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A Decade International Experience into Effective Resources and Energy Efficiency Auditing

Andrea Maffini[a*], Marco Morando[b], Antonio Saba[b], Giorgio Bonvicini[b], Bruno Fabiano[c]

a Maffini Engineering & Consulting, via D. Somma 80 – 16167 Genova, Italy
b RINA Consulting S.p.A., via A. Cecchi 6 - 16129 Genova, Italy
c DICCA - Civil, Chemical and Environmental Engineering Department, Polytechnic School - Genova University, via Opera Pia 15 - 16145 Genova, Italy
andrea@maffiniconsulting.it

Purpose of this paper is to draw a balance of a decade of resources and energy efficiency auditing activities and studies, carried out in Eastern Europe, Central Asia and Africa, aimed to support International Financial Institutions (IFIs) in improving their sustainability performances and in reducing the global environmental impact of their customer Companies. The auditing framework was designed as a step-by step sequence:

- Job Assignment from the Bank, based on specific Terms of Reference;
- Submission of a questionnaire, tailored to the particular agro-industrial sector (i.e., dairy, tomatoes processing, slaughterhouse, etc.);
- Multi-disciplinary team assessment of industrial facilities, by means of an on-site survey and meetings with the managers of the agro-industrial company for the discussion of relevant issues;
- Preparation of a draft report to be discussed with IFI and Company;
- Preparation of a final report including remarks from IFI and Company.

The paper will present the results by developing proper sustainability and safety performance indicators, in terms of energy consumption and reduction of GHG emissions reduction, as well as control of water pollution and waste generation, and their safe disposal. In designing and performing the actual auditing process, a great attention was paid to the considerations for the global environment and safety implications, especially in selecting the technologies, not limiting the efforts to the usual CAPEX and OPEX reductions and to the local impact parameters. Conclusions are drawn regarding the practical possibility of incorporating audit results in terms of environmental sustainability into the overall decision-making process.

1. Introduction

The main target of the Kyoto Protocol confirmed in the Paris summit in 2015 is to keep global warming within 2°C or better 1.5°C, by a planetary effort to curb the greenhouse gases emissions in accordance with agreed individual targets. At the same time, novel relevant issues including circular economy, sustainability and resource conservation demand a continuous improvement of efficiency in the energy consumption and generation, in the use of resources, with integration also into the safety paradigm (Pasman et al., 2021). Finally, emissions of hazardous pollutants from production facilities are not acceptable by law and cannot be borne by the environment, so that any factory, or farm or workshop should be equipped with treatment units and waste disposal systems (EC, 2008). In this context, in Europe, the Industrial Emissions Directive (EC, 2010) imposes that facilities with a high pollution potential can only be operated according to the Best Available Technique (BAT) approach, including technical, organizational and managerial measures allowing a high level of protection of the environment as a whole. In case of presence at the factory of dangerous substances in excess of threshold quantities, the prevention of major hazards and the limitation of consequences of accidents that may occur with impacts for people and environment fall under the umbrella of the EU Seveso Directives legislation (Laurent et al., 2021). The issues related to prevention and mitigation intervention costs represents an up-to-date topic, to be faced by proper optimization tools (e.g. Abrahamsen et al., 2020). Whereas the above efficiency, safety-related and pollution treatment costs could be generally afforded by the company themselves in the Western Europe or North America countries, as part of the basic investments governed by laws and regulations, this is not always the case in other nations. There, it is needed a financing body to supply the project capital, as well as a consultant that pinpoints the investments required to reach a state-of-the-art condition in resources and energy efficiency, as well as in complying with emissions limits and safety constraints standards.

2. Auditing framework and purpose

This paper relies on a decade-long experience of a multi-disciplinary team in supporting companies in Eastern Europe, Central Asia and Africa to implement new projects, with the aim of higher efficiency in use of resources and energy consumption and generation, as well as new projects to comply with local and international environmental standards. The Resources and Energy Efficiency Audits (REEA) are focused on helping the industrial customers of the International Financing Institutes to identify the opportunities to save energy and resources and persuading them to prioritize efficiency investments. Additionally, it aims at covering any gap in fulfilling the environmental and safety laws and regulations, whatever it is, either in the water or in the air or in the ground.

