'GOOD PRACTICES' TO IMPROVE ENERGY EFFICIENCY IN THE INDUSTRIAL SECTOR

SIMONE MAGGIORE, ANNA REALINI & CLAUDIO ZAGANO
Energy Systems Development Department, Ricerca sul Sistema Energetico – R.S.E. SpA, Milano, Italy.

ABSTRACT

Since the introduction of the International Pollution Prevention and Control (IPPC) directive and of the Best Available Techniques Reference (BREF) documents, the best available techniques (BATs) have become a reference both for policies and for companies to compare performance and to identify investment opportunities. Due to the environmental core of the IPPC and the Industrial Emissions Directive (IED), energy efficiency (EE) BATs are not always detailed and often lack energy-performance indicators. The H2020 EU-MERCI project is aimed at fostering and facilitating the implementation of EE projects in the manufacturing industry sectors by selecting and disseminating technological and policy best practices. A set of EE 'Good Practices' (GPs) was developed considering both BREF indications and literature analysis, and as innovative approach the outcomes of EE obligation and support measures aimed at the industrial sector. This was implemented through an in-depth analysis of the existing schemes in four countries (Austria, Italy, Poland and UK) and a thorough activity to normalise and compare the data made available by the different schemes. The outcome is available through the European Industrial Energy Efficiency good Practices platform implemented by EU-MERCI Partners. On the platform, a database of EE projects implemented in industry under the existing schemes is available. The database is searchable by country, sector, supporting scheme, implementation year and company size. The complete list is also downloadable as Excel file. Besides, a library divided by sectors is available, in which it is possible to look for the available GPs (both BATs and projects implemented under the national schemes) for each phase of the manufacturing processes. Sectoral and national analyses are finally available. This article will illustrate the methodology used for the project and the main outcomes.
Keywords: energy efficiency, Good Practices, industrial sector.

1 INTRODUCTION

Industry is a key player in energy consumption and economic impact in the European Union (EU). With the Energy Efficiency Directive 2012/27/EU (EED) [1, 2] and the Strategic Energy Technology Plan (SET Plan), the EU has defined clear goals in Energy Consumption reduction for the Member States (MSs) to be achieved through an increase in energy efficiency (EE) in three main sectors: buildings, transport and industry. According to EUROSTAT [3], industry was responsible for 25.3% of the final energy consumption of the EU in 2015. Even if the main focus for the EU EE policies will be buildings and transport, it will be important to understand how this sector can improve its efficiency and which goals can realistically be set.

The EU-MERCI project (acronym for 'EU coordinated MEthods and procedures based on Real Cases for the effective implementation of policies and measures supporting EE in the Industry'), funded by the European Commission under the Horizon 2020 programme (Grant Agreement No. 693845), tries to answer these questions. The first step has been an in-depth analysis of the different energy policies available in the MSs, followed by the collection of data regarding almost 3,000 projects put in place in different EU countries (mainly Austria, Italy, Poland and United Kingdom).

These data have been collected in a database and used for the selection of some 'Good Practices' (GPs) of EE, performed through the definition of nine Key Performance Indicators (KPIs). The GPs have then been validated by several industrial stakeholders to assess their

ISSN: 2056-3272 (paper format), ISSN: 2056-3280 (online), http://www.witpress.com/journals
DOI: 10.2495/EQ-V5-N3-259-271

in-field applicability and sustainability and evaluated in the light of the different EU policies to understand which incentive system(s) allow(s) to effectively promote their application.

All the results have been made public on the online portal called European Industrial Energy Efficiency good Practices (EIEEP) platform. In this platform, the whole database is made available, together with several studies on EU industry, on industrial processes, a collection of 'Best Practices' (BPs) taken from literature and the full description of the GPs taken from real projects implemented in the EU.

After a summary about the database building and a brief explanation of the GP selection methodology, this article presents a full statistical analysis of the complete database. The last part of this article shows in detail how the EIEEP platform is built and all the information and data which can be found in it.

