# Management system for improving energy consumption in public buildings*

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**SUMMARY**

*Based on partners experience in past research energy projects, SIMENERG project successfully integrates and validates an Energy Management System (ENMAS) to save up to 30% of energy and CO2 emissions in buildings by monitoring and control systems in real-time conditions. The software developed improves the control and management of heating, ventilation, air conditioning, lighting and other energy-hungry devices; smart metering tools as well as the use of new lighting techniques and the integration of energy micro generation systems. The Energy Management Software monitors and controls the Energy produced with the implemented renewable energy sources and performs the energy balance (Production of Energy/Consumption of Energy). The software user interface is built to make the building's network as simple as possible to use, due to a selected combination of intelligent and interoperable services. SIMENERG designs local automation systems to promote a new role for buildings that will change the consumers' behavior from passive to active consumers. SIMENERG carries out a market analysis to explore what is the state-of-the-art and track emerging trends of ICT support for energy consumption awareness and strategies for conservation.*

**Keywords:** energy efficiency, energy management software, intelligent buildings

## Introduction

Energy consumption in residential and commercial buildings and public spaces represent approximately 40% of total final energy consumption and $CO_2$ emissions in the EU [1], [5]. Activities related to buildings are a big part of the EU economy, about 9% of EU GDP and 8.7% of employment in the EU and have enormous importance of the sector in terms of the social, cultural and historical needs. Therefore, the EU buildings sector can play a key role in meeting the EU economic growth, energy and climate policy objectives fulfillment, while helping to improve the comfort and decrease energy bills for consumers [1], [6], [8]. In order to achieve the objectives, the project SIMENERG is based on experience in the field of consortium partners. The main objective of SIMENERG is to develop an application program for Energy Management System (ENMAS) to save up to 30% energy and reduce CO2 emissions in buildings and public spaces through monitoring and control systems under real time conditions.

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## 1. Objectives

1.1 Integration and validation of software ENMAS:

Data collection:

- Building general information (location, category, shape and physical data, climate area)
- Climatic data (detailed in days), heating, cooling,
- Lighting
- Energy consumption (based on metered consumption)

**Internal processing:** ENMAS uses multiple correlation saving coefficients to calculate energy savings.

**ENMAS** improves control and management for heating, ventilation, air conditioning, lighting, and other energy-consuming devices, smart metering instruments and the use of new lighting techniques and the integration of micro-power generation systems.

**ENMAS** monitors and controls the energy from conventional sources and (possibly) energy from renewable energy sources and carry out energy balance (Energy Production / Energy Consumption) and also optimize energy saving modes (heat, ventilation, cooling, lighting, etc.).

**2.2 Prediction tools for energy consumption**:

SIMENERG uses mathematical models to integrate and validate predicting tools for energy consumption in buildings by meteorological data and building characteristics (design plans). Analysis of the data retrieved can be divided into two categories: routine analysis and investigative analysis [1], [2].

**2.2.1 Routine Analysis**: This type of analysis is provided regularly. This includes analysis for the following parameters: power consumption, energy costs, energy performance and specific energy requirements for defined periods (daily, weekly, annually - far).

Techniques for analysis of the performance commonly used in routine analysis are: Specific Energy Report - SER (Specific Energy Ratio), normalized performance indicator - NPI (Normalized Performance Indicator), descriptive diagram and historical comparison.

**2.2.2 Investigative Analysis:** Investigative techniques used are similar to those used in the statistical quality control. The techniques uses and combine: linear regression, cumulative sum (CUSUM) charts and control diagrams [1], [3].

**2.3 Web service architecture for energy sensor data**

SIMENERG implements an web platform that is able to transform numerous and heterogeneous distributed raw data collected by the sensing network into suitable energy information services to make available to final users (energy consumers and/or providers).

The platform will optimize energy consumption in order to preserve energy assets and to avoid outages. Using the SIMENERG platform, the user(operator) always will know where all of the thermostats are located across its service area, regardless of network type, and can send Web Services-based messages to one or many thermostats. This type

of application can be deployed within months, quickly adding value to both energy provider and customer.

**2.4 Infrastructure sensing**

SIMENERG integrates a sensing infrastructure to collect, store and process electricity measurement data. The device is a wireless framework for power plugs and fuse boxes. This solution requires less power and fewer base stations than existing radio solutions available [1], [3].

**2.5 User Interface**

The software implements an intuitive user interface to make the buildings network as simple as possible to use, thanks to a right combination of intelligent and interoperable services.

