"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638"

Applying Energy Efficient measures for metal and metalworking SMEs and industry (EE-METAL)
GA number 694638
Start Date: 1st March 2016 - Duration: 36
Coordinator: AIN

Deliverable D2.1

EE Benchmarking methodology

Public

Work package	WP2
Task	2.1
Due date	31/8/2016
Submission date	28/02/2019
Lead beneficiary	AIN
Version	3
Prepared by	AIN
Review by	WP Leader & Partners
Approved by	WP Leader
Abstract	The main objective of this work is to produce an energy benchmarking study in small and medium size enterprises (SMEs) for the NACE Rev. 2 subsector codes 24, 25 and 28.

BUILD STATUS:

Version	Date	Author	Reason	Sections
1	31/08/2016	AIN	Initial Release	All
2	28/11/2017	AIN	Clarifications concerning the deliverables corresponding to the 1st reporting period.	Several sections
3	28/02/2019	AIN	Application and final version	Several sections

AMENDMENTS IN THIS RELEASE:

Section Title	Section Number	Amendment Summary
Methodology	2 (page 6)	Change of some indicators.
Methodology	2	Application of the methodology for each indicator with the data from energy audits and making of the bar charts.

DISTRIBUTION:

Version	Issue Date	Issued To
1	31/08/2016	Steering Board
2	28/11/2017	Steering Board
3	28/02/2019	Steering Board

TABLE OF CONTENTS

EE BENCHMARKING METHODOLOGY

1 INTRODUCTION AND OBJECTIVES

The main objective of this work is to produce an energy benchmarking study in small and medium size enterprises (SMEs) for the NACE Rev. 2 subsector codes 24, 25 and 28.

C24: MANUFACTURE OF BASIC METAL

C25: MANUFACTURE OF FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND EQUIPMENT

C28: MANUFACTURE OF MACHINERY AND EQUIPMENT N.E.C.

With an annual energy consumption of: < 38GWh for sector C24,

> 0.5 GWh for sector C25 and

> 0.5 GWh for sector C28

This study aims to be an energy analysis tool for these subsectors, to offer companies the possibility to establish comparisons with others in the same subsector, as well as to enable them to control their evolution over time.

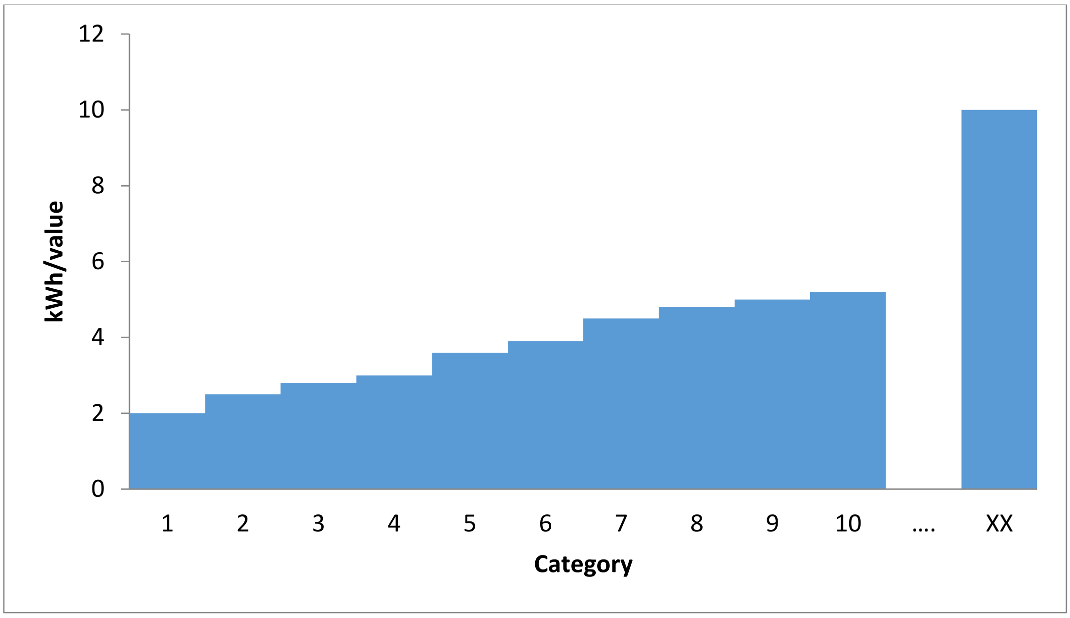
The two main objectives of this study are:

- To categorize the company within a ranking with regard to others in the same sub-sector.
- To establish the savings potential that a company could reach in terms of their position in that ranking.

For this, this study has been divided into two phases: in the first, the methodology has been defined and in the second, the methodology has been applied using the data obtained from the energy audits that were carried out.

2 METHODOLOGY

The starting point for the development and application of the methodology was the creation of a ranking. This ranking establishes categories for each of the energy indicators defined in "Table 1. Energy efficiency indicators for Benchmarking". This is represented in a bar graph of the type shown below:



The data of each axis are the following:

The X axis shows the different categories, in some cases it represents NACE code, in others it represents different technologies, way of working, type of energy ... The Y axis shows the energy efficiency indicators which are used as a comparison and whose values are provided by energy audits.

Each category represents a situation, NACE code, way of working, type of energy, … and they have been determined based on the results obtained from the energy audits that they have been carried out.

In the event that a company wants to check its situation with respect to others, it has to choose the indicator on which it wants to compare itself, look for the category that corresponds to it on the X axis and compare the data provided by the Y axis, with the his own. If this is below the indicated in the graph, the company can consider that its energy performance is better than the average. If, on the contrary, the own value is above, the company can consider that it has possibilities of improvement in its energy efficiency.

For this purpose, ten indicators have been created as shown in Table 1.

So that these indicators can take into account the specificities of each one of the countries that are part of the EE-METAL Project, we have proceeded to a harmonization of the data by means of correction factors.

The following table shows the energy efficiency indicators which have been used to establish the methodology.

INDICATORS OF ENERGY EFFICIENCY FOR THE BENCHMARKING				
INDICATORS (IEE) AND INFLUENCE FACTORS (IF)				**VALUE**
IEE_1	**Final energy consumption per production value**			**kWh / €**
IEE_2	**Primary energy consumption per production value**			**kWh / €**
IEE_3	**Carbon dioxide emissions per production value**			**Kg_{CO2} / €**
IEE_4	**Carbon dioxide emissions per final energy consumption**			**Kg_{CO2} / kWh**
IEE_5	**Carbon dioxide emissions per primary energy consumption**			**Kg_{CO2} / kWh**
IEE_6	**Displacement power factor for reactive energy (cos ϕ)**			**0-1**
IEE_7	**Final energy consumption in lighting per surface and working hours**			**kWh / m^2 h**
	IF_7.1	Lamp type:		
			Fluorescent lamps	
			Mercury Vapour lamps	
			Metal Halide lamps	
			Sodium vapour lamps	
			Glow lamp	
			Led	
			Halogen lamp	
	IF_7.2	Control type:		
			Manual	
			Automatic control	
IEE_8	**Final energy consumption in compressed air per production value**			**kWh / €**
	IF_8.1	Working pressure		
	IF_8.2	With VSD or without VSD		
IEE_9	**Final energy consumption in furnaces per production value**			**kWh / €**
	IF_9.1	Type of energy		
IEE_10	**Average efficiency of electric engines**			**%**
	IF_10.1	Power of electric engines		

The relationships between the different influencing factors set for each energy efficiency index are given below:

2.1 IEE1. Final energy consumption per production value. kWh/€

To establish this indicator, the final energy consumption and the economic value of production in 2015 have been taken into account.

For the economic value of production to be comparable between different countries it is necessary to harmonize it. For this purpose, a correction factor Fh_v has been established. The resulting energy efficiency indicator is

$$IEE = \frac{kWh}{€} xFh\_v$$

This harmonization factor takes into account Purchasing Power Parities (EU28=1) for GDP (Gross Domestic Product) of each country. Average value of the years 2007 to 2016 has been used.

These values have been obtained from the statistical office of the European Union, EUROSTAT.