2 BUILDING THE DATABASE

The starting point of the EU-MERCI database building has been the collection of data sets of EE measures and projects implemented in four selected countries (Austria, Italy, Poland and UK) in different industrial sectors. In these four MSs are located the so-called EU-MERCI Enablers, represented in the project by Austrian Energy Agency (AEA), Ricerca sul Sistema Energetico (RSE), Krajowa Agencja Poszanowania Energii (KAPE) and Carbon Trust (CT), respectively, and these institutions have access, under different titles in the respective countries, to the information related to the EE projects implemented within the national incentivising mechanisms. However, all the mechanisms have their own way to collect data and to select the most important parameters (apart from final energy savings), so the first challenge of the process has been the harmonization of the data sets, considering the very wide variety of quality and level of detail of the data made available by the different sources.

2.1 Sectors selection

Considering its importance in the EU economy, manufacturing industry has been chosen as the main focus of the analysis ('C' categorization according to NACE rev. 2 [4]). Inside this industry, a further selection of the most representative sectors has been performed using several criteria: final energy consumption, energy cost over value added, number of employees, gross value added, EE economic potential (payback time lower than 5 years) and EE technical potential (Mtoe). These data, taken partially from EUROSTAT [3] and in part from literature, have been used to prepare a ranking of the different sectors which has led to the selection of:

- Manufacture of food products – manufacture of beverages – NACE C10-C11;
- Manufacture of pulp and paper products – NACE C17;
- Manufacture of coke and refined petroleum products – NACE C19;
- Manufacture of chemicals and chemical products – NACE C20;
- Manufacture of other non-metallic mineral products (divided into glass, ceramic and cement) – NACE C23;
- Manufacture of basic metals (divided into iron and steel and other metals) – NACE C24;
- Machinery – NACE C25-28.

The number of available data in the database is 2,906.

2.2 Field selection and database harmonization

Considering the high amount of available data and the different levels of detail of the national data sets, it was necessary to define a minimum set of information to guarantee a full description of the EE measures and that were relevant for the statistical analysis of the database and the consequent selection of the GPs.

For the statistical analysis, it was also necessary to create some categories to allocate the different projects. To do so, a three-level taxonomy was built, allowing the classification of each measure according to:

- The part of the plant where it was applied to (first-level taxonomy, e.g. 'process technology', 'service technology', 'alternative energy' production);
- The process or the main phase where the measure was implemented (second-level taxonomy);
- The sub-process or involved technology (third-level taxonomy).
- These three levels are applied twice:
- In general terms ('generic taxonomy'), common to all sectors (e.g. 'heat recovery');
- In sector-specific terms ('specific taxonomy'), allowing the allocation of the adopted measure to the specific process and production line, different for each sector (e.g. 'paper-making machine').
- Finally, there can be two types of measures:
- Single measures, where one intervention was carried out (one taxonomy field for each level for each type);
- Combined measures, where more than one technology/phase was involved (two taxonomy fields for each level for each type).

A schematic of the taxonomy structure is reported in Fig. 1.

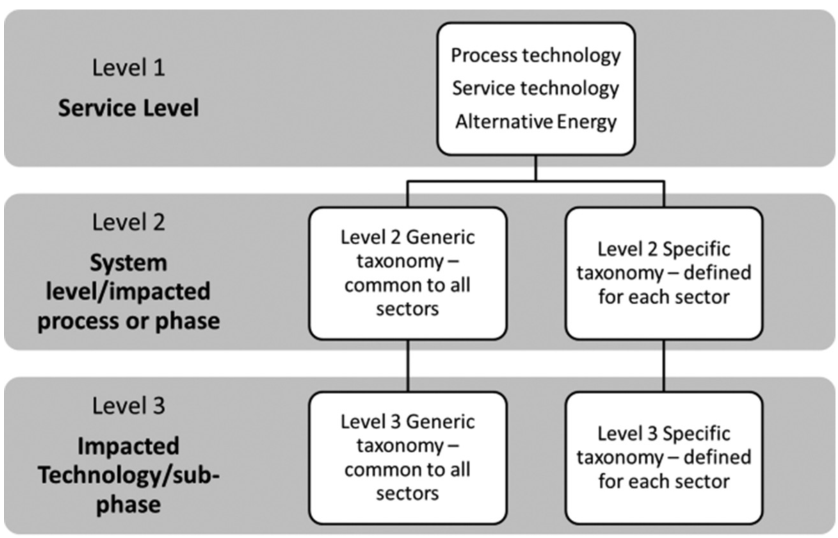

Figure 1: Structure of the taxonomy.

