Improving the energy efficiency of foundries in Europe

By

Foundrybench - Foundry Energy Efficiency Benchmarking

IEE/07/585/SI2.500402

www.foundrybench.fi

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Authors of the publication

Sini Eronen, Hermia Ltd, Finland

Markku Tapola, AX-Consulting, Finland

Emma Svensson & Per Sommarin, Swedish Foundry Association (SFA), Sweden

Joachim Helber, Institut für Giessereitechnik, Germany

Jean-Marc Piatek, CTIF, France

Jacek Przybylski, Foundry Research Institute, Poland

Patricia Caballero, Tecnalia, Spain

Pekka Kemppainen, Meehanite, United Kingdom

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1 Preface

Fostering the energy efficiency and rational energy use in the metal casting sector will result in significant energy savings due to both technical and behavioural improvements. Foundry Energy Efficiency Benchmarking (Foundrybench) -project is basically a toolbox for foundrymen who want to find energy saving actions. More specific objectives of the project have three dimensions: reducing energy use and creating of both the database and benchmarking tool. It is of vital importance in this energy-intensive industry to raise the awareness of the opportunities to reduce energy use and stimulate the spread of best practices for energy efficiency improvement in the foundry sector. Moreover, developing a database of the best energy saving practices in foundries containing practical information on energy saving solutions, their effect on energy consumption and costs, will give a useful tool for all interested parties to improve the energy efficiency in certain situations. Enabling the professional assessment of foundry energy use, a well-targeted foundry-specific benchmarking tool is needed that can be applied throughout different foundries or product types and climatic conditions.

The project consortium of the Foundrybench consists of 8 partners from following countries: Finland, Sweden, Germany, Poland, France, United Kingdom, Spain, and Italy (associated). The project was co-financed by Intelligent Energy - Europe programme of the European Commission.

Foundrybench – Foundry Energy Efficiency Benchmarking (IEE/07/585/SI2.500402) was carried out during the period 01/2009 - 12/2011. The aims of this Foundrybench project were based on enhancing the efficient energy use in the foundry industry.

February 2, 2012

The authors

2 Executive summary

In the past years and even more in the next decades energy efficiency is considered as a core issue when tackling with the sustainability. Emissions, depleting natural resources and overall sustainability have to be emphasized in all decision making and the requirements from European Union are getting even stricter.

Accordingly, the EU has announced an Energy Efficiency Action Plan to save up to 20 % of energy throughout the Union (about 39 Mtoe), and 27 % of energy in manufacturing industries by 2020. This would reduce direct costs in the EU by EUR 100 000 million annually by 2020 and would save around 780 million tonnes of CO_2 annually according to energy European Commission reference document on best available techniques for energy efficiency.

Foundry processes are energy intensive and much of the energy produced is transformed into heat and then lost to the ambient air. When energy is used efficiently in foundries, the result is a saving in heat, electricity, and water. Furthermore, reductions in energy use lead to dramatic reductions in carbon dioxide and other harmful emissions. For European foundries, sustainability has to be a strategic objective: the competitiveness of the European foundries can be enhanced by implementing key knowledge of new applications in different technologies and disciplines. However the manufacturing industry, including foundries, has to be able to produce goods sustainably.

The Foundrybench project can be seen as a first attempt towards more energy efficient foundries in Europe. The aims of the project were comprehensive and were divided in three layers: energy auditing of the foundries and identification of energy saving potential, concrete examples and tools for these improvements by good practices and benchmarking. The project also shows that investment in energy efficiency improvement is feasible, but in some cases pay-back time will exceed 2,5 – 3 year, which time a private foundry company will see slightly too long and will prioritize other technology investments more important. By supporting energy efficiency investments by grants or interest supported loans, the governments could encourage foundries to make these investments. This would have an essential positive effect on environmental issues and energy resources.

FOUNDRYBENCH - Improving the energy efficiency of foundries in Europe publication at hand gives a snapshot of the foundry industry situation in seven European countries from the energy efficiency point of view and describes the steps that have been already done in order to improve this highly energy intensive industry sector. The aim of this publication is to raise awareness on the energy efficiency in foundries, describe the results of this Foundrybench -project and the practical solutions created as well as to highlight the huge energy saving potential in this field.

Foundrybench consortium has also formulated suggestions for further steps with energy audits, benchmarking and best practices.

3 Introduction

There is a wide variety of energy efficiency techniques available from various sources and in many languages. While individual techniques can be applied and may save energy, it is specifically valuable to analyse the whole site and its component systems and their interactions strategically in order to find significant energy efficiency improvements. For example changing electric motors in a compressed air system may save about 2% of the energy input, whereas a complete review of the whole system could save up to 37%. An analysis in the sense of the Foundrybench -project describes the energy saving potential as well as the potential of financial savings by improving energy efficiency. The potential in this highly energy intensive industry is huge and there is already a wide variety of tools available for the improvements.

The following document was prepared on the basis of both the activities carried out during the Foundrybench project and the results of the action. It describes the main results of the action in the form of best practices, identifies the current situation and developmental actions needed in the foundry industry sector in various European countries as well as gives suggestions for the future based on the project results.

The Foundrybench project was divided into six project stages.

1) Basic data on the energy consumption of the audited foundries was collected in order to better identify and de-scribe the energy economy and energy saving areas of individual foundries.
2) Fieldwork and the measurement of energy consumption. The systems and equipment that consume heat, fuel, electricity, and water in the foundry were identified and studied.

3) The level of energy use of the individual foundries was analysed based on initial data, fieldwork, and interviews with foundry personnel.

4) A clear description of the energy saving measures and the relevant saving potential for each foundry. In addition, an energy use index for each audited foundry was calculated and reported.

5) A comparison of the energy saving performance of the project partner foundries and other European foundries was carried out. To non-partner foundries a questionnaire was sent in order to ascertain basic information on the products and energy use of each foundry. The energy efficiency index (EEI) of each foundry was then calculated and the foundries given a ranking based on their EEI.

6) The final stage of the project saw the compilation of a good practice guide and searchable online database giving energy saving solutions for foundries.

The majority of the valuable material produced during Foundrybench can be found from the project webpage and thus the main purpose of this document is to raise awareness on the actions that would have significant impact on energy savings in this highly energy intensive industry as well as provide information to different stakeholders on the current situation of foundry industry. One of the key aims of this document is to give insight to the foundry sector in European countries and provide valuable information and useful tools on the energy saving opportunities for foundries.

4 Best practices – toolbox for improving the energy efficiency of foundries

Part of the most practical results of Foundrybench was the best practice examples. These examples give practical tools for improving the energy efficiency of a foundry. The chosen Best Practice cases are listed below. However, the list only gives an idea of the solutions available and more detailed descriptions can be found as an appendix of this publication. Moreover, to be able to spread this valuable information effectively there is also an online database of this material available for the public.

