that can incorporate a high content of ceramic waste in the body and glaze; (ii) designing a highly sustainable body preparation process for manufacturing the above ceramic tiles, based on dry milling technologies capable of recycling all types of ceramic waste (LIFE CERAM projectm, http://www.lifeceram.eu/en/the-project/members.aspx).
- Manufacture of ceramic materials at ultra-low temperatures of 200–500 °C (ULTIMATE CERAMICS project funded by ERC, https://cordis.europa.eu/project/rcn/102188_en.html).
- Secondary raw materials-based ceramics, for example, mine tailings to produce ceramic materials by powder injection molding. Slag has been investigated for developing refractory materials with mechanical and chemical resistance of up to 1,200° C in a gaseous atmosphere.
- 3D printing of ceramic materials for various applications, for example, in the medical and dental, and aerospace and automotive sectors. After printing, the ceramic parts undergo the same processes as any ceramic part made using traditional production methods – namely firing and glazing.
- Thermal sprayed ceramic materials in various applications, e.g. steel mill rolls, disc brakes, valves, water turbine components, pump impellers and hydraulic cylinders.
- Ceramic materials in the fields of photonic and optical applications, e.g. transparent ceramics, glass ceramics, luminescence, random lasers, thermo-emissive applications, scintillators and dielectric metamaterials.
- Ceramic magnets such as the hexaferrites as component parts of motors and filters, or in devices for communication technologies.
- Bioceramics for bone tissue regeneration in medical applications.
- Nanoceramic-based drug delivering systems in medical applications.
- Electroceramic materials for solid oxide fuel cells and rechargeable batteries and supercapacitors.

The publication "Paving the way to 2050: The Ceramic Industry Roadmap" presents an analysis of some key technologies which could be applied across the ceramics industry. The report highlights both presently available technologies and possible development areas, also considering their cost-effectiveness. The breakthrough technologies described are known today, but they require further development. Some technologies like Carbon Capture and Storage (CCS) will also require significant support from regulators and/or face supply challenges beyond the industry's control.

Figure 21: Analysis of key technologies which could be applied across the ceramics industry



Source: (The Ceramic Industry Roadmap, 2018).

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Sammanfattning

Nordiska ministerrådet har genom BAT-gruppen under arbetsgruppen för hållbar konsumtion och produktion HKP bett ett nordiskt expertteam, som leds av Vahanen Environment Oy, att genomföra ett BAT (Bästa Tillgängliga Teknik)-projekt rörande tillverkning av keramik (CER) i de nordiska länderna.

Projektet har haft som mål att:

- gå igenom och beskriva den keramiska tillverkningsindustrin i Norden
- gå igenom och beskriva den teknik som används i Norden
- identifiera och beskriva de huvudsakliga miljöindikatorerna från ett nordiskt perspektiv
- identifiera och beskriva teknik som ska beaktas för att motsvara BAT vid tillverkning av keramiska produkter.

Projektet ska kunna användas som Nordens bidrag i den kommande EU-processen där slutledningar gällande BAT i den keramiska industrin kommer att granskas i enlighet med industriutsläppsdirektivet (IED 2010/75/EU). Arbetet kommer också att underlätta de nationella förberedelserna i Norden för den kommande processen. Resultaten av projektet kan också tillämpas på fabriker med en mindre kapacitet än IED. Rapporten kan också direkt användas av tillstånds- och tillsynsmyndigheter liksom av industrin själv när man överväger att införa BAT för tillverkning av keramiska produkter.

Beteckningen keramiska produkter avser olika typer av produkter som oftast är tillverkade av oorganiska och icke-metalliska material genom en bränningsprocess. Det huvudsakliga råmaterialet har traditionellt varit lera under det att många av dagens keramiska produkter inkluderar en mängd komponenter med endast en liten del lera eller ingen alls. Keramiska produkter kan vara glaserade eller oglaserade, porösa eller sintrade. Typiska egenskaper hos keramiska produkter är hög hållfasthet, nötningstålighet, lång livslängd, kemisk resistens och giftfrihet, tålighet mot värme och eld, (oftast) elektriskt isolerande och ibland också med en viss porositet.

Projektet omfattar tillverkning av följande produktgrupper vilka ytterligare kan delas in i grovkeramiska och finkeramiska produkter på följande sätt:

Grovkeramiska produkter:

- Lättklinker
- Glaserade tegelrör
- Murtegel och taktegel
- Eldfasta material

Finkeramiska produkter:

- Vägg- och golvplattor
- Husgeråd
- Sanitetsgods
- Teknisk keramik
- Oorganiska bundna slipmaterial.

Projektet omfattar också nordiska keramiska fabriker under IED:s kapacitetsgräns; fabriker som måste följa ett miljötillstånd.