3 GP VERSUS BP: SELECTION METHODOLOGY

The selection of GPs and their validation by stakeholders is the main result of EU-MERCI project. At this point, it becomes necessary to define what a GP is and how it differs from a BP or a 'Best Available Technique' (BAT). The concept of BAT/BP is well known, but the first question to deal with is whether it is technically feasible and economically affordable in the real world. This is what the concept of GP tries to address.

3.1 GP definition

The description of BATs can be found in several documents, and in Europe it is linked to the Industrial Emission Directive (IED), formerly known as Industrial Pollution Prevention and Control (IPPC) directive, and to the BATs Reference Document (BREF) produced for each industrial sector. However, it often lacks an assessment of the applicability and feasibility of the proposed solution in the real world. The EU-MERCI project tries to address this issue with the definition of GPs extracted from almost 3,000 projects available in the database which have the advantage to have really been implemented by different companies. Moreover, these records have been deemed eligible of incentives in different MSs by experts in the sector.

Starting from this point, the definition of GP is 'a technique or a methodology that, through experience and research, has been proven to reliably lead to a desired result with the minimum use of resources'. The implication is that each proposed GP satisfies the following criteria at the same time:

- It is efficient.
- It is technically feasible.
- It is economically affordable.

These criteria are the basis for the definition of KPIs which will take in consideration different characteristics of the projects to give a full overview about the sustainability of the applied EE measures.

3.2 KPIs definition and selection

KPIs are a useful resource to evaluate the technical and economic quality of the projects in the database. After an analysis of the available data and the existing literature [5–10], it has been chosen to use three categories of KPIs, defined as follows:

- Technical KPIs that take into account the energy performances of the implemented projects;
- Economic KPIs that take into account the economic performances of the implemented projects;
- Advanced KPIs that take into consideration either technical and economic performances of the projects or environmental impact and economic performances of the projects.

A summary of the defined KPIs is available in Table 1.

3.3 GP selection methodology

KPIs calculation cannot be the only way to extract GPs from the database: to guarantee the effective availability of the EE measure, an evaluation of the technical complexity of the measures and their replicability is also needed.

Table 1: KPIs description.

Type of KPI	Name of KPI
Technical KPIs	Primary Energy Savings
	Energy Consumption Improvement (ECI)
	Energy Intensity Reduction (EIR)
Economic KPIs	Simple Payback Time
	Cumulative Cashflow
	Share of Project Cost Subsidized
Advanced KPIs	Cost of Energy Savings (CES)
	Cost of Carbon Savings
	Renewable Energy Use

In the EU-MERCI project, a three-way selection method has been developed which complements different approaches. The methodology is structured in three steps:

- Statistical analysis of the database;
- KPIs ranking;
- Engineering expertise evaluation.

After KPIs ranking (that also includes the statistical analysis) and engineering expertise are applied to the database, the most interesting measures that are found in both lists are chosen as GPs, described in detail in dedicated papers, in which their replicability is also evaluated.

4 DATABASE ANALYSIS

One of the missing activities in the EU-MERCI project has been a full analysis of the final database and its fields. The main reason is that the goal of the project was to extract GPs that are mostly sector-specific: with this aim, there was no need to perform a critical analysis of all the collected data. Moreover, the very tight time schedule did not allow one to perform analyses falling outside of the project scope. With this in view, a decision was made to perform an analysis on a sector base, while a full analysis of the database has been postponed. However, to get a full understanding of the collected data, the authors performed a critical analysis on the whole database which could be a starting point for improvements in the database and for a comparison with the single sectors results.

4.1 General information about the measures

The first part of the analysis focuses on general information about the measures and the companies that have put them in place. The food and beverage sector is the most represented, followed by machinery, while coke and petroleum is the sector with the lowest amount of available data. From a country perspective, as one can see from Fig. 2, Poland is the less represented due to the fact that their White Certificate mechanism has been implemented more recently than the EE schemes of the other considered MSs. UK has the highest number of data, however for most of them very little information is available.