Database can be found from:
http://www.swerea.se/sv/swecast/Kunskapsomraden/Energi/

All in all 46 best practice examples with varying topics and different approaches were collected and elaborated. The following table lists these examples which were developed by the project contributors. It is an open list, a collection of individual situations. There will be many more of those examples. But on one hand a limited project has limited resources only and on the other hand by far not every good solution is described in a way that it can be adapted to a searchable database.

Best practices in Foundrybench project are good suggestions and each of the practices cannot be applied in all cases and in all foundries. The aim of these is to assist the foundries, in general, to consider these best practice examples from their own perspective as solutions for the energy efficiency improvements. Energy efficiency is significant in order to take competitiveness of our European foundries in the global market and to have more sustainable Europe from the energy point of view.

List of addressed best practice examples (BPE´s)

No.	Content
1	**Learning from nature**
2	**Intelligent control of compressors**
3	**Storage of heat**
4	**Ladle preheating**

5	Exchange of the recuperator
6	Energy monitoring systems
7	Low pressure air filter
8	Compressed air
9	Increase of energy efficiency by increasing the cut out
10	OxyFuelBurner
11	Flameless porous burner
12	Waste heat to dry varnish
13	Intelligent fan control
14	Energy requirements of different types of feeding systems
15	Heating premises
16	ITT Water and Wastewater - Borehole Thermal Energy Storage (BTES)
17	Highest efficiency during cupola operation (optimum operating point)
18	Foundry connected to district heating network
19	Melting temperature and overheating for cupola coupled with holding electrical furnace
20	Procedural control for induction furnaces for melting and temperature holding
21	Automatic pouring units for High Power Thermal Plasma (HPTP)
22	Top hat heat treatment furnace / seal hearth insulation
23	Pump cooling system control
24	Shelter against weathering of coke
25	Influence of packing density on the power consumption
26	Influence of the quality of scrap on the power consumption
27	Influence of the addition of Carburizing on electricity consumption
28	Detection of the waste heat from castings and heat treatment furnaces

29	**Cupola runner trough fitted with a (lining) cover on the top of the channel**
30	**Minimizing air leakage and draft in doorways**
31	**Construction tightness (heat and airborne substances ventilation?)**
32	**Heat recovery with rotary wheel in general ventilation**
33	**Heat recovery with plate heat exchanger in local/general ventilation**
34	**Heat recovery with coil heat exchanger of ventilation air**
35	**Leakage control of compressed air**
36	**Control systems of multi compressors system run**
37	**Heat recovery of cooling air of compressor rooms (summer/winter use)**
38	**Heat recovery of compressor oil cooling**
39	**Electricity generation from waste heat ORC-Steam engine**
40	**Electricity generation from waste heat ORC-Steam turbine**
41	**Minimizing the use of compressed air**
42	**Drying of water based coatings**
43	**Cupola waste heat use**
44	**Integrated heat treatment of Al castings**
45	**Recycling of shot-blast machine exhaust air**
46	**Heat recovery from gas fired heat treatment furnaces**

The list therefore may partly be recognized as an "appetizer". But it is much more than this: as contact information is involved in the elaboration as well, it is easy for the technical and financial personnel of an interested enterprise to get first-hand information about individual experiences, obstacles on introduction, and long-term rating.

This collection is embedded in a guideline which is thought to be a total and general view over the whole topic of energy efficiency in foundries (can be found form the project website). This guideline addresses more or less every aspect of energy consumption in foundry production and thus creates awareness of what ever has to be regarded and what is worth to be thought of in detail. In this way the two outcomes of the project complete each other.

5 Benchmarking – route towards more efficient foundries

Benchmarking is a tool that can be used to compare ones business processes to industry bests and/or best practices from other industries. It can also be used to make internal comparisons of process performances.

In the Foundrybench project Energy Efficiency Index values (EEI values) were collected from the European foundries. The foundries were asked to fill in a questionnaire with questions related to their use of energy.

The first important conclusion is that, despite the fact that the foundry industry is an energy intense industry, there is a large improvement potential by just inspiring the foundries to keep more track of their energy use. However, this conclusion is based on the results of the questionnaire of this project and may not represent the situation of the foundries all over Europe. Since the energy use is not the core business of the foundries they put focus primarily on other investments and improvements. However, rising energy prices help the development in the right direction.

The EEI values could primarily be used to make comparisons within the own foundry. I.e. a foundry could follow its EEI values from year to year or month to month to keep track of their energy use. The effect of investments and process changes can be followed up by measuring the changes in EEI values.

When it comes to comparisons between foundries, the EEI values have to be used with care. The reason for this is that the foundries have very different prerequisites. The number and range of activities performed varies a lot between foundries. Some foundries might have in-door fettling, heat- and/or surface treatment while other foundries outsource those activities. In order to make relevant comparisons, all this type of background information needs to be considered. To make relevant comparisons, it is important to make sure that the right system boundaries are used. Comparing the energy use of two foundries with very different operations would obviously be of no interest or use.

In most cases, the comparisons of specific processes are of most value when comparing foundries with each other. E. g. comparing the EEI values for the melting process of one foundry with that of another. This way, the system boundaries can more easily be defined, enabling more relevant comparisons.

6 Auditing the foundries

As part of the Foundrybench project, energy audits were carried out in seventeen foundries and reported. Of the seventeen audit reports, eight reports were rejected from the further study because the reports were either incomplete or the foundries audited were mixed iron and steel foundries and could not, therefore, be classified as being either iron or steel foundries. Information on energy consumption and specific energy consumption of the seventeen audited foundries can be found in appendix 1. The nine selected audit reports used in the calculation of savings potential in this report consisted of four iron foundries, three steel foundries, and two nonferrous foundries.

In order to identify the energy savings potential of the audited foundries, the average savings in total energy consumption of the nine selected foundries were calculated. As a result, it was possible to produce benchmark figures for energy savings in the European iron, steel and nonferrous foundry sectors.

An energy audit procedure for foundries was exploited that consisted of seven steps. The audits began with an overall survey of the foundry, processes, and building services. It was important that all the relevant information was available that dealt with production, energy, and maintenance. It was also important that the auditor(s) and company key personnel were present. (1) In the first meeting, all necessary material, systems, drawings, and energy use and prices were collected and handed out. (2) Energy acquisition was ascertained. This included information on the utilities, contracts, energy use, and measurement metres of the foundry. Once the energy inputs were ascertained, (3) measurements were started. These measurements included actual energy consumption, condition, and production measurements. The measurement data was normalized to mean weather and production conditions. In addition, all the flows relating to energy consumption to an accuracy of ± 5% were taken into account. The taking of measurements lasted for a minimum of one week. (4) Energy flows were analyzed and illustrated in a sankey-diagram in three phases: a) inlet (purchased - b) use (process, drives and heating/cooling/ventilation) - c) outlet (measurement results). (5) Saving options/measures were pre-designed. (6) Cost and profitability calculations were carried out for the accepted saving systems/options. (7) Finally, the results were reported and a follow-up scheme of energy use was arranged. The comprehensiveness of the analysis should be aimed at an accuracy of ± 5% of all energy use at the audit site. A good analysis should show the most important energy flows (outlets) to be minimized. In foundries, the most important energy flow is ventilation exhausts.