These values are:

	Average value (10 years)
France	1,105
Italy	0,996
Poland	0,562
Spain	0,919
European Union (28 countries)	1,000

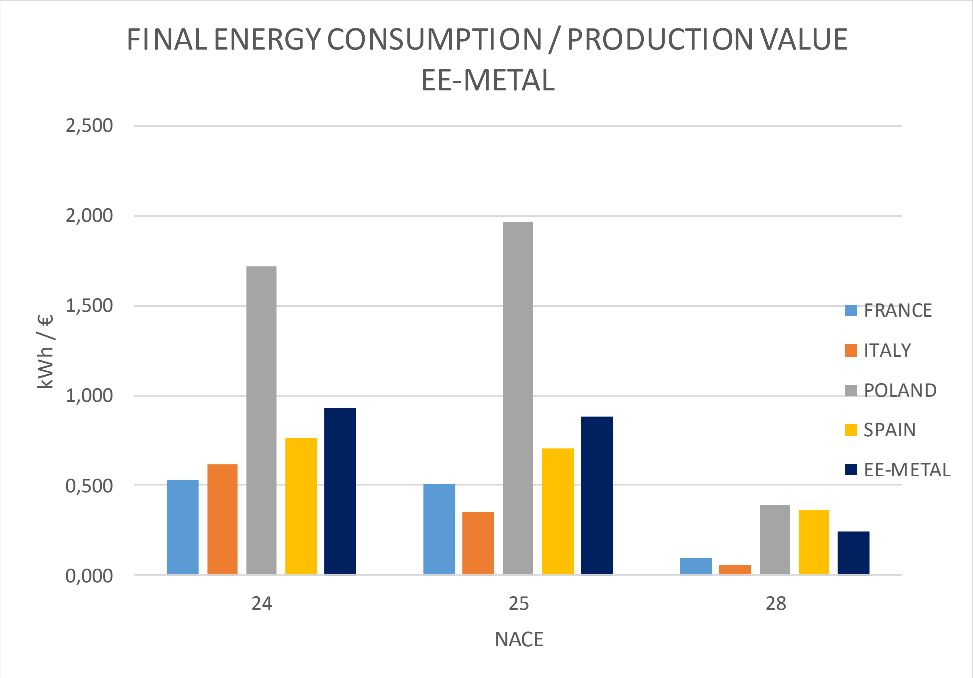
Note: To obtain the value of Poland, an exchange value of Zloty / € = 4,2207 has been considered.

The correction factor for each country is:

	F_{h_v}
France	0,905
Italy	1,004
Poland	1,779
Spain	1,088

The categories have been formed by the NACE code and by country.

Applying the data from the energy audits, the following bar graph has been obtained:



FINAL ENERGY CONSUMPTION / PRODUCTION VALUE kWh/€					
NACE	**FRANCE**	**ITALY**	**POLAND**	**SPAIN**	**EE-METAL**
24	0,529	0,621	1,715	0,760	0,932
25	0,512	0,354	1,966	0,706	0,880
28	0,098	0,054	0,393	0,361	0,244

In general, the companies included in NACE 24 are energy-intensive industries with lower added value to final products, which means that the sector 24 indicator is higher than sector 25 and sector 28, but It also includes companies that do not require high energy consumption.

Note the number of companies that are part of the sample is small especially if we consider it by country. Any data that is not similar to the rest can cause the sample to be affected in an important way.

In the case of Poland, one of the companies does not require this high energy consumption to carry out its activity, so the bar graph shows the NACE 24 indicator below the NACE 25 indicator. This company produces highly specialized products, for example for public entities or the army. These products are made for individual orders in short and limited series. Also their machinery park and technological lines are quite modern. It means that production of one piece of product is very expensive, but not so energy-intensive as it seems to be.

On the other hand, the difference in the indicator values between NACE 25 and NACE 28 is important:

In the case of France, the low consumption of C28 is explained by the fact that companies in this sub-sector have a low energy consumption process. Indeed, these companies are specialized in the assembly of components. However, it is a process that does not require production equipment that consumes a lot of energy. Usually it is manual assembly or welding. This activity consumes little, unlike those of C24 or C25 companies, which use energy-intensive production equipment (melting furnace, machining centre, etc.).

In Italy, evident difference of index value between subsectors 25 and 28 is due to:

- two metal treatment activities in NACE subsector 25, with high energy consumption but low added value on final product. This affects IEE1 index, increasing its final value;
- low energy consumption of subsector 28 companies (typically assembling processes) and, for some of them, high value products.

In the case of Poland, what should be taking into account is the fact, that all Polish companies consume energy not only for production (process equipment, auxiliary services like engines, compressed air, cooling systems, lighting etc.). Most of the energy is used for heating buildings and internal transport and is not directly reflected in the size and value of production (for example building must be heated in winter regardless of the number of elements produced). Also, services for external clients are important part of activity in many companies. It means that many companies, especially in NACE 25, offer some external services (like cutting, welding or bending of ready components) and consume energy, but do not produce any pieces by itself.

In the case of Spain, an important part of the companies included in NACE 25 are metal surface treatment, which implies a significant energy consumption and a production value not too high, since they do not manufacture the pieces themselves. On the other hand, the companies included in NACE 28 produce high value products and their energy consumption is usually low.

2.2 IEE2. Primary energy consumption per production value. kWh/€

To establish this indicator, the primary energy consumption and the economic value of production in 2015 have been taken into account.

For the economic value of production to be comparable between different countries it is necessary to harmonize it. For this purpose, a correction factor Fh_v has been established. The resulting energy efficiency indicator is:

$$IEE = \frac{kWh}{€} x Fh\_v$$

This harmonization factor takes into account Purchasing Power Parities (EU28=1) for GDP (Gross Domestic Product) of each country. Average value of the years 2007 to 2016 has been used.

These values have been obtained from the statistical office of the European Union, EUROSTAT.

These values are:

	Average value (10 years)
France	1,105
Italy	0,996
Poland	0,562
Spain	0,919
European Union (28 countries)	1,000

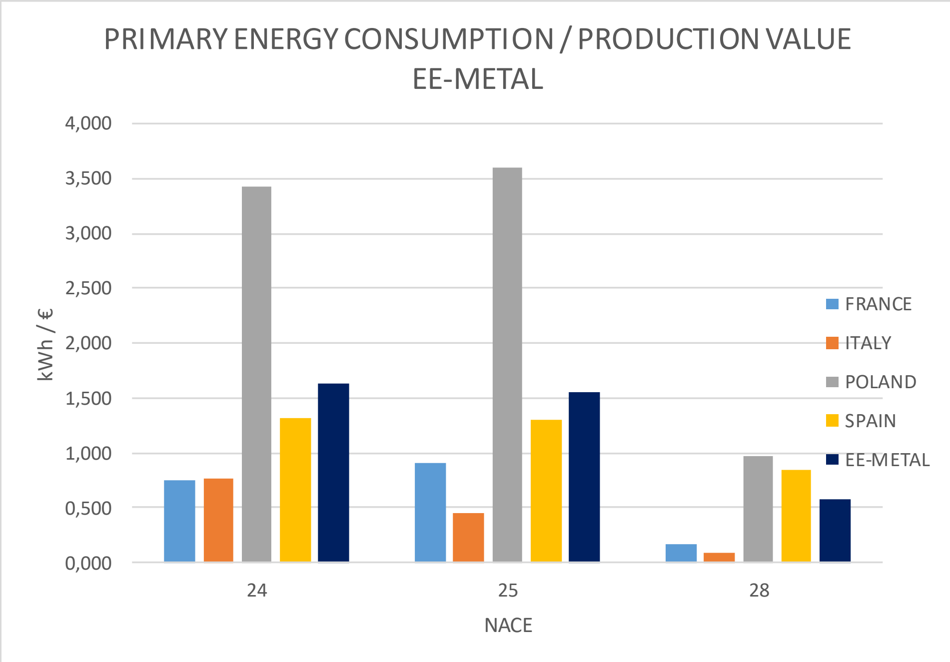
Note: To obtain the value of Poland, an exchange value of Zloty / € = 4,2207 has been considered.

The correction factor for each country is:

	F_{h_v}
France	0,905
Italy	1,004
Poland	1,779
Spain	1,088

The categories have been formed by the NACE code and by country.

Applying the data from the energy audits, the following bar graph, has been obtained:



PRIMARY ENERGY CONSUMPTION / PRODUCTION VALUE kWh/€					
NACE	**FRANCE**	**ITALY**	**POLAND**	**SPAIN**	**EE-METAL**
24	0,755	0,764	3,426	1,312	1,637
25	0,903	0,457	3,601	1,296	1,547
28	0,177	0,088	0,970	0,841	0,573

In general, the companies included in NACE 24 are energy-intensive industries with lower added value to final products, which means that the sector 24 indicator is higher than sector 25 and sector 28, but It also includes companies that do not require high energy consumption.