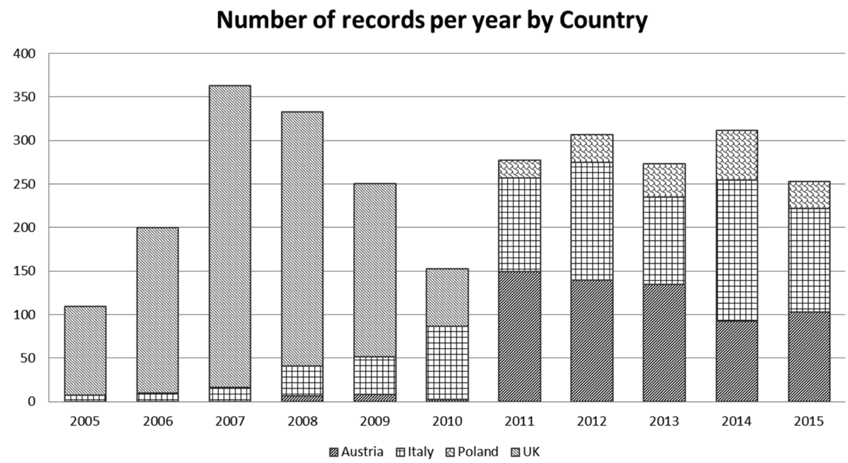

Figure 2: Number of records per year per country.

Moreover, it can be seen how different EE policies affect the realization of EE projects: for example, it is clear that, for Italy, the number of projects has increased from 2005 (the year when the White Certificate mechanism was introduced) to 2015, following the increasing know-how and spread of EE consciousness among stakeholders; the same happened for Poland; for the UK, it was a little bit different, considering that the policy was related to free energy audits to companies; for Austria the main mechanism, called KPC, started in 2011, and the few records prior to that date came from another program called klimaktiv (in which EE was just a small part of the whole policy).

Figure 3 shows how the size of the companies, in the overall database, is almost equally split among the three types (small, medium and large).

This is strongly affected by a similar distribution found in food and machinery sectors that are the ones with the higher number of records. On the opposite side, it is completely different from what happens, for example, in petroleum and iron and steel sectors, where almost all the projects were carried out by large companies, or in ceramics and cement sector, where the largest share of measures was put in place by small companies.

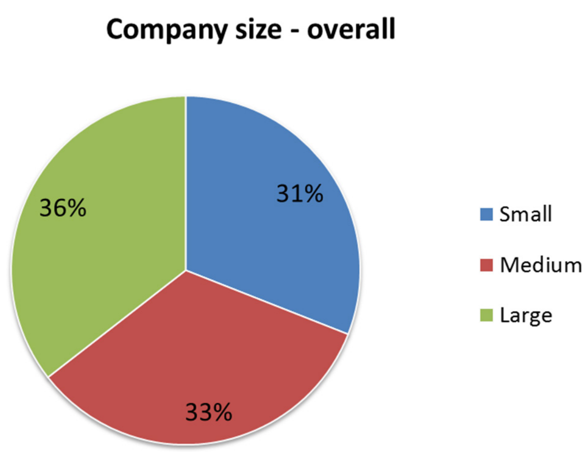

Figure 3: Size of the companies putting in place energy efficiency measures.

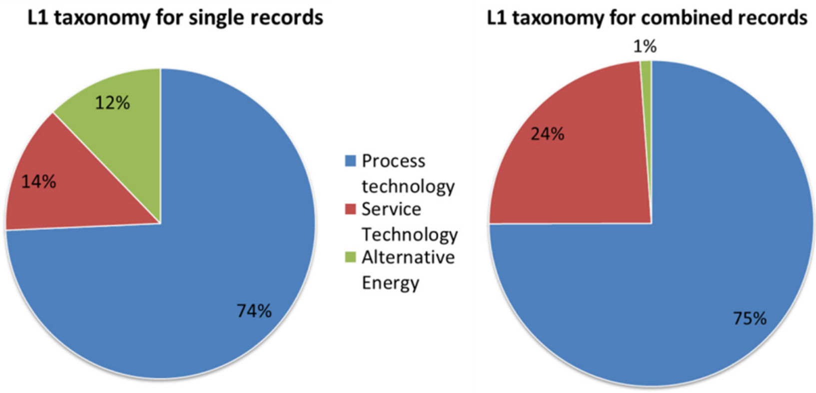

Figure 4: L1 taxonomy classification.

4.2 Taxonomy classification

Starting from the first level of taxonomy, it can be seen that most of the measures are categorized under the ‘process technology’. In single records 74% of the cases are related to processes and for combined records the amount of process-related measures increases up to 81%, while alternative energy systems are rarely applied in combination with other measures as can be seen in Fig. 4.