In the following chapters, the results of the foundry audits are presented. The mean results are not one hundred percent applicable to all European foundries. Large cupola melted, automation oriented, long series foundries definitely use a higher percentage of melting energy (up to 75%), and small hand moulding foundries use less than 40 % for melting. The following results will help individual foundries to map their position in energy use. When reading these results, one should not ignore the individual characteristics of each specific foundry nor how energy use is effected by these characteristics. Should energy use be higher than stipulated in these results, the foundry should be worried and should commission a professional energy audit. According to the results of the energy audit, saving measures should be undertaken.

6.1 Savings potential identified in the selected audited foundries

The results of the energy audits undertaken in the iron, steel, and nonferrous sectors of the foundry industry as part of the Foundrybench project show significant energy savings potential. The average savings in specific energy consumption (MWh/t) identified in the audited iron, steel, and nonferrous foundries are presented in Table 6.1 below.

Table 6.1 Average savings in specific energy consumption identified in the selected audited foundries.

Foundry Type	Savings Thermal MWh/t	Savings Electricity MWh/t	Savings Total MWh/t
Iron	0.45	0.10	0.55
Steel	1.07	0.28	1.35
Nonferrous	0.73	0.08	0.81
TOTAL MWh/t			**2.71**

The estimated annual average savings in energy consumption (MWh/a) for each foundry sector are presented in Table 6.2 below.

Table 6.2 Average annual savings in energy consumption identified in all audited foundries.

Foundry Type	Savings Thermal MWh/a	Savings Electricity MWh/a	Savings Total MWh/a
Iron	2 039	784	2 823
Steel	3 900	819	4 719
Nonferrous	4 009	2 641	6 650
TOTAL			**14 192**

The estimated average annual savings in energy consumption costs (€/a) for each foundry sector are presented in Table 6.3 below. The savings are calculated based on an average price of 95 €/MWh for electricity and an average price of 50 €/MWh for thermal energy. The prices do not include VAT.

Table 6.3 Average annual savings in energy costs identified in all audited foundries.

Foundry Type	Estimated Savings Thermal €/a	Estimated Savings Electricity €/a	Savings Total €/a
Iron	101 950	74 480	176 430
Steel	195 000	77 805	272 805
Nonferrous	200 450	250 895	451 345
TOTAL €/a			**900 580**

6.2 Savings potential of the European foundry industry

The main aim of the Foundrybench project was to improve the energy performance of the European foundry industry because the cost of energy is directly related to the economic performance of an enterprise and, therefore, energy saving is an important defence mechanism in the current global economy.

As a result of the findings of the Foundrybench project, it is possible to calculate the potential savings in energy consumption of the European foundry industry. The annual production volumes and number of foundries in operation (2008) in each foundry sector are presented in Table 6.4 below.

Table 6.4 Annual production volumes and number of foundries in operation in each foundry sector.

Foundry Type	Annual Production 1000 t/a	Number of foundries in operation (2008)
Iron	12 607	1 932
Steel	1 023	308
Nonferrous	3 485	2 594
TOTAL	**17 115**	**4 834**

The total annual savings in energy consumption for each foundry sector are presented in Table 6.5 below.

Table 6.5 Total annual savings in energy consumption for each foundry sector.

Foundry Type	Annual Savings Thermal TWh/a	Annual Savings Electricity TWh/a	Savings Total TWh/a
Iron	5.66	1.24	6.90
Steel	1.10	0.28	1.38
Nonferrous	2.54	0.28	2.82
TOTAL	**9.29**	**1.81**	**11.10**

The annual savings in energy consumption costs for each foundry sector are presented in Table 6.6. The savings are calculated based on an average price of 95 €/MWh for electricity and an average price of 50 €/MWh for thermal energy. The prices do not include VAT.

Table 6.6 Total annual savings in energy consumption costs in each foundry sector.

Foundry Type	Annual Savings Thermal M€/a	Annual Savings Electricity M€/a	Annual Savings Total M€/a
Iron	283	118	401
Steel	55	27	82
Nonferrous	127	153	153
TOTAL	**465**	**172**	**636**

The average annual savings in energy consumption costs for individual European foundries identified as a result of the findings of the Foundrybench project are presented in Table 6.7 below.

Table 6.7 Total identified average annual savings in energy consumption costs for individual foundries.

Foundry Type	Average Annual Savings M€/a	Number of Foundries
Iron	0.208	1 932
Steel	0.266	308
Nonferrous	0.059	2 594
TOTAL	**0.132**	**4 834**

6.3 Audited systems for foundries´ energy efficiency

In this chapter, the most frequently applied systems for achieving practical energy efficiency in the audited foundries will be presented. This chapter addresses the practical state of the art because these systems can be met in a form in the existing foundries and they can be qualified as practical and profitable systems. The systems described below are handled in a more exact and technical way in other deliverables of this project. They can be found from one or several deliverables such as Description of Energy Analyses, Training Materials, Audit and Analyses Reports and Best Practice Guides. This is why they can be presented here as good practices but only on a more general level.

A high yield improves energy efficiency as well. If yield is improved from 9% to 4%, the overall energy efficiency improves automatically by 5% too. This issue is out of the scope of this project and that is why the important subject will not be handled more in the report.

6.3.1 Melting furnace cooling or heat recovery system

All electrical melting furnaces need to be equipped with cooling systems to avoid surplus heating causing damage to induction furnace coils or the steel structures in electric arc furnaces. In these types of furnaces, the cooling effect represents some 20% of input prime energy. This represents some 100kWh/ton of melted metal. In addition, cupola furnaces emit a lot of surplus heat. Cupolas may be cooled down externally by water and exhaust gases contain lots of energy because of the high temperature and CO content. The energy of the exhaust gases can be recovered by using CO ignition and water coils in the exhaust gas flow.

Re-circulating cooling water is cooled with a fan coil that transfers cooling energy to the ambient air, to pool or river water, or to cooling towers. This cooling energy can be recovered for the heating of the foundry premises or for hot tap water. This is why several large foundries in Central and Northern Europe have fitted this type of heat recovery system. In parallel with the heat recovery system, a cooling system for warm periods as illustrated above is required. The normal payback time period is three years in a Northern Europe climate.

6.3.2 Improvements in melting operations

Melting is usually the most intensive energy consuming operation in foundries. It represents some 30 - 45% of all energy use. Therefore, it is important that melting is investigated in energy audits as well. Electric melting is considered to be the best practice method having an energy efficiency of up to 70%. Earlier, cupola melting had the advantage of cheap fuel prices. However, the price of coke has increased dramatically during the past few years. The main disadvantage of cupola melting is the large loss of flue gases. With lower price fuels and heat recovery systems, e.g. heisswind-kupolofen, however, the energy efficiency of cupola melting has improved. Reverberatory furnaces have a much lower energy efficiency of only 20 -35%.