Note the number of companies that are part of the sample is small especially if we consider it by country. Any data that is not similar to the rest can cause the sample to be affected in an important way.

In addition to what was revealed with the previous indicator on the differences in consumption between the different NACEs and countries, we must add in this case, the influence of the final energy conversion factor to primary energy of each of the energy sources used. In the case of electricity, it depends on the energy mix of each country, that is, on the final composition of the electricity (which is supplied to the companies) according to the source of generation.

2.3 IEE3. Carbon dioxide emissions per production value. $KgCO_2/€$

To establish this indicator, the energy consumption per type of energy source and the economic value of production in 2015 have been taken into account.

For the economic value of production to be comparable between different countries it is necessary to harmonize it. For this purpose, a correction factor Fh_v has been established. The resulting energy efficiency indicator is:

$$IEE = \frac{kWh}{€} xFh\_v$$

This harmonization factor takes into account Purchasing Power Parities (EU28=1) for GDP (Gross Domestic Product) of each country. Average value of the years 2007 to 2016 have been used.

These values have been obtained from the statistical office of the European Union, EUROSTAT.

These values are:

	Average value (10 years)
France	1,105
Italy	0,996
Poland	0,562
Spain	0,919
European Union (28 countries)	1,000

Note: To obtain the value of Poland, an exchange value of Zloty / € = 4,2207 has been considered.

The correction factor for each country is:

	F_{h_v}
France	0,905
Italy	1,004
Poland	1,779
Spain	1,088

For the calculation of CO_2 emissions, the following has been considered:

- ✓ Total emission of CO_2 for fuel = fuel consumption x fuel emission factor
- ✓ Total emission of CO_2 for electricity = electricity consumption x electricity emission factor

To calculate emission of carbon dioxide, the reference values of the fuel calculation factors, approved by Regulation 601/2012 of the European Commission, have been used.

Annex VI of: http://eur-lex.europa.eu/legal-content/ES/TXT/?uri=CELEX%3A32012R0601

In the case of electricity, each country uses its reference value, because it depends on its energy mix.

French source: https://www.rte-france.com/en/eco2mix/eco2mix-co2-en

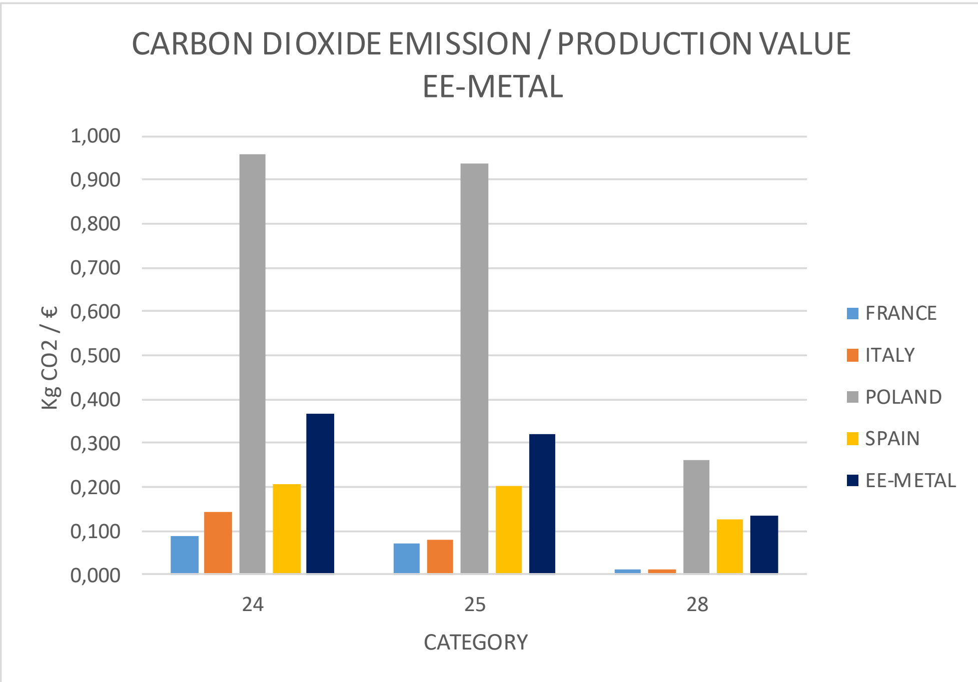
Italy source: http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni/fattori-di-emissione-per-la-produzione-ed-il-consumo-di-energia-elettrica-in-italia/view

Poland source:http://www.kobize.pl/en/fileCategory/id/28/wskazniki-emisyjnosci

Spain source: https://gdo.cnmc.es/CNE/resumenGdo.do?anio=2016

The categories have been formed by the NACE code and by country.

Applying the data from the energy audits, the following bar graph, has been obtained



CARBON DIOXIDE EMISSION / PRODUCTION VALUE Kg CO2/€					
NACE	**FRANCE**	**ITALY**	**POLAND**	**SPAIN**	**EE-METAL**
24	0,089	0,143	0,961	0,206	0,368
25	0,072	0,081	0,938	0,201	0,323
28	0,014	0,014	0,260	0,127	0,136

In general, the companies included in NACE 24 are energy-intensive industries with lower added value to final products and consequently more carbon dioxide emissions, which means that the sector 24 indicator is higher than sector 25 and sector 28, but It also includes companies that do not require high energy consumption.

Note the number of companies that are part of the sample is small especially if we consider it by country. Any data that is not similar to the rest can cause the sample to be affected in an important way.

In this indicator, the most important is the type of energy used, for example in Poland, in addition to natural gas and electricity, coal and coke have a very important weight as a source of energy used. That is why we can see the very high CO_2 emission rate in Poland.

The difference between the NACEs 25 and 28 is explained in the IEE1 indicator.

2.4 IEE4. Carbon dioxide emissions per final energy consumption. $KgCO_2/kWh$

To establish this indicator, the energy consumption per type of energy and total final energy consumption have been taken into account.

For the calculation of CO_2 emissions, we have considered the following:

- ✓ Total emission of CO_2 for fuel = fuel consumption x fuel emission factor
- ✓ Total emission of CO_2 for electricity = electricity consumption x electricity emission factor

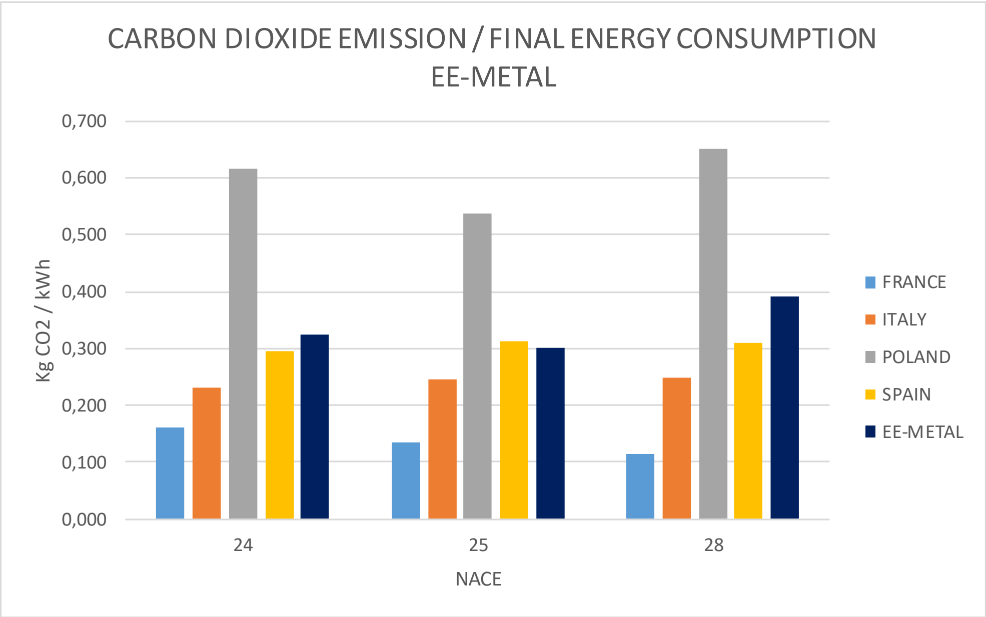
To calculate emission of carbon dioxide, the reference values of the fuel calculation factors, approved by Regulation 601/2012 of the European Commission, have been used.

