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# Producing, storing, using and selling renewable energy: The best mix for the small medium industry

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ABSTRACT

Over the last decades, the production of "sustainable energy" has provided a very fertile research field, involving aspects that are traditionally considered in an independent manner, namely renewable energy production, energy storage and efficient usage of available energy. A combined analysis of these three aspects within an industrial context is the main focus of this work.

We provide an insight on the problems that a small or medium manufacturing firm can expect to address when it decides to move from traditional energy suppliers to an as much as possible autonomous energy production. In particular, we consider the contribution that ICT can offer in order to allow the firm to decide the best size and composition of its own "energy production plant", based on data regarding its production needs and weather-related data.

We propose an open source framework aimed at making it possible to model various systems including both energy production, storage and consumption elements. The framework also allows the use of different approaches to optimize and fine tune the system in terms of both design and usage costs. We show how the framework can be specialized in order to be used for a typical industrial test case representing a small medium manufacturing firm that decides to change its position from a pure energy consumer to an energy combined producer, storer and user.



## 1. Introduction

The transition to a new renewable energy system is coming much faster than anyone could have anticipated just few years ago. There are two main drivers in this transition: the rising of world energy demand along with the cost of fossil fuels and the decreasing trend in the price of green energy.

According to the International Energy Agency (2006), the increasing world population along with the economic growth of the emerging countries will imply a rise in the energy consumption of about 1.5 in 2030 with respect to its current level. The price of green energies is decreasing rapidly due to new available technologies as well as to economies of scale. For example, in 2006 the retail grid parity for photovoltaic sources was expected to take place in 2016 ÷ 2020. Nevertheless, due to rapid decreasing pricing, (corresponding to increase of 30% of installed capacity every year) more recent calculations suggest that the grid parity will be reached within 2015 [1].

European Community is supporting this transition through proper economical policies: the objective is to sustain the development of a democratization of energy production as one of the main pillars of what has been defined as the Third Industrial Revolution [2]. In this economic scenario, the paradigm around which almost all small medium European manufacturing industries are being reorganized is: producing, storing, using/selling renewable energies.

In this scenario, we propose an open source framework to help modeling and optimizing systems that not also use energy, as traditional firms have always done, but also produce and store renewable energy as a mean to reduce costs or to produce extra earnings.

The modeling framework is not intended as a software tool to be directly used by the final user, but it is rather designed to be a common starting point for researchers or practitioners who want to realize design tools that can be used by energy systems designers as well as by consultants in order to prove the effectiveness of investing in renewable energy production and storage in terms of costs and profitability of the available choices.

In Section 2 we provide a short review of the main software tools that can be used to model and optimize systems including renewable energy sources in general, while in Section 3 we focus on the possible approaches to deal with renewable energy sources management within the industrial sector. The modeling framework

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is described in Section 4 and its application to a real case is reported in Section 5.

## 2. Renewable energy management tools

Providing a thorough review of the software tools aimed at the design and management of renewable energy systems is beyond the scope of this work. However, a synthetic comprehension of the main different possibilities that both the academic and the commercial sectors propose is important to better collocate the contribution of this work. A classification scheme is provided by [3], which defines four main categories:

**Pre-feasibility** These tools assist the designer in determining whether a system is feasible in terms of energy supplied and in terms of the life cycle cost of energy. These instruments are usually oriented towards a rough sizing of the components involved in the system. In fact, they are usually implemented as worksheets, as they require only the automation of simple calculations. These tools are typically used by vendors, system promoters, etc, or generally by people who need to evaluate whether an opportunity exists for a specific hybrid system application.

**Sizing/optimizing** A sizing tool determines the optimal size of each system component in order to satisfy the energy requirements. Most sizing tools provide detailed information about energy flows among components and indications of the critical periods during the year. Usually these tools are software packages with high usability. Some of them allow the selection of system element types (such as wind turbines, battery banks, etc.) from a library of predefined components with their technical characteristics. Sizing tools are mainly used by system installers.

**Simulation** Differently from sizing tools, simulation products require to know the properties and size of each system component. Once all parameters are defined, the simulator tool provides a detailed analysis of the expected behavior of the system. The time resolution of the simulation (i.e., the length of the time step) can depend on the level of detail required or on the availability of input data (e.g. weather data). Simulation tools can also be used for sizing. In this situation the user has to identify the decision variables and perform several simulation runs, manually adjusting the variables to converge to an acceptable sizing. Some packages provides an automation of this process.

**Open architecture** The tools of this type provide a selection of "routines" that describe the various components and a platform that enables the connection among them. In this way, a higher degree of flexibility can be achieved and the user has the option to choose or change the behaviors and interactions of each component. The flexibility and power of this platforms are the main reasons for which these solutions are chosen by research organizations. The most used software in this category is MatLab/Simulink, developed by MathWorks.

There is no single software tool that provides a solution to all the issues related with a complex energy system configuration problem. Usually the most appropriate tools or optimization methods are chosen depending on the objective to be achieved.

A characterization of the control strategies, which can be seen as an add-on to the above classification, is introduced in [4]. Control strategies are needed when an evaluation of the system subject to certain behavior rules is required. For example if we consider a system including a diesel generator and battery banks, it may be necessary to determine how the batteries are charged and what element have priority to supply energy power when the renewable production is not sufficient to satisfy the demand load. The control strategy is a feature that can be included in all types of software tools defined in the previous classification. The main control strategies categories are also described in the work.

Further reviews of the available software tools addressing the problems related to renewable energy-systems design is presented in [5,6]. In Table 1 we summarize the more widely used and flexible software tools from two points of view: the ICT-related aspects (platform, license, extendibility) and the methodological approach (sizing, simulation or optimization tools). The columns in Table 1 report:

**Name** the name of the software tool;

**Developer** the company or university/research center that releases the tool;

**Platform** the environment used by the tool (operating system and/or specific environments);

**License** the license type of software tool, namely: commercial, free or open source;

**Input and output** these two columns define the format used to provide the data input and to summarize and view the results, respectively;

**Methodology** the main features offered by the tool in terms of system design;

**Extendibility** the possibility to customize the system either by editing existing components or allowing the definition of new components;

**Reference** the bibliography reference for the tool.

The proposed approach tries to encompass what we perceived as the most important features that an energy system design and management tool should have, naturally starting from the existing tools reported in Table 1. In this regard, our approach is close, in different ways, to both HOMER and OSEMoSys projects.

HOMER provides scenario and sensitivity analysis that allow the user to evaluate different options from an economical and technical point of view. The user-friendly interface makes the software easy to use for non-technical users. HOMER, however, does not provide a way to define new components from scratch and this aspect can restrict the modeling capabilities of the tool. Furthermore, its "optimization" feature consists in the ranking of all possible scenarios for the current energy project, but it does not apply any optimization and/or heuristic algorithm in order to solve the optimization problem. This exhaustive approach obviously forces the user to define very specific limits on the problem's decision variables in order to obtain a relatively small set of solutions on which a simulation approach is used to evaluate the costs.

OSEMoSys, on the other hand, is a modeling tool for long-term energy planning which is entirely based on mathematical programming. Its structure is characterized by the division into functional blocks that can be combined together to form a customized model, where each block presents different levels of abstraction [1]. However, the system core is represented by the implementation of a linear programming model formulated in a specific programming language (GNU Mathprog) and solved