Ways of saving energy can be found from the use of equipment and on the other hand from melting operation procedures. The more delays there are in melting and pouring operations the higher the energy losses. The melting process should be as continuous as possible without any cooling-down periods in between. This makes the use of tandem furnaces efficient. The more furnaces you have the more important it is to have a careful melting schedule for melting and pouring operations. Maintenance plays an important role. Furnace insulation must be kept in good condition and furnace covers must be closed. All these melting procedures can save up to 10 % of all melting energy and in general 3 - 5 % savings can be achieved in average foundries.

6.3.3 Cooling systems for sand reclamation

Most foundries recycle the mould sand some 3 - 8 times. The sand reclamation system contains a sand cooling system as well. The recycled moulding sand cannot be too cool or too hot, and it is usually used at a temperature of 20 to 40 °C. In the shake out stage, the sand temperature can vary from room temperature up to 400 °C. The weight ratio of the moulding sand to castings is usually 1:5, i.e. for one ton of casting the mould contains some 5 tons of sand. This means that as much heat can be recovered from sand cooling as can be recovered from furnace cooling. Thus, the saving potential can be calculated as 100 kWh/ton castings.

This energy can be recovered easily for heating purposes as well. Because the sand is usually cooled down with water coils the cooling water can be jointed to a similar heating system as the one described in a previous chapter.

6.3.4 Heat recovery of ventilation exhaust air

High emission rates and harmful emission compounds demand very efficient ventilation in foundries. There is also lot of surplus heat in the indoor air. In normal production conditions when the supply air temperature is some 15 °C, the exhaust air temperature raises to the level of 30 - 35 °C. With a quick glance at an energy Sankey-diagram of the foundry, one recognizes the huge potential for energy saving in the exhaust air. Usually 70 – 80% of output energy from foundries escapes in the exhaust air. With the proven technology of heat recovery systems, approximately 50% of this energy can be recycled. The question is more of the objects where the energy can be used than how to recover it. The practical examples of saving potential exist in Finnish, Swedish, and German foundries that show more than 50% temperature efficiency for heat recovery representing some 0.3 MWh/ton in iron and non-ferrous foundries and up to 0.7 MWh/ton in steel foundries. Investments are reasonably high 3000 €/ m^3/s air flow. These investments give the return of 3 - 5 years payback time.

Exhaust air recycling is the most efficient way of recovering heat from ventilation. These solutions have become more common because of high efficiency dust filters. The exhaust air of the fettling shop booths, the shot blast, and sand reclamation are nowadays cleaned to the level of below 1 mg/m3. This makes it possible to recycle the exhaust air free from harmful gaseous compounds back to the work premises. The exhaust air return system must be equipped with a control system such as dust content monitoring instrumentation or a back-up filter with pressure drop control.

The best options for ventilation heat recovery are general ventilation systems and dedusting systems after exhaust air cleaning. These saving options can be, e.g. melting furnace exhaust, shake-out exhaust, shot-blast exhaust, fettling shop exhaust, and natural gas fired heat treatment.

6.3.5 Energy savings in compressed air systems

Compressed air (CA) systems use s lot of electricity in fettling, sand transport, and dust filter cleanup. Total consumption share is between 5 - 8% of all energy in normal sand foundries. This corresponds to 0.1 - 0,3 MWh/ton. The most common cause of needless energy use in CA systems is leakages. Hoses, joints, fittings, and valves are not tight enough. In the audited foundries, the leakages from each system were from 15 to 40%. This situation can be improved with better control and maintenance only. Another reason for wasted energy use originates from poor control of the CA-system. In the case of several compressors in simultaneous use, a sophisticated automation system saves easily 5 - 10% of annual electricity consumption.

In general, compressors and pneumatic machines work at very low efficiency when changing electricity to mechanical work. The total efficiency is below 10%. This means that 90% of electrical energy is converted to heat in the compressor room. This warm cooling air should be transferred to the heating of the premises and only in summer time to be blown outdoors. Electricity driven hand machines with the high efficiency of 90% are expected be developed more light and handy for fettling work.

The biggest saving can be reached with correct decision in the design stage. The sand should be transported as little as possible pneumatically and more with elevators and belt conveyers. This is why shake-out, sand silos, and mixers should be placed as near to each other as possible. Nearly half of CA-energy can be saved in this way. With automated fettling operations such as robotized cut arms, etc, a lot of fettling work and pneumatic air use can be replaced. This development is widely applied in foundries and will have a big effect on other foundry processes and energy use in the future too.

The audited systems were not in good condition. In one foundry 40% savings could be achieved with low cost and a shorter period than a year payback. Even the CA-systems in the best condition can be improved with 15% saving options.

6.3.6 Ladle preheating

Ladle preheating uses much energy. Usually, they are heated with natural gas flame burners. The efficiency is very low at only 15 – 20% of the energy that can be transferred to ladle structures. In the case of convective flame heating, the efficiency can be improved with tighter lid systems. Modern porous burners use much less gas and create high radiation improving energy efficiency to the level of 30 - 40%. The best efficiency can be reached with a heating station of high temperature electricity resistors. They have an efficiency of up to 70- 80%.

6.3.7 Lighting

Lighting uses several percentages (3 - 6%) of foundry energy. With energy efficient lamp types, consumption can be lowered by 20 - 30%. At the moment, sodium lamps, metal halide lamps or led lamps offer the best light efficiency (lm/W). Metal halide and LED lamps have been developed with their spectrum of light (colour rendering) and they can be considered as the best selection for foundry premises. They ensure good and safety lighting in work places.

The saving potential depends on the existing situation. In the case of having fluorescent lighting as general lighting, the change to halide or LED lamps offers a saving of 25% in energy use. In practice, the potential saving lies at the level of 10 - 20% (0.1 MWh/ton). The maintenance of lamps is important too. Dirty reflectors are commonly found in dust-loaded work places.

6.3.8 Ventilation

Several types of harmful compounds are emitted from foundry processes. Ventilation ensures safe working conditions in foundries. Ventilation systems exchange exhaust air to clean outdoor air. In winter, the supply air is heated up and in warmer climates the supply air will be cooled down mechanically during the summer. The ventilation plays an essential role in foundries using some 15 - 25% of energy.

Ventilation has efficiency as well. The better the ventilation system transfers emissions away from room the more efficiently it works. The ventilation efficiency is $e = C_e/C_o$, where C_e is the concentration of exhaust air and C_o is the concentration of the occupation zone. In the case where contaminants rise up to the exhaust openings and will not be mixed, the occupation air on the floor level has good efficiency. In complete mixing ventilation, the efficiency equals to 1. With displacement ventilation, one can reach two or three times lower occupation zone concentrations than the concentration of the exhaust air. This means that with efficient displacement ventilation one can use only half of the airflow that you have in mixing ventilation. This means half of the energy to heat up the supply air. This all means that you have to use the minimum air flow of stratification. This condition is usually fulfilled in foundries because there are a lot of surplus heat and contaminations.