Annex VI of: http://eur-lex.europa.eu/legal-content/ES/TXT/?uri=CELEX%3A32012R0601

In the case of electricity, each country uses its reference value, because it depends on its energy mix.

The categories have been formed by the NACE code and by country.

Applying the data from the energy audits, the following bar graph, has been obtained



CARBON DIOXIDE EMISSION / FINAL ENERGY CONSUMPTION Kg CO2/kWh					
NACE	FRANCE	ITALY	POLAND	SPAIN	EE-METAL
24	0,161	0,232	0,616	0,295	0,326
25	0,136	0,246	0,537	0,311	0,300
28	0,114	0,249	0,651	0,309	0,390

In some countries, the results seem to be in contradiction with IEE5, with specific emission values of NACE 28 larger than emission of NACE 24.

This is due to different fuel mix of each subsector: usually, in NACE 28 electricity covers large part of consumption while in 24 there is a relevant share of natural gas.

Since emission factor of electricity, referred to final energy, is higher than thermal energy value (natural gas), NACE 28 companies typically will have higher specific emission for kWh of final energy than NACE 24. On the other hand, considering emission factor for primary energy (IEE 5), situation is opposite because of different values of generation efficiency.

For a better comprehension, data in the following table can be observed (values of efficiency are approximated but realistic).

	Average generation efficiency	CO_2 emission factor for final energy*	CO_2 emission factor for primary energy**
Electricity	40 %	0,30 $kgCO_2/kWh$	0,12 $kgCO_2/kWh$
Thermal energy (natural gas)	90 %	0,20 $kgCO_2/kWh$	0,18 $kgCO_2/kWh$

*kg CO2 for each kWh of final energy available for the end user (whatever it is electricity or heat).
** kg CO2 for each kWh of primary energy used for generation of electricity or thermal energy.

2.5 IEE5. Carbon dioxide emissions per primary energy consumption. $KgCO_2/kWh$

To establish this indicator, the energy consumption per type of energy and total primary energy consumption have been taken into account.

For the calculation of CO_2 emissions, we have considered the following:

- ✓ Total emission of CO_2 for fuel = fuel consumption x fuel emission factor
- ✓ Total emission of CO_2 for electricity = electricity consumption x electricity emission factor

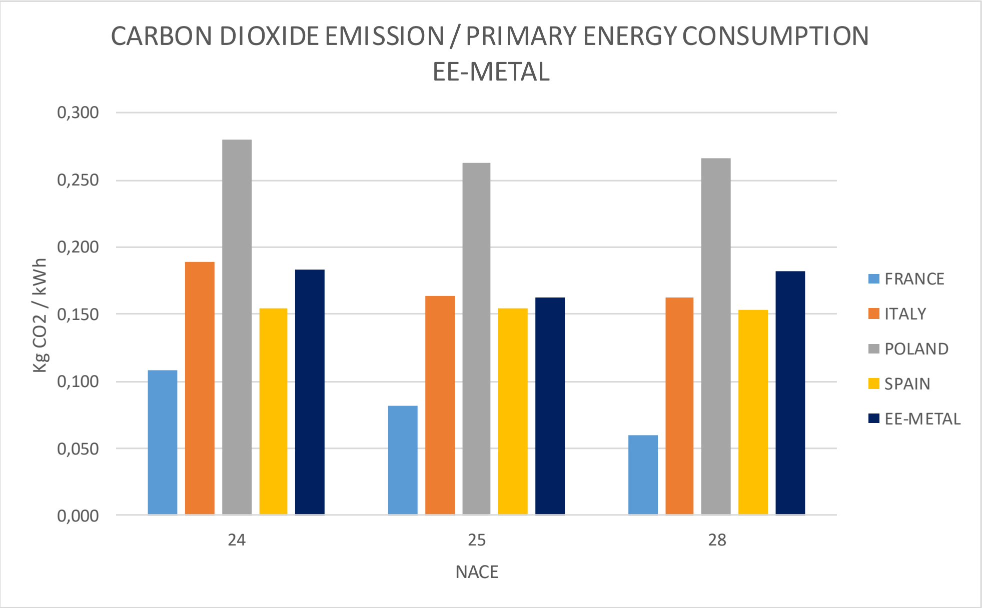
To calculate emission of carbon dioxide, the reference values of the fuel calculation factors, approved by Regulation 601/2012 of the European Commission, have been used.

Annex VI of: http://eur-lex.europa.eu/legal-content/ES/TXT/?uri=CELEX%3A32012R0601

In the case of electricity, each country uses its reference value, because it depends on its energy mix.

The categories have been formed by the NACE code and by country.

Applying the data from the energy audits, the following bar graph, has been obtained:



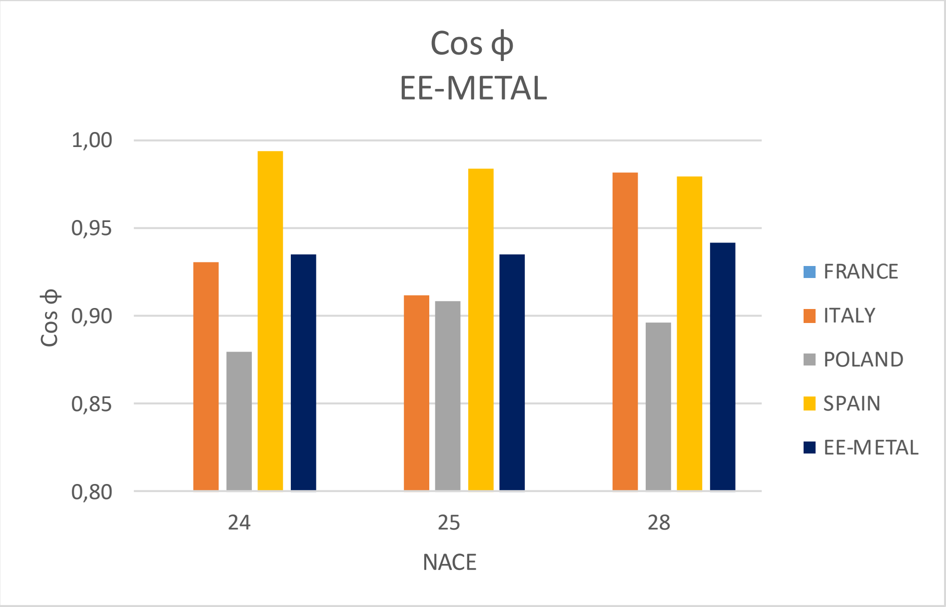
CARBON DIOXIDE EMISSION / PRIMARY ENERGY CONSUMPTION Kg CO_2/kWh					
NACE	**FRANCE**	**ITALY**	**POLAND**	**SPAIN**	**EE-METAL**
24	0,108	0,189	0,281	0,155	0,183
25	0,081	0,164	0,263	0,154	0,163
28	0,059	0,163	0,266	0,154	0,182

Explanation is included in comments of IEE4

2.6 IEE6. Displacement power factor for reactive energy. Cosφ

This indicator has been obtained from the electricity bills.

The categories have been grouped according to NACE code and by country.



Cos ɸ					
NACE	**FRANCE**	**ITALY**	**POLAND**	**SPAIN**	**EE-METAL**
24	--	0,931	0,880	0,994	0,935
25	--	0,912	0,908	0,983	0,935
28	--	0,982	0,896	0,980	0,942

Note that electrical installations that operate with a low power factor affect the electricity network in both low and high voltage. The most important consequences of a low power factor are:

- Increased losses due to Joule effect by increasing the electric current and therefore decreasing the durability of the power lines.
- Increase of CO_2 emissions by the generation of electric power.
- Reduction in the capacity of the Electricity Network and the quality of supply.
- Increase in the voltage drop of the line and therefore worse regulation of the voltage.

2.7 IEE7. Final energy consumption in lighting. kWh/(m^2 x working hours)

To establish this indicator, the energy consumption in lighting, the illuminated surface and the number of working hours in 2015 have been taken into account.