Considering L2 taxonomy, the results are reported only for the most common ones in Table 2. The others, having less than 1.5% relevance, are not shown.

The results, for both types of measures, are quite aligned, except in the case of renewable energy sources that, as already seen for L1, are rarely applied in combination with other measures. The other significant differences are in motors and drives, mostly concerning the installation of variable speed drives, that are often combined with other measures, and the heat recovery and cooling systems that are mainly applied as single projects. Most of the

Table 2: L2 taxonomy classification.

L2 generic taxonomy	Single (%)	Combined (%)
Heat recovery and cooling	18.1	9.1
Process design and optimization	18.0	16.1
Compressed air	13.9	16.6
Motors and drives	13.0	25.6
Renewable energy sources	10.5	0.8
Combustion	8.0	10.6
Refrigeration	4.3	5.2
Drying, separation and concentration	2.3	2.1
Medium transport	1.9	3.3
CHP	1.7	0.1
Process instrumentation and control systems	1.5	4.1

records are concerning 'classical' measures that are widespread in Europe: heat recovery, compression, motors and drives. Process-specific measures cover a significant part of the database between 16% and 18%.

L3 taxonomy results are not presented in this article, since they cover too many types of measures to be summarized here. Moreover, specific taxonomy, strictly related to processes, will not be presented due to the diversity of the various sectors.

4.3 Saving analysis

As already stated, savings were available for all the records. This was set as a prerequisite for the building of the database. The total final energy savings achieved were about 1.6 Mtoe, with an average value of savings equal to 490 toe/record. For each energy carrier, different savings were achieved, as can be seen in Fig. 5.

The largest savings were from natural gas, followed by coking coal, electricity and fuel oil. While natural gas, electricity and fuel oil were expected, coking coal was the 'surprise', considering that it is used in few processes. However, it represents a highly consumed resource in the iron and steel sector, one of the most energy-intensive sectors; this could explain the reason why it is saved more than electricity. Instead, this last carrier is probably less spread than others due to the choice that has been made at the beginning of the project to exclude the records not related to process (e.g. those related to office buildings and to lighting); another reason could be that the electricity-fed technologies (e.g. variable speed drives) are widespread, but they are not always ensuring high energy savings.

The sector in which most energy is saved is iron and steel. The one with the highest specific savings is petroleum and coke. Both of these sectors have a very high energy intensity, so this result was expected.

4.4 Cost analysis

Considering costs, it has to be highlighted that the total costs for all the projects collected in the database are around 3,000 M€. The two sectors with higher total costs were

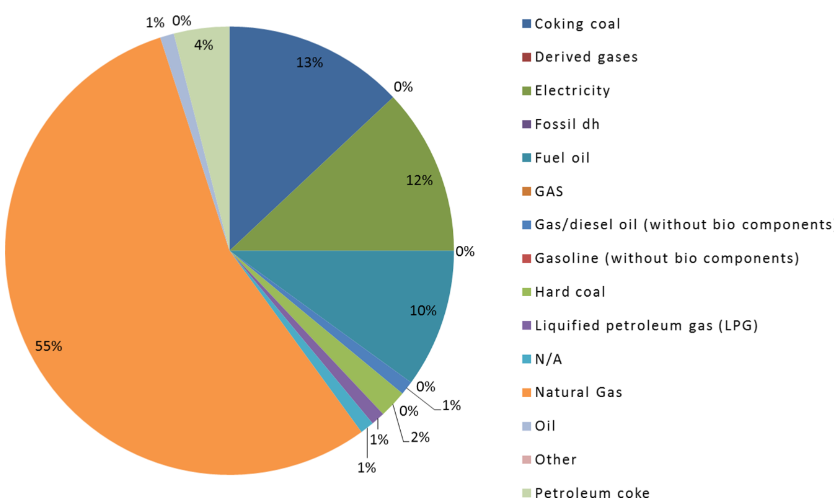

Figure 5: Energy savings by energy carrier.