With the correct strategy of ventilation, some 0.2 MWh/ton of specific energy can be saved. Ventilation should also always be controlled by air quality or process operations to avoid unnecessary operation.

In displacement ventilation, properly heated supply air is introduced to floor level (occupation zone) directly and hot contaminated air is exhausted out from the ceiling level. The mixing ventilation blows supply air jets with high velocity and mixes all the indoor air at the same concentration and temperature.

6.3.9 Summarized results of the audited foundries

In table 6.8, the energy consumption results of the audited foundries have been summarized. Iron foundries data was quite uniform but the deviation in steel and nonferrous foundries depends much on the production technology, steel quality and castings. Especially, this depends on the heat treatments needed for the steel castings. The business value figures are not absolute because they are not checked from the companies directly.

Table 6.8 Average energy use in different foundry types

Unit/Foundry type	Iron foundry	Steel foundry	Nonferrous
Energy/tonne, MWh/t	**2,5**	**5 - 8**	**4 - 10**
Energy cost of business value, %	**5 - 8**	**6 -11**	**4 -8**

Table 6.9 is a summary of energy consumption split in a more detailed way. The table contains nine subgroups of production processes having remarkable meaning in energy use. This distribution shows an average with the deviation and saving potential. The saving range differs from foundry to foundry. The foundries are in a very different situation. Some of them have huge potential for energy saving options and others are already on their way to saving. They do differ a lot with the quality of the material produced and the climatic conditions of the location. The saving potential of the audited foundries shows a value of 17% (+7 %).

In Table 6.9, the unit process "drives" includes all the motors driving mixers, cranes, pumps and fan etc. but not compressors that are located in the unit process of compressed air (CA) system. Ventilation includes all the supply air heating whether there is heat recovery or not. Heating means the space heating with radiators, floor heating or indoor air recycling fan coils, i.e. mostly the energy to compensate heat transmission of constructions and infiltration.

Table 6.9 Energy saving potential of European foundries

Unit processes	Iron foundry energy share, % and the range, ±%	Steel foundry energy share, % and the range, ±%	Nonferrous foundry energy share, %, the range , ±%	Saving potential, %
Melting	**55 ±10**	**45 ±5**	**65 ±10**	**6 - 10**
Annealing	**1 ±1**	**25 ±2**		steel **(3)**
Drives	**12 ±4**	**9 ±2**	**11 ±5**	**1**
CA-system	**7 ±3**	**5 ±2**	**5 ±3**	**2**
Ladle preheat	**4 ±2**	**4 ±2**	**3 ±2**	**2**
Venti-lation	**14 ±5**	**7 ±5**	**10 ±8**	**4 - 7**
Heating	**3 ±2**	**2 ±1**	**3 ±2**	**1**
Lighting	**4 ±1**	**3 ±1**	**3 ±1**	**1**
Total	**100**	**100**	**100**	**17- 24**

7 Overview: Experiences across Europe

7.1 Sweden

The Foundrybench project has resulted in increased knowledge on several levels. The knowledge can be used and developed further in up-coming projects. This way it will continue to be furthermore disseminated among Swedish foundries.

One of the important outcomes is the fact that we have learnt to know the foundry sector and institutes in Europe better. The contact with the partners in this project has given us a very good network for further work in coming projects and for solving foundry issues in the future.

The increased knowledge includes for example the following areas: benchmarking and benchmarking methods, European foundries knowledge of their energy use (as well as potential for improvement in this regard), better overview of energy saving solutions. The methods developed within the project will be used and refined over the coming years. This will imply that time will be saved in future projects and work. Parts of the results can be disseminated several years after the actual project has been finished. Some of the results of the Foundrybench project has already been taken advantage of in recently started projects, such as e.g. Foundenergy.

The barriers and drivers for improvement of energy efficiency are primarily related to economy. Barriers such as lack of budget funding and other priorities for capital investments are ranked high. Drivers are threat of rising energy prices and cost reductions resulting from lowered energy use. Committment from top management is also ranked as an important driver for energy efficiency.

Our experience is that more focus should be put on the management issues regarding energy efficiency. You could have all the technical solutions in the world to achieve energy efficiency, but if there is no will or knowledge to implement them there will not be any change.

An evaluation of energy audits performed in Sweden during 2011 showed that on average 15 % of the energy used in a Swedish foundry is used for heating of the premises. 45 % of the energy saving potentials in Swedish foundries is related to reducing the energy used for heating. Efficient best practices in Sweden therefore include recycling waste energy for heating. One challenge is that the available waste heat often varies over time while the need for heating is more constant. This can be solved by storing the heat by using either short time storages such as e.g. accumulators or by using seasonal storage facilities like borehole thermal energy storages or aquifers.

7.2 Finland

Finnish foundry industry is small. The total annual iron and steel casting production in the highest capacity has been 140 000 tonnes in 2008. Nonferrous casting production was 20 000 tonnes/a. Number of ferrous foundries are some 20 and nonferrous foundries are 16. In the project four foundries were audited and 12 of them answered to benchmarking. Most of foundries are small. The biggest iron foundry has production capacity of 30.000 tonnes/a.

The energy use in Finnish foundries is on reasonable level. Specific energy use (MWh/t) is lower than generally in Europe according the findings of deliverable D8. Only Spanish foundries had lower specific energy use. This is understandable because of the energy audit has been completed already once or twice in the most of the Finnish foundries. The audit results show that Finnish foundries could have additional saving of 31 % in thermal energy use and 5 % in electricity use. Because of cold climate ventilation and heating require nearly 30 % of foundry energy use.

Still there are lot to be done in energy saving. The companies do not find the energy saving too profitable if the saving period for investment is longer three years. This attitude should need extra driving forces or some substitution mechanism to be created.

The seven step method developed proved to be accurate enough to do correct decisions for profitable investments. General methods of energy auditing have been taking into use some 20 ago in Finland. The weakest point is the missing experience and knowledge of realistic practical saving measures and systems to be applied in foundry industry. This is the experience that is developing by doing and completing installations and followup on the field only. It is not only question of best practices available but more the practical experience of the operation of energy saving systems. They must be feasible and reliable systems under careful maintenance that are worthwhile to be installed in heavy industry. As a next step recommendation to foundry industry that should be takin is the compendium of practical best practises with the data of feasibility, investment neede, reliability and savings achieved.

Foundrybench project offered a good platform for foundry industry to further improve energy use and profitability. This is very important way of development because low cost countries havs rapidly taken over more share of global casting markets. It is also clear that energy price will rise rapidly during next years and this is the case especially in Europe.