This indicator of energy efficiency is especially influenced by the following factors:

- The type of lamp used. In industry, the following technologies are mainly used:
  - Fluorescent lamps
  - Mercury vapour lamps
  - Metal halide lamps
  - Sodium vapour lamps.
  - Glow lamp
  - Led.
  - Halogen lamp
- The type of control. There are usually two situations
  - Manual control: corresponds to the usual practice of lighting on and off by the worker.
  - Automatic control: by time control or by natural light controllers, and progressive regulation. One sensor of light, installed in a strategic location, measures the level of natural light received and automatically adjusts the input of artificial light to what is necessary, …

For this value to be comparable between different countries an important factor to consider is the number of daylight hours. Due to the different geographical situations of European countries, the number of daylight hours varies between one and another. Therefore, the value of this indicator has been harmonized with regard to the hours of daylight available in each of the countries, with the factor Fh_a. The resulting energy efficiency indicator has been:

$$IEE = \frac{kWh}{(m^2 x\ working\ hours)} xFh\_a$$

The values of hours of sunshine obtained from the World Meteorological Organization are taken into account to calculate the value of Fh_a.

http://www.wmo.int/datastat/wmodata_en.html

http://data.un.org/Data.aspx?d=CLINO&f=ElementCode%3a15

The values used are the average annual values of the meteorological stations of each country in the last collection period. (1961-1990, 30 years).

Therefore, the values used are:

	Average value (30 years) hours/year
France	2.107
Italy	2.270
Poland	1.507
Spain	2.543

Fh_a are relative values that show the ratio between different countries for the same content.

E.g. If mean number of hours of sunshine per year in Spain are 100 and in France 82,89, then the Fh_a between France and Spain is 1,21. This means that one hour of sunshine in France equals 1,21 hours of sunshine in Spain.

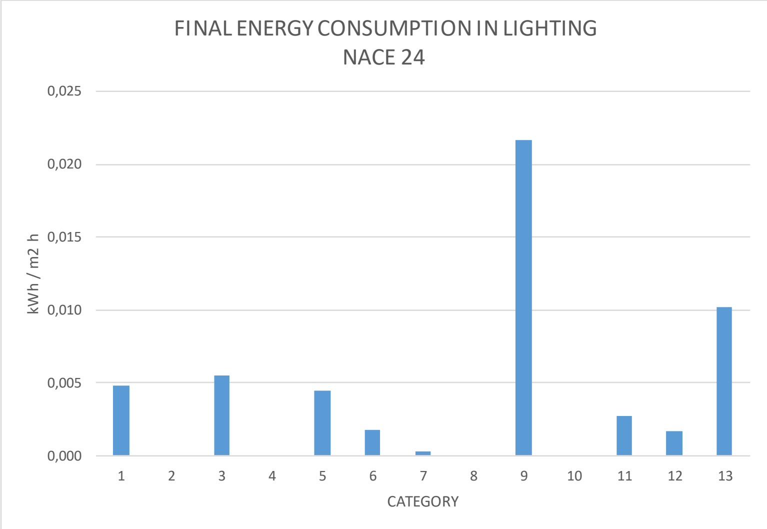
With this base the following values of Fh_a are obtained:

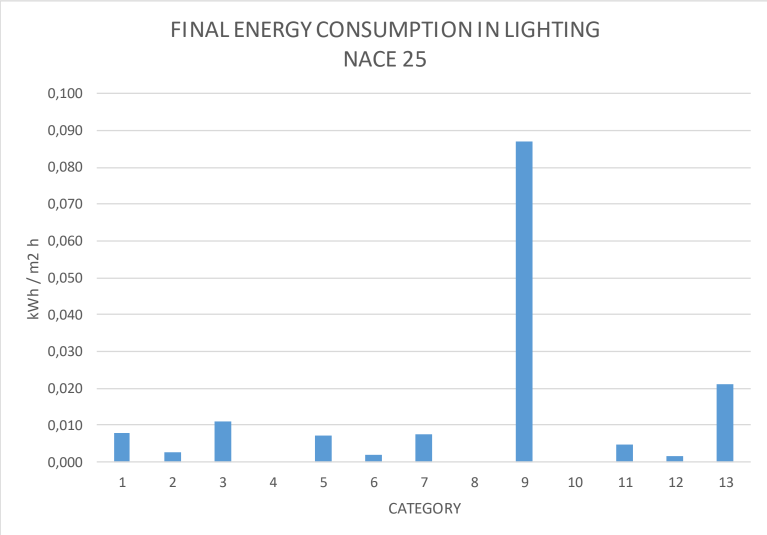
	F_{h_a}
France	1,21
Italy	1,12
Poland	1,69
Spain	1,00

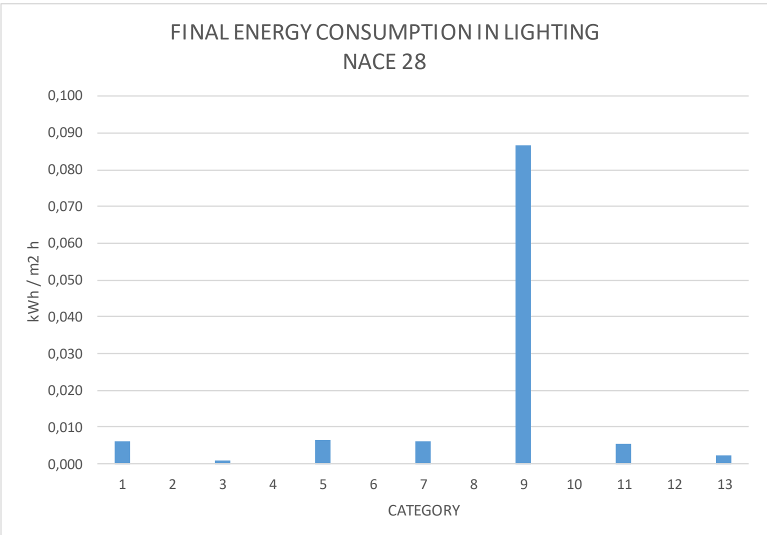
For this indicator, the categories have been established by technology groups, lamp type and control type.

CATEGORY	TYPE OF LUMINAIRE	CONTROL TYPE
1	Fluorescent lamps	Manual
2	Fluorescent lamps	Automatic
3	Mercury vapour lamps	Manual
4	Mercury vapour lamps	Automatic
5	Metal halide lamps	Manual
6	Metal halide lamps	Automatic
7	Sodium vapour lamps	Manual
8	Sodium vapour lamps	Automatic
9	Glow lamp	Manual
10	Glow lamp	Automatic
11	Led	Manual
12	Led	Automatic
13	Halogen lamp	Manual

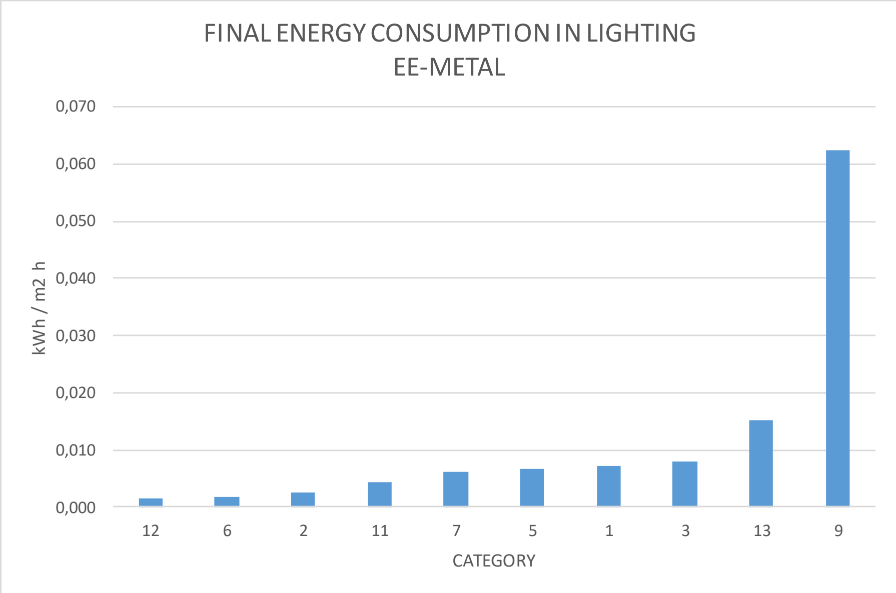
With these hypotheses the bar graphs obtained by NACE code, are:







If the aggregate values by the Project EE-METAL are considered, the following bar graph is obtained:



FINAL ENERGY CONSUMPTION IN LIGHTING EE-METAL kWh/m2h	CATEGORY	TYPE OF LUMINAIRE	CONTROL TYPE
0,00163	12	Led	Automatic
0,00177	6	Metal halide lamps	Automatic
0,00248	2	Fluorescent lamps	Automatic
0,00447	11	Led	Manual
0,00606	7	Sodium vapour lamps	Manual
0,00658	5	Metal halide lamps	Manual
0,00726	1	Fluorescent lamps	Manual
0,00807	3	Mercury vapour lamps	Manual
0,01529	13	Halogen lamp	Manual
0,06245	9	Glow lamp	Manual

LED with automatic controls is logically the more efficient technology for illumination.