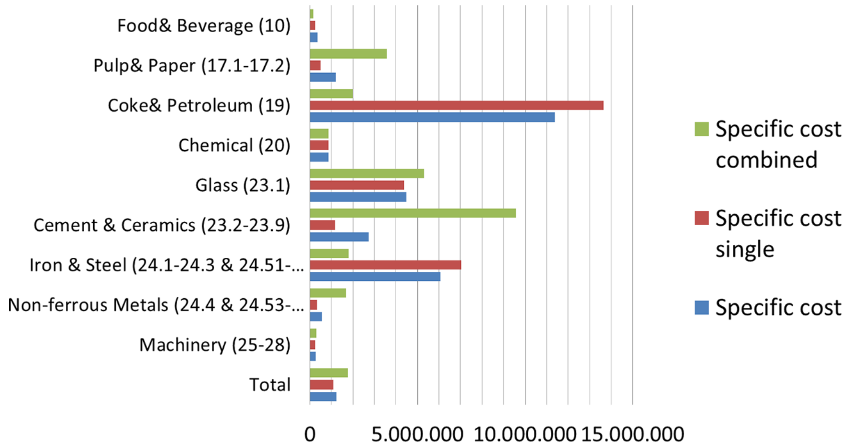

Figure 6: Specific costs per each case.

coke and petroleum and iron and steel. Since a comparison in terms of total costs does not give any added value, it is more interesting to analyse the specific cost per case and the specific cost per achieved saving. As can be seen in Fig. 6, it can be concluded that, for the coke and petroleum sector, the specific cost, especially for single measures, is very high: this depends also on the fact that the equipment used in this sector is very expensive and the considered cases are high-saving ones. Instead, in the cement and ceramics sector, the most expensive measures are the combined ones, usually involving massive interventions on the furnace and on the related equipment. On the opposite side, in the machinery and food and beverage sectors, the specific costs are very low for both single and combined records. This is also explained by the fact that, especially in food sector, many savings were related to fuels switch (mostly to biomass), so the total savings had to be reduced by the 'negative' savings (consumption increase) of these energy carriers.

Another interesting parameter for industrial stakeholders is the average investment cost that has to be spent to achieve 1 toe of energy savings. This is called cost of energy savings (CES) and it is also relevant for the calculation of payback time that is one of the main drivers of EE project implementation. In this case, as can be seen in Fig. 7, the sectors are mostly aligned with the exception of food and beverage. However, the high CES can be justified in the same way as above: fuels switch 'decrease' the net energy savings that are achieved due to the increase in 'green' energy carriers consumption.

Another interesting result is related to combined cases that are always 'less expensive', per saved toe, than single ones: this might be explained by the fact that they are more suitable to exploit scale economies.

4.5 Conclusions

In the previous sections, the most interesting numerical results of the database are shown, in an attempt to satisfy the needs of both researchers in the field and stakeholders (e.g. industrial managers seeking to carry out an EE project). Some other interesting parameters have been calculated for each sector (e.g. specific costs per adopted measure, studies on the other KPIs, etc.) and can be found in the specific papers published on the project website.

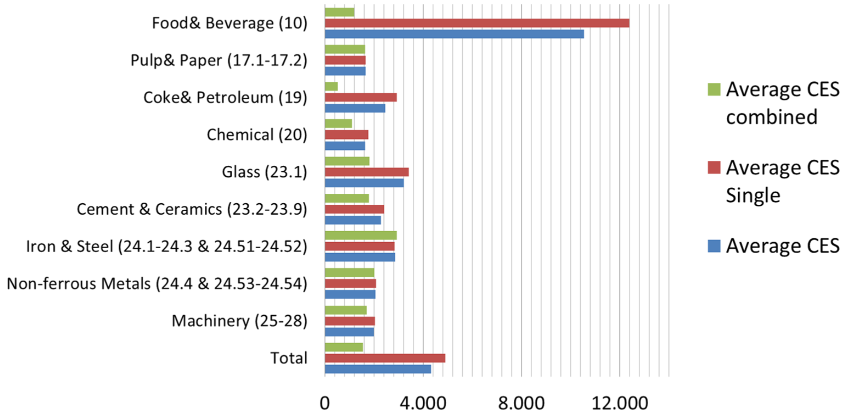

Figure 7: Average cost of energy savings.