All the Resources and Energy Efficiency Actions proposed during the Audits at the relevant industrial facilities are evaluated, in order to identify some key parameters; they are applied for presenting the expected results of the investments. The typical summary table for each proposed investment shows the average capital expenditure per unit of energy saved in unit of time (GJ/year), the average capital expenditure per unit of Green House Gases (GHG) emissions reduction (tonCO_2/year), the total cost, the total energy saving and the total GHG emissions reduction for the twelve categories of actions identified above.

Another purpose of the audit is to improve the environmental conditions and permit regulation verification:

- water consumption users and wastewater discharge points are identified to see the supply and treatment duties and check the possibility for streams recycling through a segregation of each water duty system;
- exhaust gases streams are identified for treatment and for possible heat recovery;
- waste generated in the factory is sorted by type, and management according to hierarchy is assessed for proposal of new solutions; particular attention is given to bio-waste and its sustainable utilization;

The overall analysis expands the main findings identified in the plant survey visits: it often consists in the verification of the improvement actions aiming at energy efficiency implemented by the plant managers, but also in the appraisal of any other environmental or safety relevant technical action, or adopted managerial strategy.

3. Methodology

The purpose of the REEA is the investigation and appraisal of investment opportunities with the objective of increasing the Resource Efficiency (RE) levels of industrial Companies, taking into account the use of raw materials, water, by-products, wastes, wastewater, recyclables, etc. The REEA analysis relies on the conceptual methodology previously developed for energy audits by Hasanbeigi and Price (2010). The developed framework was accurately tailored to encompass all actors along the whole value chain from different types of feedstock, through transformation into intermediate and end-products/services. Specifically developed for and tested on the Chemicals and Agribusiness sectors, the REEA can be applied within the system boundaries (ISO, 2006) of any industrial or service company, covering different sectors. A sector is defined as an area of the economy in which businesses share the same or a related product or service: sectors can be mining (ores, coal, etc.), agriculture, industries (e.g., breweries, dairies, pulp & paper, power plants, etc.), or services (transports, logistics, waste management, etc.). The major objectives of the REEA include to:

- preliminarily evaluate the overall resource efficiency potential;
- collect data of activities and carry out a benchmarking analysis;
- identify a preliminary set of investment opportunities and technically and financially assess them.

In order to implement the analysis, it is necessary to define the following concepts:

- a baseline Scenario (also known as 'reference' or 'non-intervention' scenario): it depicts the actual or assumed situation or state of a Company, used as the starting point in comparison to the new proposed investment.
- a project Scenario: situation which would be the actual case, should the proposed investment plan be implemented.

3.1 Desk activities prior to site survey

Some technical information might be available before the site visit. However, deskwork is useful to better understand the technology of the single case and the context: for instance, the Company may have the factory in an area out of any logistic support or in the mountains where conditions are extreme: this would require a specific approach. The desk research will help to find alternatives for technology improvement also by submitting to the Company a questionnaire according to a format prepared for each sector (i.e., dairies, fine chemicals, etc.), which is tailored to the case under observation. It is expected that the questionnaire is filled by firm technical experts before the Site visit of the industrial plant, so that the following collection of on-site data results generally more effective. Elaboration of data collected from the questionnaire and relevant attached documentation allows to carry out a preliminary plant performance analysis. The following main data are expected from the questionnaire and relevant attachments:

- Equipment specifications;
- Resources consumption data;
- Production data;
- Waste and wastewater production and off-gas emissions;
- Mass and energy balance data;
- Capital and Operating Costs of the existing facilities and of planned investments.

Step A of the REEA evaluates the potential level in resource efficiency investment of a Company and is aimed at identifying areas of major interest. The potential assessment includes the evaluation of the following items:

- operational improvement potential: an initial and not exhaustive review of facilities vs. a standard pre-defined set of best reference techniques (technical performance) for both process and utilities, including the evaluation of the ageing of installations and of the Corporate Sustainability Practices;
- resource sustainability improvement potential: including assessment of the availability of resources (supply chain), adaptation risks (due to climate change), potential scarcity of resources risks (in particular water and rare materials) and waste management (exposure to potential changing business restrictions);
- commercial improvement potential: including resource pricing (e.g., subsidies, price distortion, protected market, etc), indirect and hidden prices, variations in prices for input materials (in particular water), waste residues disposal, as well as product competitiveness (risk of product obsolescence).