Important note: despite normalization on working hours, companies with high values of working hours (typically with three-shift operation) will have higher specific consumption for lighting (with the same technology) than companies with one or two shift operation because they work also during night, where there is no natural lighting.

2.8 IEE8. Final energy consumption in compressed air. kWh/Production value.

To establish this indicator, the final energy consumption in compressed air during 2015, the economic value of production, the working pressure and the type of regulation have been taken into account.

For the economic value of production to be comparable between different countries it is necessary to harmonize it. For this purpose, a correction factor Fh_v has been established. The resulting energy efficiency indicator is:

$$IEE = \frac{kWh}{€} xFh\_v$$

This harmonization factor takes into account Purchasing Power Parities (EU28=1) for GDP (Gross Domestic Product) of each country. Average value of the years 2007 to 2016 has been used.

These values have been obtained from the statistical office of the European Union, EUROSTAT.

These values are:

	Average value (10 years)
France	1,105
Italy	0,996
Poland	0,562
Spain	0,919
European Union (28 countries)	1,000

Note: To obtain the value of Poland, an exchange value of Zloty / € = 4,2207 has been considered.

The correction factor for each country is:

	F_{h_v}
France	0,905
Italy	1,004
Poland	1,779
Spain	1,088

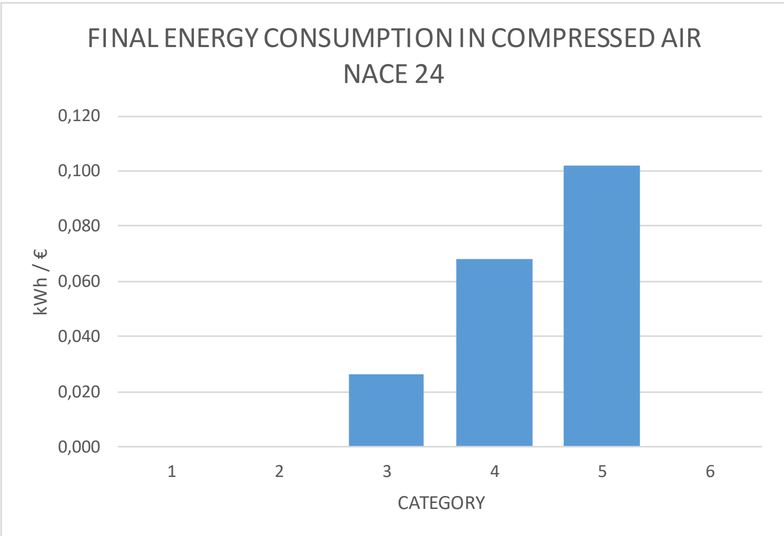
This indicator of energy efficiency is also influenced by the following factors:

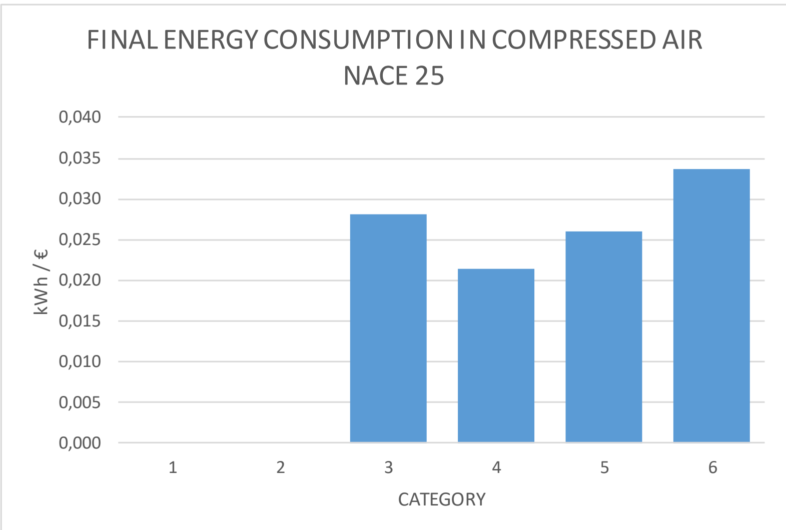
- The working pressure.
- The type of regulation – there are usually two options:
    - Compressor without variable speed drive technology.
    - Compressor with variable speed drive technology.

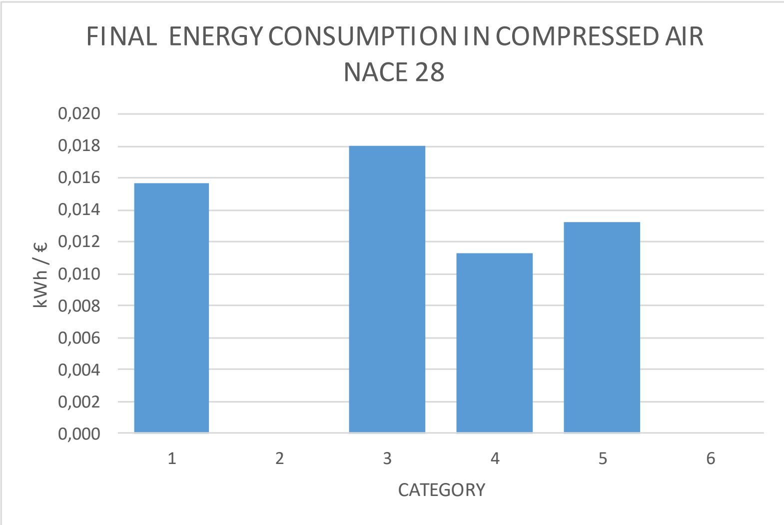
For this indicator, the categories have been established by groups according to working pressure and regulation type.

CATEGORY	WORKING PRESSURE	REGULATION TYPE
1	Pm <= 6 bar	VSD
2	Pm <= 6 bar	NO VSD
3	6 bar < Pm <= 8 bar	VSD
4	6 bar < Pm <= 8 bar	NO VSD
5	Pm > 8 bar	VSD
6	Pm > 8 bar	NO VSD

With these hypotheses the bar graphs obtained by NACE code, are:

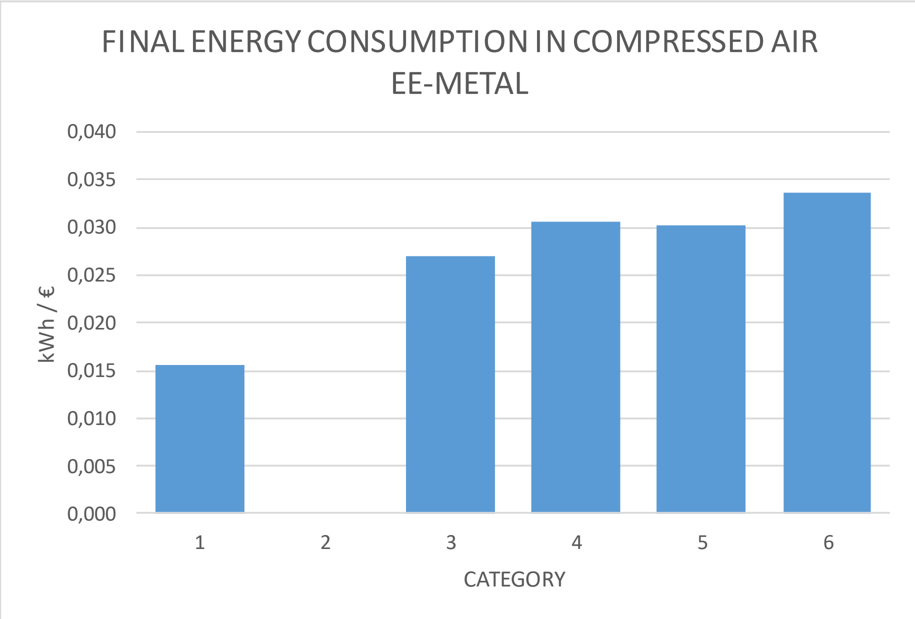






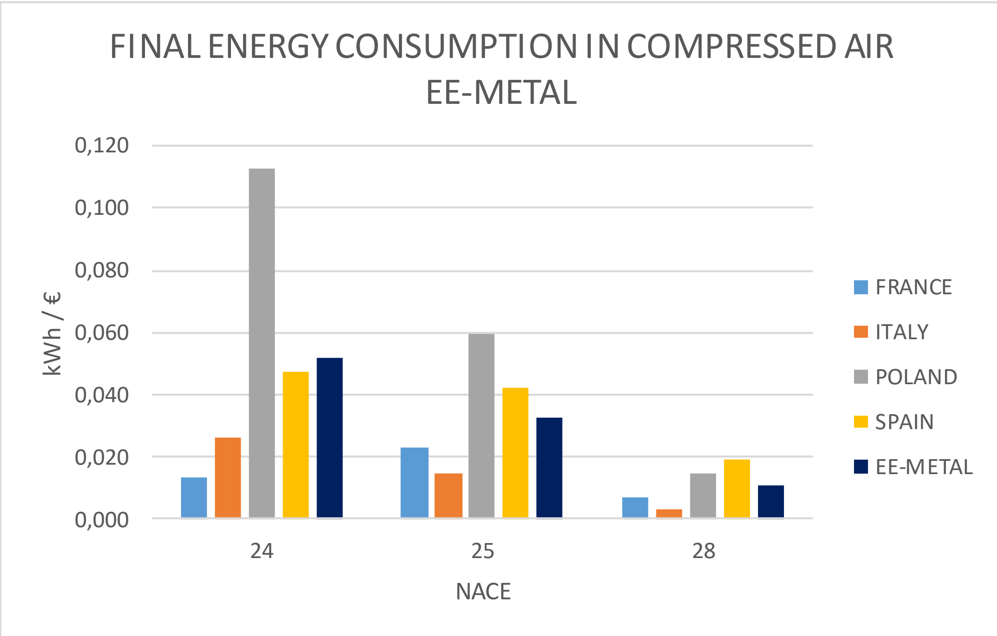
Situation in NACE 25 and 28 for pressure between 6 and 8 bar is interesting because it shows a bigger specific consumption for system with VSD technology. This could be due to an improper use of VSD in one of the most common plant situations in metal industry (6-8 bar). In fact, VSD optimal application is only in case of variable request of compressed air.

If the aggregate values by the Project EE-METAL are considered, the following bar graph is obtained:



FINAL ENERGY CONSUMPTION IN COMPRESSED AIR / PRODUCTION VALUE EE-METAL kWh / €	CATEGORY	WORKING PRESSURE	REGULATION TYPE
0,016	1	Pm <= 6 bar	VSD
--	2	Pm <= 6 bar	NO VSD
0,027	3	6 bar < Pm <= 8 bar	VSD
0,031	4	6 bar < Pm <= 8 bar	NO VSD
0,030	5	Pm > 8 bar	VSD
0,034	6	Pm > 8 bar	NO VSD

If the aggregated values by NACE code and by country are considered, the following bar graph is obtained:



FINAL ENERGY CONSUMPTION IN COMPRESSED AIR / PRODUCTION VALUE kWh/€					
NACE	**FRANCE**	**ITALY**	**POLAND**	**SPAIN**	**EE-METAL**
24	0,014	0,026	0,113	0,048	0,052
25	0,023	0,015	0,060	0,042	0,033
28	0,007	0,003	0,015	0,019	0,011

Specific consumption for compressed air has a decreasing trend from NACE 24 (highest value) to NACE 25 and then to NACE 28. Metallurgical processes in fact requires a lot of pneumatic energy and final product has lower added value than metalworking operations.

In the case of France, the particularly low compressed air consumption for C24 (compared to C25) is explained by the fact that the sample of C24 companies is not homogeneous. Indeed, 1 of the 3 foundries has a particularly high consumption and "dilutes" the results of the other 2. This explains this atypical distribution of C24 energy consumption.

2.9 IEE9. Final energy consumption in furnaces. kWh/Production value

To establish this indicator, the energy consumption in furnaces during 2015, the type of energy and the economic value of production in 2015 have been taken into account.

For the economic value of production to be comparable between different countries it is necessary to harmonize it. For this purpose, a correction factor Fh_v has been established. The resulting energy efficiency indicator is

$$IEE = \frac{kWh}{€} x Fh\_v$$

This harmonization factor takes into account Purchasing Power Parities (EU28=1) for GDP (Gross Domestic Product) of each country. Average value of the years 2007 to 2016 have been used.

These values have been obtained from the statistical office of the European Union, EUROSTAT.

These values are:

	Average value (10 years)
France	1,105
Italy	0,996
Poland	0,562
Spain	0,919
European Union (28 countries)	1,000

Note: To obtain the value of Poland, an exchange value of Zloty / € = 4,2207 has been considered.

The correction factor for each country is:

	F_{h_v}
France	0,905
Italy	1,004
Poland	1,779
Spain	1,088

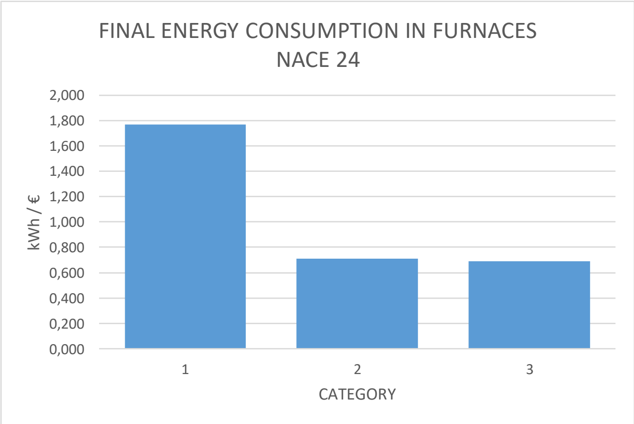
This energy efficiency indicator is also specially influenced by:

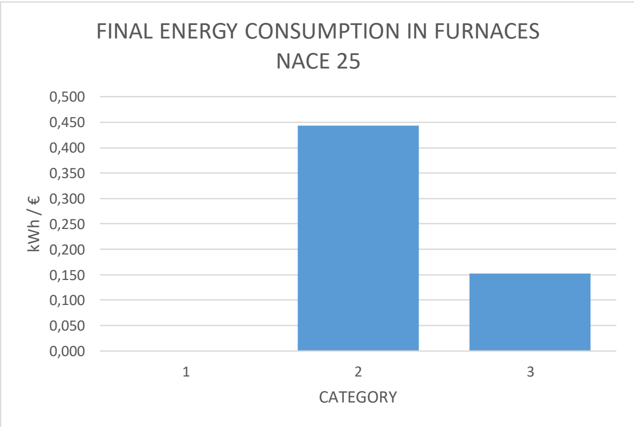
- The type of energy consumed.
    - Coke
    - Natural gas
    - Electricity

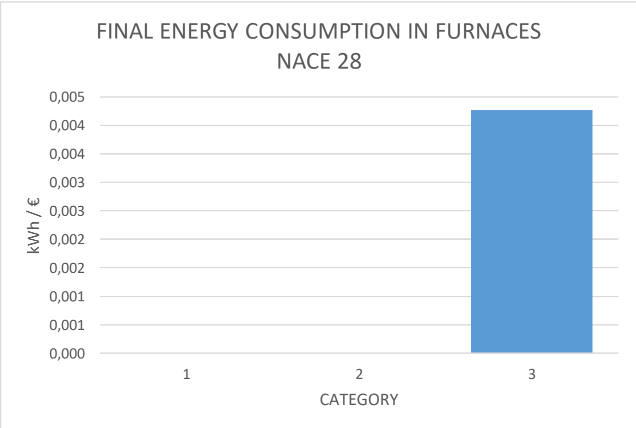
For this indicator, the categories have been established by groups according to the type of energy consumed.