The most important conclusions that can be drawn, apart from what is already reported earlier, are however some general recommendations that can be addressed to policymakers and, more generally, to whoever collects and analyses data about EE projects:

- There is a general lack of standardization in the quality of data that are required from companies when carrying out an energy audit (as per art. 8 of EED) or asking for incentives: this leads to different results when trying to analyse records received from different countries (e.g. savings reported either in final or primary energy, different references for baseline, different ways of evaluating technical life of the installed equipment);
- Some fields should be properly defined and their boundaries should be well set: e.g. for the replicability analysis of the projects in different sectors or different companies, it could be useful to have the process baseline consumption for each energy carrier to scale it to the desired technology (e.g. toe/ton of product);
- There are different quality levels of the reported savings: while in some countries savings will be measured and periodically reported with strict verification procedures (e.g. in Italy), in others deemed savings are considered enough, so leading to unreliable results and also in the view of 2030 targets achievement;
- To simplify the collection of data and the reporting from companies, a large effort should be put, in the EU, to develop precise taxonomies, at both generic- and sector-specific levels that allow one to standardize the description of the adopted measures, insert them in a common matrix and ease the work of incentives evaluators.

These are the minimum requirements that will allow one to achieve all the EE targets in a correct and standard way.

5 THE EIEEP PLATFORM

To collect all the results of the project and to promote the adoption of EE GPs in EU, it has been decided to build an online platform that is publicly accessible. This platform has a novel approach towards users through its unique technological architecture which allows them to selectively access, customize and download what they need for their analysis and studies. The platform is available at the website http://www.eumerci-portal.eu/ (Fig. 8) and is composed by three main sections:

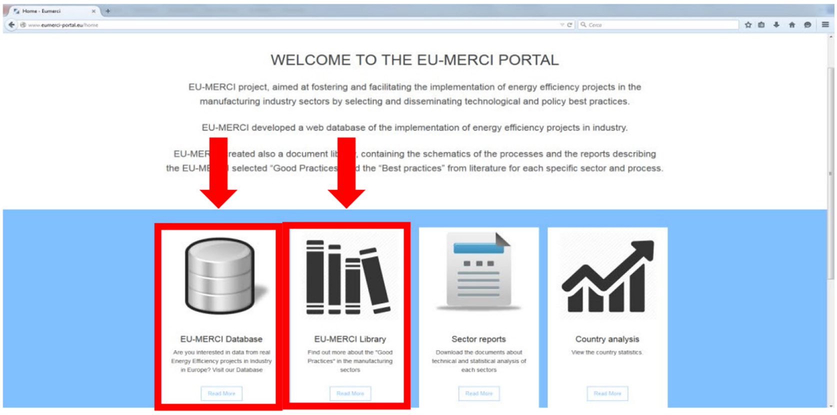

Figure 8: Screenshot of the homepage of the European Industrial Energy Efficiency good Practices platform.

- 'Database' that contains raw information on the EE measures analysed in EU-MERCI;
- 'Library' that shows the BPs from literature and the GPs identified in EU-MERCI project for different sectors and manufacturing process' phases;
- 'Surveys' that present the results of the surveys conducted with different stakeholders (companies, ESCOs, sector associations) for the characterization of EE in Industry.

These sections, with their subsections, will be explained in detail in the following text.

5.1 Database section

The database section has been created with the scope of allowing external users to access the records collected and examined by the project partners. Through the platform, this is, at the present moment, the largest publicly available database of EE projects in Europe.

This section has two subsections that allow the users to access the database at different levels of detail:

– 'Free navigation': through which the users have access to the whole database, and exploit the download functions, also with the possibility to download a part of the database using a sorting function; by selecting a single record, it is possible to open a wider selection of data about it;
– 'Queries' (accessible through the button 'Select'): through this section, the user can have access to a sorted part of the database by using different available queries and download the results in PDF format.

5.2 Library section

The library section has been created to collect the results of the elaborations made by the different partners by analysing the database. It collects and displays the main results of the work organized through four different subsections:

– 'Tutorial sectors' (accessible through 'Select a sector' button): It is divided into the sectors selected for analysis in the project, and it contains process schematics and links to all the BP found in literature and the GPs identified by the project partners for the specific sector and validated with industrial stakeholders;

- ‘Sector technical analysis’: it contains a technical assessment of the sectors analysed in the project;
- ‘Country analysis’: it contains statistics data about industry and energy in the countries involved in the project;
- ‘Factsheets’: it contains two-page summaries of the most important results for each sector.