The use of these interfaces will increase the consciousness of energy issues; support the end user to make the right choices from energy efficiency point of view, and by the efficient management of local heat and power networks.

**2.6 Dissemination and Awareness**: An important goal of SIMENERG is encouraging an awareness of the energy problem and showcase what is possible to be technically done. This action is important in the area of energy where it is essential to create a public awareness of the energy problem, particularly showing that there are solutions and alternatives. SIMENERG presents technical and scientific results obtained during implementation of the project on the website that will be done and in the literature (articles in particular) [1], [7].

**2.9 Future Electricity Market:** SIMENERG designs local automation systems to promote a new role for buildings that will change from passive to active consumers. Buildings ability to participate in the energy market will be substantially represented by their capability of modulating the load profile as result of market signals (electricity price) or system signals (network emergency event) [1], [4], [5].

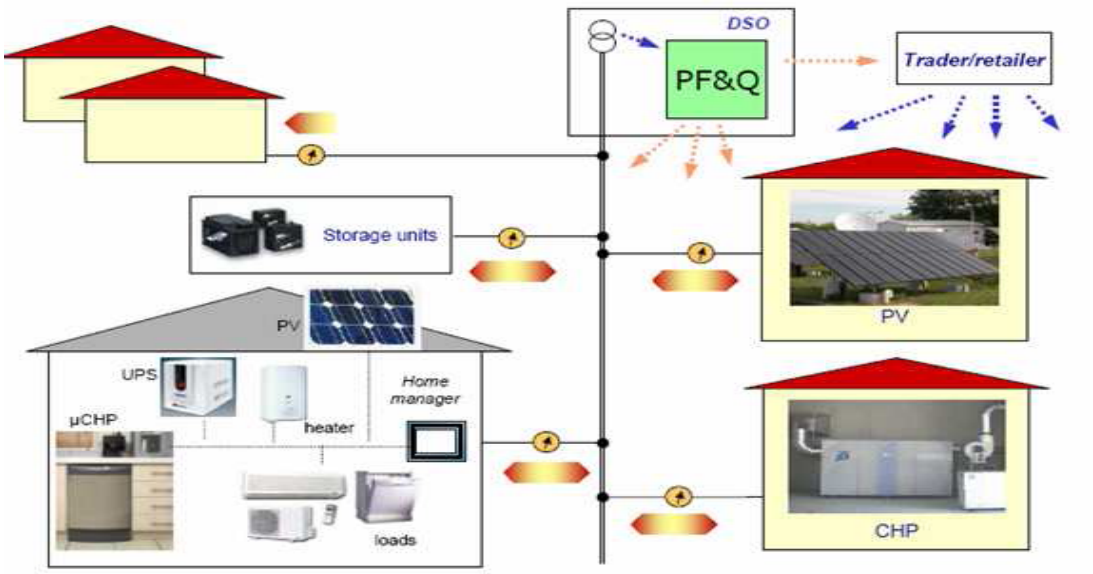


Fig 1. Management system of energetic consumers

ENMAS in accordance with the European Committee of Standardizations (communications within an intelligent building) may be divided into three areas, in terms of its functions and the equipment used:

- Level 1: Field level, covering sensors and actuators, lighting systems
- Level 2: Automation level, covering the outstation/controllers
- Level 3: Management (i.e. supervisory) level

Communication protocols include: Ethernet, ModBus. The trend of development is that the ENMAS will become an integral part of an information management system.

## 3. THE novelty and complexity

SIMENERG brings the following novelties compared with already implemented solutions at national and European level:

### 3.1 Innovations

ENMAS (Energy Management System): The Energy Management System (ENMAS) is a computer-based control system that will be installed in buildings/public spaces and controls and monitors the building's mechanical and electrical equipment such ventilation, lighting, cooling, heating and power systems.

The software program is configured in a hierarchical manner, using protocols. Its core function will be to manage and monitor the environment temperature, CO2 level and energy consumption within a building and public spaces.

ENMAS software monitors and controls the energy produced with the renewable energy sources implemented and will perform the energy balance (Production of Energy/Consumption of Energy).

The main objective of the Energy Management System (ENMAS) is to reduce CO2 emissions and save up to 30% of energy consumption in buildings and public spaces by monitoring and control systems in real-time conditions [1], [3], [5], [6].

The innovations that ENMAS will bring about are:

The "intelligent" objects: these objects will have embedded electronic chips, as well as the appropriate resources (including potential OS) to achieve local computing and interact with the outside, therefore being able to manage appropriate protocol(s) to acquire and supply information [1].