Information och uppgifter om keramiska produkter, använda tekniker och utsläpp samlades in över hela Norden från dokument och genom kontakter som erhölls från besök vid ett antal tillverkande fabriker. Fabriker av olika slag och storlekar och som använder olika slag av utrustning och tillverkar olika slag av produkter kontaktades och besöktes för att uppnå bredast möjliga täckning. Även industriföreningar kontaktades.

Tillverkningen av keramiska produkter har en lång tradition och har tidigare varit en stor industri – med hundratals fabriker också i de nordiska länderna. Idag finns relativt få produktionsanläggningar kvar i de nordiska länderna och dessa utgör några få procent av den totala produktionen av keramiska produkter i EU. Många av produktionsanläggningarna i de nordiska länderna hör idag till större internationella industrigrupper med tillverkning av keramiska produkter i många fabriker både i Norden och i andra länder.

I Norden finns några få procent av den totala produktionen av keramiska produkter inom EU. De största producentländerna i EU är Italien, Tyskland, Spanien, Frankrike, Storbritannien, Polen, Portugal och Österrike.

De huvudsakliga miljöindikatorerna i denna studie är (utan prioritetsordning):

- Råvaror, tillsatsämnen/kemikalier och bränslen
- Utsläpp till luft
- Utsläpp till vatten
- Processförluster/avfall
- Energiförbrukning/utsläpp av CO_2

För att hitta kandidaterna för BAT skapades först en lång lista av aktuella tekniker. Från den långa listan skapades sedan den korta listan enligt följande prioriteter:

- BAT, som berör de huvudsakliga miljöindikatorerna
- BAT, som bedöms ha en betydande effekt på utsläpp och utsläppskonsekvenser
- BAT, som är ekonomiskt och tekniskt genomförbara med tanke på kostnader och fördelar

- BAT, som primärt är utvecklad eller har sitt ursprung i Norden.

Området täcker många olika slag av produkter som tillverkas från olika råvaror i anläggningar av olika typ och storlek. Den tekniska och ekonomiska genomförbarheten liksom miljöeffekterna av BAT varierar mycket och är mycket beroende av det enskilda fallet på grund av betydande variationer i produktionsteknik mellan grovkeramiska och finkeramiska produkter och expanderade lerprodukter. I Norden finns endast några få fabriker av varje slag med undantag för tegeltillverkning där det finns fler än 15 fabriker, de flesta i Danmark. Dessutom påverkas miljötillstånden av fabrikernas lokalisering och lokala förhållanden.

De BAT-kandidater som presenteras finns listade i Tabell 6 BAT-kandidater. Referenser görs i huvudsak till Europeiska kommissionens BREF-dokument från augusti 2007. På många sätt är detta dokument fortfarande aktuellt för den keramiska industrin i Norden, som inte genomgår stark teknisk utveckling och många för miljön viktiga åtgärder från 2007 gäller därför ännu och är tillämpliga. Utsläppsnivåer jämförs också med senare rapporter från Umweltbundesamt (2018) och Ricardo Energy & Environment (2018) som beskriver bästa teknik/BAT i anläggningar för tillverkning av keramiska produkter där huvudsakligen anläggningar i Österrike och Tyskland granskas.

Table 6: BAT kandidater

		Fabriker för grov keramik	Fabriker för fin keramik
1	Återanvändning av processsvatten	Potentialen för egen återanvändning av processvatten på den egna anläggningen är stor.	Potentialen för egen återanvändning av processvatten i den egna anläggningen är begränsad. Återanvändning av processavfall från tillverkning av finkeramik är begränsad till tidiga processteg för sanitetsgods. För hushållskeramik är återvinning av processavfall i praktiken inte tillämpbart på grund av en mer komplex teknik i början av tillverkningsprocessen.
2	Återanvändning och behandling av avloppsvatten	Återanvändning av avloppsvatten är relativt enkelt.	Det mesta av avloppsvattnet kan inte återanvändas och måste släppas ut till ett effektivt avloppsreningsverk för att avlägsna huvudsakligen oorganiska fasta partiklar och lösta metaller, oftast med hjälp av kemisk fällning och eventuellt sandfiltrering; i undantagsfall genom adsorbtion eller jonbytare om fluorid eller bor måste avlägsnas.
3	Utbyte av vissa råvaror mot återvunna material	Oftast möjligt i viss utsträckning, till exempel används olika biprodukter och avfall från andra industrier som råvara vid tegeltillverkning och tillverkning av lättklinker. Ekonomi och tillämpbarhet måste undersökas från fall till fall.	Begränsade möjligheter.
4	Utnyttjande av modern automatiserad processteknik vid formning av produkter för att spara energi och minska avfallet	Inte tillämpligt	Högtrycksformning minskar både användningen av gipsformar i anläggningen liksom energiförbrukningen.

