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# Compared analysis of the economic and environmental benefits by using an energy management system in different European countries

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**Abstract**

The European Union has approved a new energy strategy for 2030, the target being to save the 27% of primary energy compared with the business-as-usual scenario and to reduce the CO2 emission of 40%. Each member state shall establish an indicator showing the energy efficiency contribution towards the Member State's 2030 target. Under such challenging target, the use of optimized energy management system has the potential to greatly contribute to the reduction of both the primary energy and the CO2 emission. Of course, the economic benefit for installing these systems is also an important issue from owner's point of view, and it has a big influence on the technical solution choice. The energy management systems are capable to optimize the schedule of boilers, electric chillers, and other kind of generators. In this latter case, the use of cogeneration systems is often applied, in order to increase the overall efficiency of the plant, often in combination with absorption chillers to make effective use of the heat also with large cooling loads and small heating duties. The fuel sources of all these pieces of equipment are represented by natural gas and electricity, so the result of optimized operations is greatly modified depending on the situation of gas and electricity prices, which are strictly dependent on the country which the analysis is referred to. The purpose of this study is to clarify the influence of the electricity price and the natural gas price of each country on the optimum operation of an energy management system, considering the acquired energy demand pattern and the configuration of a multi-generation production plant consisting in a small Italian factory. The energy price scenarios which will be analyzed are related to 7 countries with large GDP in the EU region, on which optimization algorithm will be applied. The results will be focused on the comparison of the economic benefit, primary energy saving and reduction of CO2 emissions for each country, applying different target function of the optimizer (minimum running costs, primary energy consumption, or GHGs emissions), in order to highlight the most relevant parameters determining the benefit of the energy management system.

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## 1. Introduction

In recent years, reducing GHGs emissions and improving energy efficiency has become a major issue in the energy field due to the global increase in energy demand and the impact of climate change. In particular, the European Union has targeted challenging objectives going towards the cited direction by issuing the Energy Efficiency Directive 212/27/EU [1] with the environmental and energy targets to 2020, and a new energy strategy for 2030 with the aim of reducing long-term greenhouse gas emissions [2]. These actions are encouraging investments in advanced low carbon technologies, namely the increase in the share of the renewable energy sources coupled with the development of distributed generation systems. This new energy paradigm is leading to the institution of a new concept for the user, being no longer a passive element of the energy chain, but gaining a more active role becoming a prosumer. In this complex context, a fundamental role is thought to be played by local Energy Management Systems (EMSs), which are demanded to effectively and efficiently manage the disperse generators owned by non-expert users, in order to achieve the final goals of deceasing the carbon footprint of the energy systems.

In order to be economically competitive with the rest of the World, the new efficient and environmental-friendly technologies shall also determine an economic advantage in the user point of view, so that the target of the EMSs must take into account the running costs of the energy facility, in addition to primary energy and equivalent CO2 emissions performance: an optimized operation strategy has to be automatically defined by means of purposefully developed algorithms taking into account several constraints, both internal (e.g. type and characteristics of the installed generators) and external (e.g. electric and fuel energy prices, regulations for the power exchange with the grid).

Many authors propose several optimization techniques, being them linear and non-linear, most of them providing effective results when multiple commodities are considered within the optimization process also involving the presence of cogeneration systems and thermal and/or electric storages, applied in a well-defined context. Adam et al. [3] considered the suitability in terms of CO2 emissions of a fuel cell-based CHP installation in the UK context, while Caliano et al [4] analyzed the economic effect of different operation strategies for micro-CHP systems in Italy. Similarly, Lödige et al. [5] proposed an optimal economic management of cogeneration units in the German energy scenario, with Tichi et al. [6] which proposed an operational strategy of CHPs in Iran based on particle swarm optimization. Anyway, poor results can be found if considering the application of an energy optimization system in different context, in order to understand how the local generators are differently used when the boundary conditions (mainly in terms of energy prices) are modified.

This work aims to show the results of the optimized operations of a Multi-Generation Plant (MGP) starting from daily loads demand of an actual Italian small enterprise considering the energy prices of 7 countries with large GDP in the EU region. In more detail, in the second paragraph all the details of the problem will be provided, namely the load profiles of the case study, the plant layout (including the specification of the equipment), the energy price of each country, and the overview of the optimization algorithm. In the third paragraph analysis results are shown and discussed, and finally the most relevant parameters in terms of economic benefits will be reported and summarized.

## 2. Problem definition

### *2.1. Definition of the case study*

The analysis of the EMS performance is carried out considering as a case study the actual energy consumptions of a small enterprise located in central Italy, involved in performing mechanical, chemical, and durability tests for the industries. For the cited activities the company needs heating, cooling and electricity for the test benches, in addition to the thermal requirements for the space conditioning and the power of the office area. In the following, two load patterns will be analyzed, considered as representative of the operating conditions of the company during the summer