7.3 Poland

Polish foundry industry with their output close to one million tons/annum including of more than 450 foundries, is a serious consumer of energy. At the beginning of the project was no a clear regulations in the energy management. Growing energy costs on European level accelerated elaboration of new energy regulations. 15th of April 2011 was voted act concerning of energy efficiency, came into force in August 2011. Aforementioned regulation also includes auditing of the energy use, understanding the audit results and implementing the energy management program, setting ideas for general energy management opportunities, putting it all together. In addition, access to the capital funds has improved, due to new regulations and directives. Also some funds in the frame of Regional, environmental etc. funding is easier available for industry sectors including foundries.

Among the barriers for the improvement of energy efficiency in foundries the lack of budget funding, other priorities for capital investments, access to capital and poor measuring equipment were emphasized. The emphasized drivers were rising energy prices, cost reduction resulting from lower energy use, beneficial loans for energy efficiency investments, investment subsidies for energy efficient technologies, emissions taxes and long-term energy strategy.

The most significant added value of Foundrybench in Poland has been the increase in awareness among foundry users concerning of energy efficiency and management role.

Adaptation of being in force Energy Efficiency Act to the foundry conditions is a task for nearest future.

Due to the climate and work conditions the majority of the practical actions are directed to heat savings from the technology processes as well exchanging of energy-consuming devices and drivers (using of Power Optimizers®, inverters, etc). For new installations a modern control system, drivers and other energy equipments are designed.

7.4 Spain

Before the Foundrybnch project the Spanish foundries already had started to realize their situation in relation sustainable energy. However, the project audit results showed that an urgent reaction the foundries needed. Audits are the snapshot of the current energy consumption situation. This supports the fact that energy consumption is of vital importance in the Spanish Foundry sector and others sectors. In Spain there are different organizations (such as CADEM in the Basque Country) helping in relation to sustainable energy. The Foundrybench project helped realizing that the Spanish foundries need to improve energy efficiency versus their consumption and that they can compare with others European foundries.

For instance in Spain there are only 5 cupolas (media consumption 1000 Kwh/ton) comparing with others countries, but there are many induction furnaces with a good relation kWh per one tonne (less than 650) but sometimes with inefficient practices in preheating and head treatments. And the cost of these inefficient practices is estimated to be between 1-2 % of the total costs of the energy consumption. Currently foundries are beginning to change these habits and are installing control systems to monitor all the processes and equipment including software supporting. In addition, they are developing new systems to recuperate the energy losses during the manufacturing process. In this context there are projects are such as EDEFU, to develop of optimised furnaces using new technologies to manufacture optimised furnaces with lower energy consumption, fewer emissions to the environment and a better utilisation of the raw materials.

The results of the Foundrybench project could be used in others projects, such as e.g. Foundenergy coordinated by TECNALIA and other proposal of projects.

Material created in Foundrybench, such as the task guidance sheets published in order to attend good practices, are tools to improve in energy efficiency. This context provides a summary of good practices which is a flash of ideas of what would be a simple guide of good practices in energy efficiency. Practices are good suggestions and taking into account each of the practices cannot be applied in all cases.

Barriers for the improvement of energy efficiency in foundries are the budget funding and the expectations for new installations (such as ROI system) may be relatively expensive and long range. On the other hand the Spanish foundries have a good driver: the cost of the energy is high in comparison with the other European countries (France, Finland) so it needed in order to save energy and to control their budget energy. Other positive aspect is that Spain has a good climate, in general without hardly ever extreme sub-zero temperatures and hardly so high summer temperatures, especially in the northern Spain where is concentrated the major steelmaking and foundry industry. So usually the energy used for heating and cooling represents less than 10%.

Communication with the partners in Foundrybench has been good exchange technical experiences all and understanding the complexity of energy efficiency in each country makes this all more valuable: it is also good to see that the challenges of getting feedback from the foundries in Europe are rather similar.

7.5 Germany

Energy consumption and energy pricing are significant issues in the German Foundry sector. There are numerous technical developments, guidelines, governmental support bureaus and commercial consultant offices, congresses and so on. The public awareness is very high. In contrast to this the awareness in the industrial sector of the saving potentials was not well developed in the beginning of the project in 2009. The general impression about this situation was that experts are needed to find these potentials by systematic analyses. Enterprises which had installed a task force to find options were on a good way. Energy management systems were not implemented that time. Today between 2 and 5 % of the foundries in Germany have such a system and are regarded by us to be benchmark leaders very frequently.

Technically the secondary and tertiary use of waste heat is the scope where emphasis and expectations are mostly focused on. Here the biggest potentials can be found. But as the available temperature ranges are often low, installations may have to be large and costly, which disappoints the common ROI´s expectations. Therefore especially two drivers can be identified for being responsible for fostering this development: the energy costs and a sustainable business development.

A speciality of German foundry business is the wide spread use of cupolas for the smelting of iron based alloys. From an energy benchmark view, these installations are disadvantageous, as they need about 1000 kWh for one tonne of liquid iron, whereas a modern induction furnace needs only about 600 kWh per tonne. In contrast to this the overall energy efficiency – based on fossil energy – is much better with a cupola as the conversion factor from carbon incineration to electric current is poor. So the *local* consumption balance of a cupola foundry is principally not the best.

With the introduction of the greenhouse gas trading system for big foundries this discussion (and also the secondary use of off-heat) reaches a new dimension. It is not within the scope of this work to evaluate the more preferable approach. For practical reasons it will stay this way for a longer period (cupola operation), as is will not be easy to supply the big foundry production sites with 1.1 TWh/a extra to smelt electrically. So one should keep in mind that energy benchmark has always to be a "relative" instrument.

7.6 France

Materials forming industries are to some extent aware of energy consumption and energy efficiency: the less the energy consumption, the more competitive and profitable is the factory. In case of foundries, they are basically ready to act, but only few do the first step.

Energy efficiency is nowadays a hot topic all over the world, but it was already true in the past. The Foundry Industry History is a very good example with the case of the cupola furnace. Because of a very high risk of fuel (wood) shortage during the XVIIth century, coke (it was called coak at this time) was used as new kinds of fuel.

The development of cupola with coke was a revolution. Such this short historical review, on the same way, energy efficiency challenge is a good way to increase the activity and the robustness of the industries. This is the reason why new projects, prototypes and retrofit should be actively promoted and financially supported by organization and government.

As described in the energy saving guides or in energy management systems (ISO50001), the first step to improve energy efficiency is the energy audit. The energy audit can be done with internal human resource of the foundry, or if not enough time and resources are available, the audit can be done by an energy services company.

Concerning energy audit and France, the situation is paradoxical. On the one hand, there is a national terms of reference for implementing an energy audit in the industry. The specifications and requirements are described in the guide *BP X 30 120*, which is now mentioned as a basis for energy audit in many countries. If one wants to perform an energy audit or if one wants to receive some funds for this, it is better if the task will be done in accordance with this guide.