CATEGORY	TYPE OF ENERGY
1	Coke
2	Natural gas
3	Electricity

If the aggregated values by NACE code are considered, the following bar graphs are obtained:

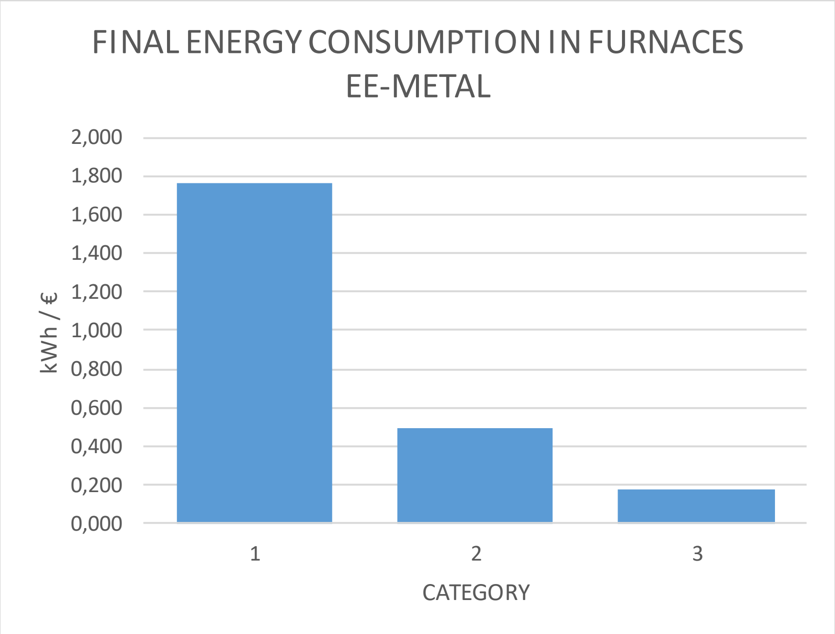






Analysis of this indicator reflects characteristics of manufacturing process for each subsector:

- high relevance of furnace (melting, refining and holding furnaces) in metallurgy (NACE 24), also because of the lower added value of final product;
- furnaces are used also in other subsector but in less energy intensive processes (painting, hardening, etc.)
- coke is used in metallurgy only (Poland);



ENERGY CONSUMED IN FURNACES/PRODUCTION VALUE EE-METAL kWh / €	CATEGORY	TYPE OF ENERGY
1,768	1	Coke
0,495	2	Natural gas
0,179	3	Electricity

2.10 IEE10. Average efficiency of electric engines. %

To establish this indicator, the power of the electric engines and their nominal efficiency level have been considered. Only low voltage asynchronous squirrel cage motors have been taken into account.

For this indicator, the categories have been established by power range groups:

CATEGORY	POWER (P)
1	P ≤ 5,5 Kw
2	5,5 < P ≤ 11 kW
3	11 < P ≤ 22 kW
4	22 < P ≤ 45 kW
5	P > 45 kW

The calculation of the average efficiency in each range is the weighted average of the electrical engines included in that range.

E.g.: In the category 1 the following electric engines are included:

Electrical Power (kW)	Level of efficiency
1,1	IE2
0,75	IE1
1,5	IE3
0,75	IE1

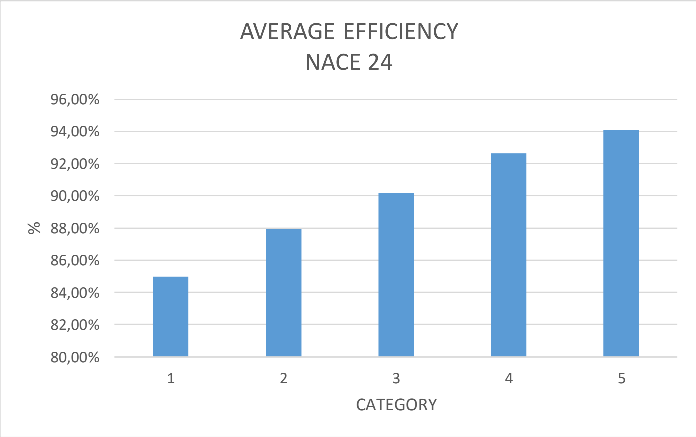
According to the electric engine, the power, the level of efficiency and the tables corresponding to the minimum efficiency guaranteed by the regulations, the following nominal performance are obtained:

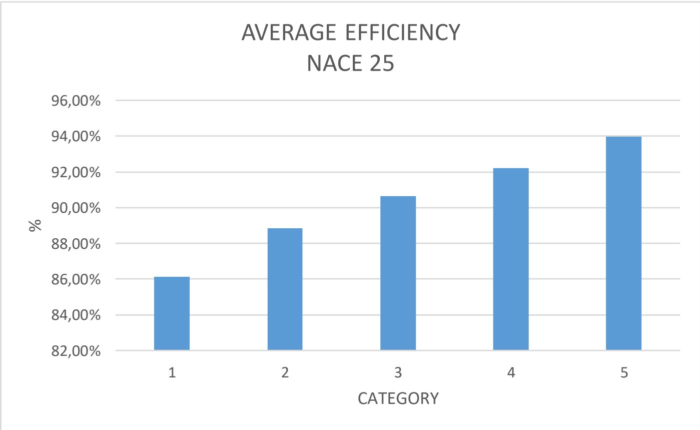
Electrical Power (kW)	Level of efficiency	Nominal efficiency
1,1	IE2	81,40%
0,75	IE1	72,10%
1,5	IE3	85,30%
0,75	IE1	72,1%

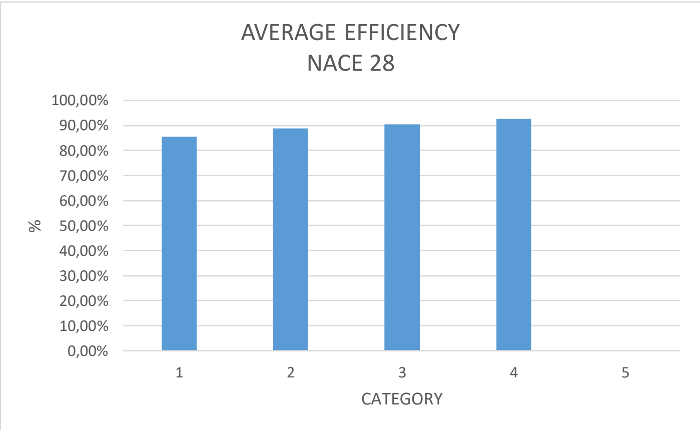
The average efficiency (%) for the category 1 is:

((1,1*0,81)+(0,75*0,72)+(1,5*0,85)+(0,75*0,72)) / (1,1+0,75+1,5+0,75) = 79,17%

Applying the data obtained from the energy audits, the following bar graphs are obtained:





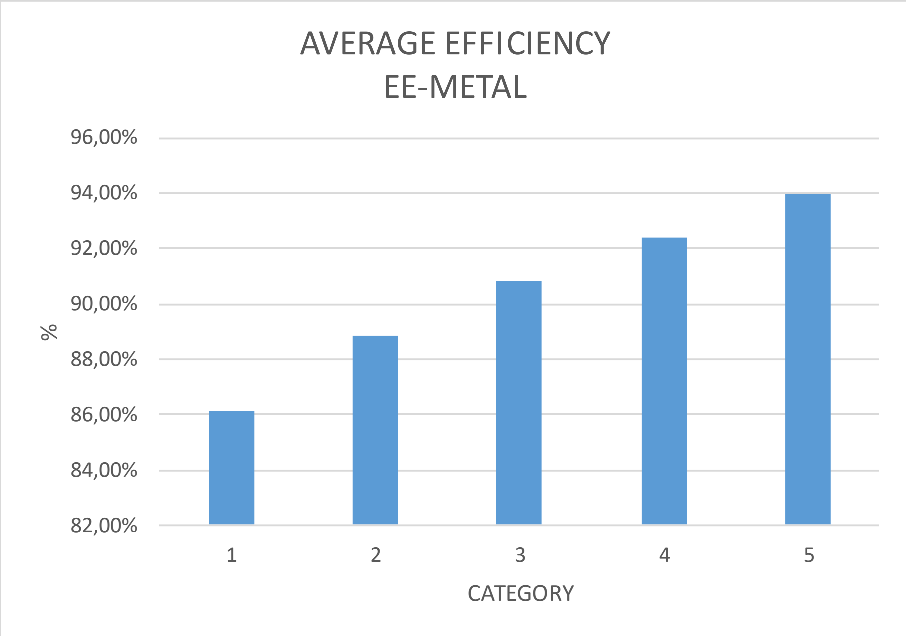


This indicator shows a strong correlation between efficiency of engines and their size.

The bigger the power of engine, the higher its efficiency is.

Two main reasons can explain this:

- minimum efficiency fixed by law (ERP Directive) increases with size of electric engine;
- if size of the engine is big, company usually pays more attention to energy efficiency aspect. Often the same logic is not applied to small size equipment.



AVERAGE EFFICIENCY EE-METAL	CATEGORY	POWER (P)
86,10%	1	P ≤ 5,5 Kw
88,83%	2	5,5 < P ≤ 11 kW
90,80%	3	11 < P ≤ 22 kW
92,37%	4	22 < P ≤ 45 kW
93,95%	5	P > 45 kW