3.2 On-site Activities

The site survey is the core of all the auditing activities: here, the first assessment made on the basis of the questionnaire contents and on the available technical data is extended and compared to the direct information gathered in the meetings and in the plant visit. The on-site activities allow direct data collection through on-site auditing made by the experts in order to review and complement the remote data collected through the Questionnaire anticipated to the Company. Additionally, it is also possible to identify plants areas whose performance shall be assessed through dedicated on-site measurements; in particular, it will be defined a measurement campaign (type of measures, timeframe, sampling frequency, etc.) also to verify enforced maintenance programs and possible ageing management plans drawbacks (Ancione et al., 2020). In plants with large heat distribution networks (e.g.: steam, superheated water or diathermal oil), also an assessment of the level of thermal insulation of distribution pipes is carried out by means of an infrared camera, in order to identify the sources of thermal losses and the potential improvement actions. A visual example is provided in Fig, 2 a and b, respectively referred to a steam collector under ageing conditions and with non-insulated valves/flanges and one to a well-insulated and maintained steam piping.

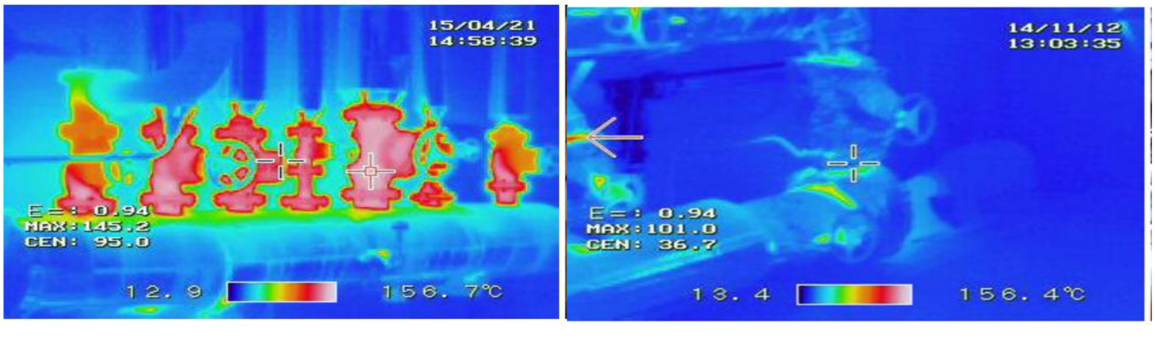

Figure 2: Example of Infrared Camera Assessment: (a) left hand side; (b) right-hand side.

3.3 Benchmarking Analysis

The Benchmarking Analysis is divided into qualitative and quantitative analyses, which lead to the preliminary identification of the potential investment opportunities. This step includes:

- review of the previously-performed Preliminary Assessment, based on additional data collected during on-site activities;
- assessment of the Company system boundaries, disaggregation of its process in sub-processes and definition of the process Block Flow Diagram and including all Company activities which fall within the scope of work of the REEA;
- Resource Balance preparation, in order to highlight the resource consumptions and waste / wastewater generation levels, as well as Company products and by-products;
- qualitative gap analysis: the sector best available techniques (BAT) are determined and compared with the Company as it is in order to identify technological gaps;
- quantitative gap analysis: technical and economic Key Performance Indicators (KPIs) are used to measure the Company performance in comparison with the sector benchmarks, which often shall be properly "adjusted" in order to be comparable with the Company conditions; the adjusted benchmarks are expressed as a range (the "high performance benchmark" is the extreme of the range which corresponds to the better performance and the "low performance benchmark" to the lower performance);
- preliminary identification of potential investment opportunities at the audited Company, based on the benchmarking gap analysis, improvement potential assessment and on the areas of lower KPIs performance.