On the other hand, energy audit is not very widely used in the foundries. Only few foundries did the step to perform an energy audit. The results of the Foundrybench questionnaire describe clearly the fact: less than 40% of the French foundries performed an energy audit.

In France a very strong motivation should be undertaken to encourage foundrymen to perform an energy audit. Foundrybench project results could be mentioned as a reason to act together more significantly.

Energy audits can give many tools for improving the energy efficiency. Some of those are the best practices for saving energy consumption. This type of energy management action is done once and for which the cost is not considered too high (low cost). They are very well received by the manufacturers who are demanding for these kinds of actions.

More elaborated technical saving energy solutions and retrofit can be proposed with high cost. This energy management action is done once but the cost is significant. In this case, it requires more time, analysis and investment. It is more difficult to take action. In practice, retrofit is done when equipment is threadbare.

There are many important barriers for the improvement of energy efficiency in foundries, for example: the relatively low cost of energy price in France, the underestimated savings generated by energy efficiency actions, the lack of metering and subdivisonary energy consumption measurement in factory. Favourable best practices for improving energy efficiency in France could be the implementation of an energy management system and energy efficiency training for foundrymen.

At the end of the Foundrybench -project, most of the foundrymen and associated persons with the project are more aware of energy efficiency - thanks to the communication about the energy efficiency in factories and the increasing energy price.

7.7 United Kingdom

United Kingdom is an old industrial country – actually it is the origin of the industrialization. Especially England and Wales have earlier been the sources of energy with their coal mines. At the moment oil drilling near Scotland and wind farms around UK are the base for domestic energy resources. Although UK has own energy sources, energy price is following the world market price including green house gas emission costs. So there is an increasing pressure to minimize energy use and take all possible actions to save energy in UK foundries.

Foundry industry in UK has possibly suffered the most during globalization; thousands of foundries have been closed when financial competitiveness has not been enough for the local machine and car manufacturers. UK can be called a post industrialized country with strong financing sector and growing service sector. Only specialized foundries have survived and even they have not been able to invest enough to keep technology on a world class level. There is a lack of investments also present in foundries so there is a lot of potential to take more energy efficient processes, equipment and working practices into use. UK foundries should utilize many of the best practices listed and described in this document and take actions to implement them first.

During the project it became clear that from climate point of view UK has more in common with Scandinavian countries than South European countries: heating of offices and especially foundry production premises is an essential cost in UK foundries for several months a year. On the other hand heating is not needed as much as in colder countries, so most of that can be done by waste energy. The best applications seem to be to use waste heat from electric melting and sand cooling. The third big source of waste energy but also a potential for saving electricity seems to be high pressure air systems. These examples showed that pay-back time of the first investments is less than two year average and in best applications less than one year.

UK foundry industry has a big burden from history: because the structure of customer market has changed so dramatically after the most existing foundries were built, they are wrong type or wrong size for today's production. For example if foundries can run only in one shift five days a week, this loading does not give enough profit to invest in new technology. The market has become too small for specialized foundries as well as for automotive foundries. The future trend can also turn around and import from low cost countries can become local manufacturing again. In that case foundries shall be designed to work 24/7 and be built in modules to optimize investment. These new or renovated foundries also need to use all possible means to minimize energy usage and to improve energy efficiency.

7.9 Summary

There are both similarities and differences between foundry industry sectors in different European countries. Identified similarities relate to few main areas: foundry management and funding. Differences then originate from different climatic conditions and the requirements based on those as well as on the energy price. However, on the other hand, foundries in whole Europe are rather similar in relation to the equipment, aims and results. The differences are mainly based on to the dimension of the foundry (small, large family, shareholders…) and their product and sector (automation, valves, aerospace, railway…).

Many actors have identified foundry management as one core issue of the improvement of energy efficiency in European foundries. Energy consumption monitoring, courage for new energy efficient technology investments, operational improvements on top of technical improvements are just the examples on how foundries could be operated in a more efficient way. Also limited funding is still seen as a challenge, but there has also been positive development in this issue because of regulation and directives (i.e. in Poland).

Main differences relate to the varying energy price and climatic conditions. In some countries the energy price acts as a driver towards more efficient foundry operation (i.e. Spain) and on the contrary in France the lower energy price is seen as a barrier for better energy efficiency. Climatic conditions vary a lot within Europe and for instance, Scandinavian countries vs. countries in Southern Europe require different focus areas in the case of i.e. heating. There are differences also in the environmental policy of each country or region.

By taking into account not only the energy consumption of the production processes but also the demands of air conditioning, significant differences across the European regions occur. Even in an energy intensive industry like the foundry industry up to 30 % of the overall energy consumption is spend on heating the premises (Finland), whereas on the other end (Spain) less than 10 % energy is used for heating even in the winter time. By separating this influencing factor from the energy analysis of the processes it was intended to make the processes comparable. Furthermore, it was found out that energy prices in the different countries differ so greatly that optimization potential has to be investigated individually by taking into account very different ROI periods for the same technique but applied in different countries.

However, common to all foundries in the participating countries is the urgent need for the improvement of energy efficiency as well as the fact that there is huge energy saving potential in this industry sector. Foundrybench has been assisting the foundries in participating countries by helping with the first steps towards more efficient operation: energy audits, best practice examples and benchmarking.

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8 Future actions – priorities suggested by Foundrybench project

	Top priorities	Second term priorities	Long-term priorities
Audits	• Audit done at least in foundries consuming more than 5 GWh/year • Forming a section i.e. in FRI for energy audits performance • Foundry management improvement	• Audit done at least in foundries consuming of 1-5 GWh/year • In case the foundry is getting grants from EU or domestic government an energy audit and a new technology strategy should be required	• Audits done in foundries consuming below 1 GWh/year
Benchmark	• Promotion of energy benchmarking idea on seminars, conferences, fairs, lectures etc. all over Europe	• Introducing a benchmarking principle to educational programmes of foundry technology and management faculty on a high level of education	• Analysis of energy consumption in foundry sector on the base of yearly reporting (comparing of EEC)
Best practices	• Possible promotions of own best practices in energy saving • National program to update situation in foundries every two years • To distribute Foundrybench reports to teachers in all technical universities and other schools as a free educational information	• Implementing of best practice examples with observance of third parties rights and interests	• Exchanging of electric drives in foundry sector • to build a system to update the best practices of energy efficiency into BAT • to make one criteria for energy efficiency in all BAT

9 Significant factors influencing European foundry industry

During the past 10 years the global growth has focused mainly on developing countries like BRIC-countries (Brazil, Russia, India and China) but also in earlier developed countries like South Korea, Taiwan and Mexico. The key driver has been and still is the overall growth and development in those countries. China is the only one of those countries in which an essential part of GNP growth has come from export. In all other countries domestic need has increased GNP and so is the case also mainly in China, too.