5	Förnybar energi	Det finns möjligheter att till exempel använda biogas eller andra förnybara bränslen som tillsatsbränsle. Genomförbarheten och tillämpligheten för alternativa förnybara bränslen skiljer sig starkt från fall till fall.	Det finns möjligheter att till exempel använda biogas eller andra förnybara bränslen som tillsatsbränsle. Genomförbarheten och tillämpligheten för alternativa förnybara bränslen skiljer sig starkt från fall till fall.
6	Minskning av utsläpp till luften genom val av råvaror och bränslen	Utsläppen av vätefluorid kan minskas genom att använda råvaror med låg fluoridhalt. Utsläppen av svaveldioxid kan minskas genom att använda råvaror och bränslen med låg svavelhalt.	Utsläppen av vätefluorid kan minskas genom att använda råvaror med låg fluoridhalt. Utsläppen av svaveldioxid kan minskas genom att använda råvaror och bränslen med låg svavelhalt.
7	Minskning av utsläpp till luften genom behandling före utsläpp	Filter för att minska partikelutsläpp. Andra åtgärder är i allmänhet inte ekonomiskt tillämpliga.	Textilfilter eller elektrostatiska stoftavskiljare för att minska utsläpp av partiklar. Ibland också avlägsnande av HF och HCl med kalkskrubber, alternativt alkalisk våtskrubber.
8	Processernas energieffektivitet	Tillräckligt långa tunnelugnar Stort antal välkontrollerade brännare för att kunna optimera temperaturkurvan för bränningsprocessen Värmeväxlare för heta rökgaser från ugnen till luft för torkning och för uppvärming av lokalerna Kylluft som tillsätts efter bränningen kan användas i torkar God produktionsplanering för att uppnå verksamhet med hög produktionsvolym och för att undvika förluster	Tillräckligt långa tunnelugnar Stort antal välkontrollerade brännare för att kunna optimera temperaturkurvan för bränningsprocessen Värmeväxlare för heta rökgaser från ugnen till luft för torkning och för uppvärming av lokalerna Kylluft som tillsätts efter bränningen kan användas i torkar God produktionsplanering för att uppnå verksamhet med hög produktionsvolym och för att undvika förluster
9	Användning av ett miljöstyrningssystem (EMS)	Använd ett miljöstyrningssystem (EMS) med alla sina viktiga element.	Använd ett miljöstyrningssystem (EMS) med alla sina viktiga element.
10	Övervakning av utsläpp	Minst två gånger per år för rökgaspartiklar, fluorid (HF), klorid (HCl), och svaveldioxid (SO_2). En mätning per år kan vara tillräckligt om utsläppsnivåerna är stabila.	Minst två gånger per år för rökgaspartiklar, HF, HCl, och SO_2 För efterbehandling av avlopp med suspenderat material, biologiskt och kemiskt syreförbrukning (BOD och COD). En mätning per år kan vara tillräckligt om utsläppsnivåerna är stabila. För anläggningar med avloppsbehandling beror antal mätningar per år på anläggningens karakteristika.

Kapitlet om viss teknik under utveckling beskriver ny teknik som ännu inte kan anses som BAT eller som inte ännu används i industrin, men som kan komma att bli BAT-kandidater i framtiden. I sista kapitlet diskuteras forskning och utveckling inom keramiska material och deras tillverkningstekniker. Energi- och resurseffektivitet är viktiga ämnen inom forskning och utveckling för industrisektorn.

Följande konsulter har bidragit till rapporten:

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- Johan Mjöberg, Foritec AB
- Juhani Anhava, Anhava & Partners Oy

Stödgrupp:

- Hannu Pyy, Vahanen Rakennusfysiikka Oy

BAT-projektet har följts och kommenterats av den nordiska BAT-gruppen. Medlemmarna i BAT-gruppen är:

- Anne Kathrine Arnesen, Miljödirektoratet, Norge.
- Kaj Forsius, Finlands miljöcentral
- Lena Ziskason, Miljöverket, Färöarna
- Einar Halldorsson, Miljöverket, Island
- Mikael Stjärnfelt, Ålands miljö- och hälsoskyddsmyndighet
- Birgitte Holm Christensen och Mette Lumbye Sørensen, Miljöstyrelsen, Danmark
- Elin Sieurin, Naturvårdsverket

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Nordic Ceramics Industry – Best Available Technique (BAT)

The cheramic sector covers very different types of products made of mostly inorganic and non-metallic materials by a firing process. This report covers the manufacture of the following product groups:

Coarse ceramics:
- expanded clay aggregates
- vitrified clay pipes
- bricks and roof tiles
- refractory products

Fine ceramics:
- wall and floor tiles
- household ceramics
- sanitary ware
- technical ceramics
- inorganic bonded abrasives

The report was initiated by the BAT Group of the Nordic Council of Ministers and financed by the Working Group for Sustainable Consumption and Production.

The results will serve as Nordic input to the EU revision of BAT conclusions for the ceramic sector under the Industrial Emissions Directive.

The report also covers the Nordic ceramics manufacturing plants below the IED capacity threshold: that is, plants with an environmental permit.

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