The library has the scope to give the users an overview of all the results of the project from the literature reviews (e.g. BP descriptions and country analyses) to the specific products of EU-MERCI (e.g. the selected GPs). All the files are publicly accessible and downloadable in PDF format.

5.3 Survey section

In the first phase of EU-MERCI project, it was decided to directly involve industrial stakeholders to understand what were the needs of EU industry. This has been done by the use of surveys, focused on the type of stakeholder. In particular, three types were selected, and the obtained results with each of them are shown in the respective section: sector associations, companies and ESCOs.

The surveys had the objective to provide the project partners with insights about EE from stakeholders’ perspective, considering especially the level of awareness about EE issues, their interest in carrying out EE projects and their perception of barriers and weaknesses that can slow down the process of EE increase in European manufacturing industry.

6 GENERAL CONCLUSIONS

EE remains one of the main ways to reach 2030 targets of the EU in terms of climate change mitigation. Industry plays a key role, but it needs to be oriented towards the most effective solutions that allow the achievement of high savings, while also considering the economic return of the investment (i.e. one of the decision-making parameters for industrial stakeholders). One of the goals of EU-MERCI project is to act as a ‘guide’ for all the involved stakeholders to:

- Spread the existing know-how about EE in industry;
- Allow all the involved stakeholders to access detailed data about what is implemented in their or other countries through the public database;
- Allow industries to take example from other companies in the same or other sectors through the GPs.

The EIEEP platform is the ideal tool to achieve these goals, and its added value lies, in fact, in the ‘reality’ of the presented projects and results, which is often lacking when analysing BATs, combined with the high number of publicly available data through the EU-MERCI database.

The next steps will be the further developments of the EIEEP platform with the addition of new data both in the sectors already analysed and in new sectors.

ACKNOWLEDGEMENTS

This work has been funded partially by the Research Fund for Italian Electric System under the Contract Agreement between RSE and the Italian Ministry of Economic Development and partially by the European Commission under Grant Agreement No. 693845 (EU-MERCI project). The authors would like to thank the other project partners, especially AEA, KAPE, Carbon Trust, CRES and FIRE and the colleagues from RSE for the constant support.

REFERENCES

[1] *Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC*. Official Journal of the European Union, Online, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN. Accessed on: 7 February 2020.

[2] *Guidance note on Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EC, and repealing Directives 2004/8/EC and 2006/32/EC Article 8: Energy audits and energy management systems - (SWD/2013/0447 final)*. EU Commission, Online, http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52013SC0447&from=EN. Accessed on: 7 February 2020.

[3] *Statistics Explained - Consumption of Energy*, Eurostat, Online, http://ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy. Accessed on: 7 February 2020.

[4] Eurostat, *NACE Rev. 2 - Statistical classification of economic activities in the European Community*, European Commission, 2008.

[5] Chan, Y. & Kantamaneni, R., *Study on Energy Efficiency and Energy Saving Potential in Industry from possible Policy Mechanisms*, ICF Consulting Limited, London, 2015.

[6] IEA (International Energy Agency), *Capturing the Multiple Benefits of Energy Efficiency*, OECD/IEA, Paris, 2014.

[7] IEA (International Energy Agency), *Energy Efficiency Indicators – Highlights*, OECD/IEA, Paris, 2016.

[8] Rota, L. & Zagano, C., *Misure di Efficienza Energetica nel settore industriale*, Rapporto Ricerca di Sistema 15000306, RSE, Milan, 2015.

[9] Bazzocchi, F., Gobbi, M., Lanati, F., Zagano, C. & Bertani, D., *Le potenzialità di efficientamento energetico dei principali settori dell'industria: criticità ed opportunità*, Rapporto Ricerca di Sistema 16002187, RSE, Milan, 2016.

[10] Maggiore, S., Di Santo D., Realini, A., De Chicchis, L. & Mori, F., *Energy efficiency good practices in industry: the EIEEP platform*, ECEEE Industrial Summer Studies 2018 proceedings, Online, https://www.eceee.org/library/ conference_proceedings/eceee_Industrial_Summer_Study/2018/4-technology-products-and-system-optimisation/energy-efficiency-good-practices-in-industry-the-eieep-platform/. Accessed on: 26 February 2020.