Table 1 provides a worked example of KPIs selection referred to pulp mill sector.

Table 1: Definition of Key Performance Indicators covering the paper mill sector

Technical KPI	Definition	Rationale for the KPI definition
Raw Material Use	ton of material input/ ton of paper production.	This indicator is inversely proportional to the "Products" indicator.
Materials Intensity	Ton of raw material / ton of raw material used	Used to estimate if any raw materials input (recycled paper, starch, painting, coating, etc.) are used with inefficient yield (independently from the raw materials utilization degree).
Total Energy Use	kWh of total energy consumed / ton of paper production	Purchased energy + energy generated from renewable sources (electricity from wind/solar, thermal energy from solar, or biogas from internally available wastes, etc.)+ waste-to-energy recovered (e.g., the energy content associated with the waste combustion or with its chemical conversion into a fuel or synthetic fuel).
Purchased Energy Use	kWh of purchased energy / ton of paper production	Purchased energy
GHGs Emission	kg of GHGs emission / ton of paper production	Used to indicate the total GHGs emission.
Fresh Water Use	m^3 of fresh water input / ton of paper production	Fresh water is used as the only indicator (not total or re-circulated water) as it takes into account both the process use of water and the recycling of water.
Wastewater Discharge	m^3 of wastewater output / ton of paper production	Used to indicate the total wastewater residual output.
By-products Recovery	ton of by-products output (sludge, etc.) / ton of paper production	Even if by-products are sold (e.g. paper production rejected sludge sold to cement plants), by-products minimisation is related to the maximisation of primary product yield.
Waste Discharge	ton of waste output / ton of paper production	Addressing the total waste residuals output.
Waste Recovery	ton of recoverable waste output / ton of paper production	Addressing the waste residual output which could be reused as raw material, by-product or waste-to-energy.

The preparation of the list of BATs for comparison with the audited Company techniques is based on the EU IPPC BREF documents, according to the following steps. For each industrial sector, the process-integrated BAT, which minimises emissions to air, water and ground using the best substances and techniques is applied. In case IPPC is not available or not sufficiently detailed/updated, other sources can be used, with a similar approach. Frequently, the characterization of resource consumption impacts of a Company requires a high number of data and indicators. The tool assures that the resulting information is correctly compressed to enable a sound decision-making, however, it is important that this requirement for operational usefulness does not cause a loss of relevant information. Company KPIs are converted into a score from 0 to 100 and displayed on a spider diagram. Each axis of the chart quantifies the performance of the Company for a specific aspect, e.g., consumption of raw materials, consumption of water and energy, generation of by-products, waste, wastewater and GHG emissions with respect to the generated product output. The spider diagram clearly identifies the position of the audited Company (grey line) compared to sector benchmarks (100=high performance benchmark, 40= low performance benchmark). If the value is above 100, it is automatically set at 100; if the score is negative, it is automatically set to 0. A Company's KPI score of 0 to 40 indicates a remarkable improvement potential, 40 to 80 indicates an improving potential and a score above 80 shows that there is no or negligible improving potential. In a similar way to the technical KPIs, the economic KPIs indicate the resource purchase / waste disposal costs of the audited Company in the three considered years, in comparison with the costs associated with the benchmark technical performance range and the same tariff/price levels. The quantitative and qualitative benchmarking analysis performed in this step allows the experts to preliminary identify a set of potential resource efficiency measures / investments able to address the identified inefficiencies / low performances. In order to put into evidence the capability of the approach, in the following result and discussion section we detailed the investment appraisal referred to an actual case-study.

4. Results and discussion

The Investment Appraisal includes:

- detailed technical and economic analysis of each identified measure / investment as well as their financial analysis (including sensitivity analysis);
- evaluation of the potential impacts of the proposed measures on the Company and evaluation of the remaining "gap" of the Company with respect to benchmarks.

An example of technical KPIs ex-post implementation ("project") in comparison with the baseline is shown in Figure 3. Similarly, the economic KPIs in the project scenario are compared with those of the baseline scenario, showing the resource cost saving achievable through implementation of the REMs (Figure 4). The continuous line represents the net balance of the considered costs/revenues, while the dashed lines represent the net costs associated with the benchmark level technical performance. Finally, the impact of the measure / investment on the Company is assessed, in order to estimate their mitigation effect on the resource efficiency risks of the company.