Casting usage is strongly following the living standard of each country and old industrialized economic areas like EU, NAFTA and Japan have very similar structure of casting usage. The difference in manufacturing of castings is also rather small: most of castings are made locally for car and machine building industry. At the moment there is a big infrastructure boom going on in BRIC countries especially and this situation has also shown the huge need of castings for building industry related machinery.

European casting market has suffered because of low price competitiveness of some European casting user markets and not so much for direct import of castings. In USA the situation has developed even further: most of the machine building has disappeared from USA and actions are now taken to get it back. A challenge of doing this is the lack of foundries producing specialized in big parts and components. In Europe we can hinder this development before the majority of our machine building has vanished. One of the actions is to improve cost efficiency including energy efficiency in foundries.

Energy price will get higher in future, that is a fact. This development affects strongly on transport costs, material manufacturing costs and foundry operating costs. Many foundry materials are either oil based, like resins as binders, or need a lot of energy in their manufacturing process, like ferroalloys. In foundry processes direct energy use in melting, making of the pressure air, drying ladles, curing and drying cores and moulds and getting light is an essential part of such costs structure which foundry management can affect directly.

All saving potentials should always be compared to the net profit: how much could this saving method improve our profit. It is often much better motivator than only compare it with turnover. The best time to take into account all these recommendations and best practices explained in this report is of course when a new foundry is designed. The new foundry needs to be designed for certain products, for 24/7 running time and as flexible regarding product development, process development and capacity usage as possible. And additionally in all respects energy efficiency needs to be one important driver.

The energy audit results of the project promise to the European foundries 17 - 24 % savings in energy use. This corresponds to the improvement of the profitability from 1 to 2 percent. It is remarkable amount of money in the time of recession and market fight with low cost countries. The foundries use nominal energy from 2,5 to 9 MWh/tonne. With the practical and reliable measures this could turned down to 1,9 - 6,5 MWh/tonne good castings. For individual foundries this means annually on average a sum of 130 000 €. To save this all in production means lot of improvements, extra work and invests.

Results show that the European iron foundry sector can potentially save 401 M€/a in energy costs, the steel foundry sector 82 M€/a in energy costs, and the nonferrous foundry sector 153 M€/a in energy costs. This amounts to a total of 636 M€/a in energy cost savings for the European foundry industry identified in the Foundrybench project.

10 Conclusions

The main aim of the project was to assess the energy consumption and energy saving options in European foundries in order to improve energy performance. Because the cost of energy is directly related to the economic performance of an enterprise, energy saving is an important defence mechanism in the current global economy. As a result of the findings of this project, an energy consumption benchmark will be developed that European foundries of all types will be able to use to compare their nominal energy consumption. It is envisaged that the energy consumption benchmark will serve first as an internal development tool as well as later on as a marketing tool for each foundry.

However, there are both similarities and differences between European foundry industries in different countries. Identified similarities relate to few main areas: need for better foundry management, easier access to funding and huge saving potential. Differences then originate from different climatic conditions and the requirements based on those as well as on the energy price which can be seen both as a barrier and driver, depending from the country.

To conclude with, common for all foundries in the participating countries is the urgent need for the improvement of energy efficiency as well as the fact that there is huge energy saving potential in this industry sector. Foundrybench has been assisting the foundries in participating countries by helping with the first steps towards more efficient operation but still a lot of work is needed in order to make the European foundry industry more competitive through energy efficiency.

11 EACI contact person and Foundrybench partners

The project was co-financed by Intelligent Energy - Europe programme of the European Commission.

European Commission – Executive Agency for Competitiveness and Innovation (EACI)
Mr. Francesco Ferioli, project officer
francesco.ferioli@ec.europa.eu

Mail: European Commission Enerrgy Efficiency Unit, Head of Unit Mr. Vincent Berrutto, COV2, Office 10/112, B-1049 Brussels, BELGIUM
http://ec.europa.eu/intelligentenergy, http://ec.europa.eu/eaci

European Commission – Executive Agency for Competitiveness and Innovation (EACI)
Mr. Francesco Ferioli, project officer
European Commission, Energy Efficiency Unit
francesco.ferioli@ec.europa.eu
http://ec.europa.eu/intelligentenergy, http://ec.europa.eu/eaci

Hermia Ltd.
Hermiankatu 1
33720 Tampere, Finland
Ms. Sini Eronen, coordinator
sini.eronen@hermia.fi
www.hermia.fi

AX-Consulting
Kuokkamaantie 4
33800 Tampere, Finland
Mr. Markku Tapola
Markku.tapola@ax.fi
www.ax.fi

Swerea SWECAST/Gjuteriföreningen
Box 2033
550 02 Jönköping, Sweden
Mr. Conny Gustavsson
conny.gustavsson@swerea.se
http://www.swerea.se/en/swecast

Institut für Giessereitechnik gGmbH
Sohnstrasse 70
40237 Düsseldorf, Germany
Mr. Joachim Helber
helber@ifg-net.de
http://www.ifg-net.de/

Centre Technique des Industries de la Fonderie
44 av. de la Division Leclerc
F – 92318 Sévres Cedex, France
Mr. Jean-Marc Piatek
piatek@ctif.com
http://www.ctif.com/

Foundry Research Institute,
Ul.Zakopiańska 73
30-418 Kraków, Poland
Mr. Marcin Latallo-Anulewicz
mlatallo@iod.krakow.pl
Mr. Jacek Przybylski
jprzyb@iod.krakow.pl
www.iod.krakow.pl

Fundación Tecnalia
Paseo Mikeletegi, 2.
E-20009 Donostia, San Sebastián, Spain
Mrs. Patricia Caballero
patricia.caballero@tecnalia.com
www.tecnalia.com

The International Meehanite Metal Company Ltd.,
Kantokatu 7,
04200 Kerava, Finland
Mr. Pekka Kemppainen
pekka.kemppainen@meehanite.org
www.meehanite.org

Assofond (Federazione Industriale Fonderie)
via Copernico 54
20090 Trezzano sul Naviglio (Milano), Italy
Mr. Michelangelo Lafronza
m.lafronza@assofond.it
www.assofond.it

Foundrybench - Improving the energy efficiency of foundries aims at showing the path towards more energy efficient foundries. The industry is highly energy-intensive and the potential for both energy saving and economical savings is huge. Both the Foundrybench -project material and this publication serve as guide and toolbox for foundrymen and other interested stakeholders towards energy efficient foundries.

Foundrybench -project intended to boost three focus areas that are closely linked to each other – energy auditing, benchmarking and best practices. Through the description of the results of these main areas the most significant barriers and drivers as well as success stories can be addressed. The authors provide information on the foundry industry of today, development needed to improve energy efficiency and also practical tools for concrete actions. There is also a country specific perspective of the partner countries: Sweden, Finland, Germany, France, Poland, Spain, UK and Italy.

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