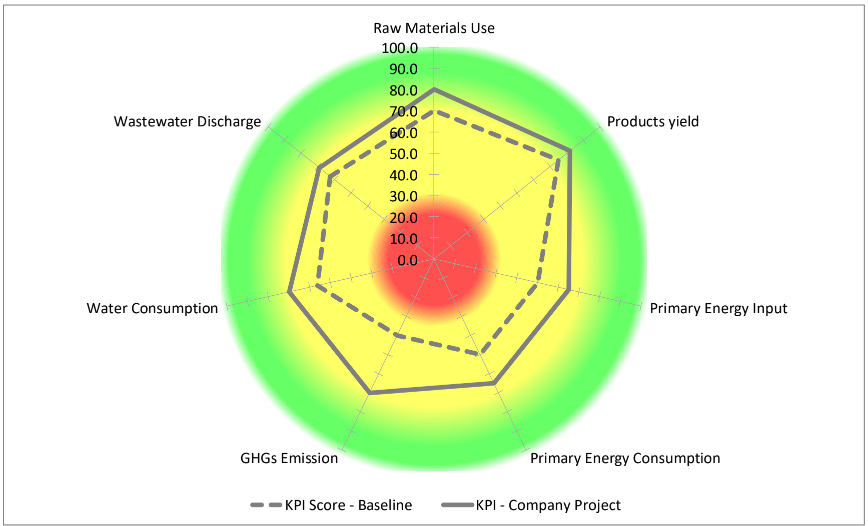

Figure 3: Impacts of Resource Efficiency Investment on Technical KPIs

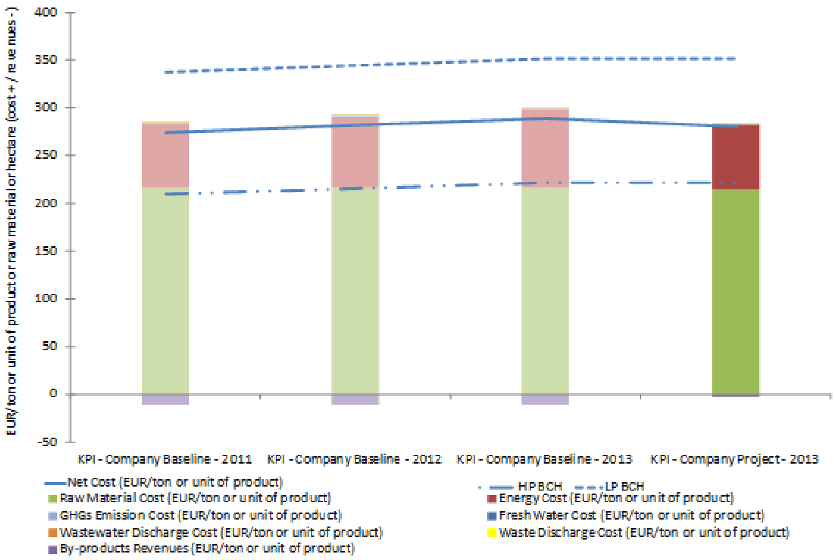

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Figure 4: Impacts of Resource Efficiency Investment on Economic KPIs

5. Conclusions

This paper outlines a framework for performing audit activities allowing effective improvements in the sustainability of plant operation, through a range of proposals for the increase of resources and energy efficiency and the reduction of local and global environmental impact. As shown by a real example, the auditing entails a powerful methodology to boost sustainability and cut emissions, especially for GHG, managing as well main issues relevant to safety, environment and process efficiency. As a whole, the auditing activities covering globally about 200 companies allowed designing along the last decade an overall cut of GHG emissions estimated as 1 to 2 million tonsCO_2eq/year, with roughly 20% to 30% expected to be achieved thanks to financed projects. The developed approach offers a method for prediction of resources and energy use, providing the company management an effective tool to fit the sustainability into their overall decision-making process.

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