The communications: these will allow sensors, actuators, indeed all intelligent objects to communicate among them and with services over the network. They will be based on open standardized protocols.

The multimodal interactive interfaces: the ultimate objective of these interfaces is to make the in-house network as simple to use as possible, thanks to a right combination of intelligent and interoperable services, new techniques of man-machine interactions

(ambient intelligence, augmented/dual reality, tangible interfaces, robots, and so on), and learning technologies for all communicating objects. These interfaces should also be means to share ambient information spaces or ambient working environments thanks to personal advanced communication devices. They should adapt to the available attention of users, using and avoid overloading their "cognitive bandwidth" with unnecessary warnings or redundant feedbacks [1], [2].

The development of these pillars is based on the current legacy and State of the Art, which includes [1], [2]:

• Wired and wireless sensors: lots of various remote controlled devices, with the use of such devices (HVAC, lighting, audio-video equipments) being currently investigated in the built environment through preliminary deployment and experimentations.

• Wireless and wire line connection models & protocols: still under development and even more looking for harmonization and standardization (NFC-Near Field Communication, Bluetooth, Wi-Fi, RFID, PLC, etc.)

• Proprietary platforms & networks: current platforms implementing connected objects are mainly experimental platforms, with no standardization of management of and communication between any kind of “intelligent” objects. There are already developments around de-facto standard platforms or execution environments, but these are still mainly at an experimental level.

• Multimodal context-aware interfaces / devices: still few intelligent objects that are not intrusive and offer appropriate interfaces to allow the final user to seamlessly integrate the ubiquitous network.

• Scheduling

Holiday Scheduling. ENMAS software typically provides the holiday schedules as default. These schedules are as simple as a full-day shutdown at setback levels (such as a typical weekend day) or a partial shutdown of the facility for various hours of the day. Holiday schedules can be programmed a year or more in advance, often for 26 or more special holiday schedules. Each holiday can be designated as a single date or a range of dates for extended shutdowns. This feature reduces unnecessary energy use on unoccupied dates.

Zonal Scheduling. Zonal scheduling refers to controlling ENMAS at the zone level with schedules, so that unoccupied areas can be shut down. Ideally, this means that when a space is unoccupied, the dampers of the terminal units go past minimum to shut. The zone terminals do not open (except to maintain a low or high limit) until the zone is occupied (controlled by occupancy sensors or tied to light switches, etc.). This saves energy during generally occupied periods and greatly saves during afterhours overrides.

**Benefits**:

The Energy Management Software ENMAS monitors and controls the Energy produced with the renewable energy sources and will perform the energy balance (Production of Energy/Consumption of Energy) [1], [6].

SIMENERG allows the end user visualization on a display for all data circulating in the system (of an onsite - dispatcher) on the assumption that this exchange of data happens in real time. It will allow the real-time display of all equipment, always knowing the behaviour of the installation and condition of the electrical distribution lines of the installation.

Sending information to end user on commodity prices or consumer advice in the hope that the end user adjusts power consumption according to the situation or prices, or even adjust consumption behavior, regardless of pricing.

Via a communication network to the energy company that will now have a complete overview on the consumption and consumption behaviour of all connected end users (premises); this data exchange is likely to be on a daily basis with an option for more frequent updates.

Sending the end user information on commodity prices or consumption advice with the expectation that the end user adjusts his consumption according to the price situation, or even adjusts his consumption behaviour irrespective of pricing.

Control of the use of certain appliances at the end user site, provided that the building automation network controlled electronic devices and interfaces to allow communication access through the meter and the gateway device.

Enable the on-line parameterization of all connected devices, facilitating the configuration of all of them from the control unit. It will be able to be programmed: digital outputs, analog inputs and outputs, etc.

**Alarm module:** The alarm module, through a pre-programming, the user can display in real time any incident occurring at the installation. The alarms can be easily attached to any parameter either an integrated electrical parameter or process with the purpose of carrying out an excellent preventive maintenance of the installation.

**Great versatility and easy to use:** The ENMAS is an easy and intuitive tool. No need any training in data acquisition system.

**Comfort**: Avoiding automatically energy meter disconnection when power absorption exceeds contractual limit. The user specifies a priority level for each appliance in order that most important loads may keep goes on working while the local energy & power manager sheds less important ones. Critical equipment (security devices, etc.) obviously are not subject to the local power management.

## 4. Description of the management energy system

Functions performed by SIMENERG energy management system are:

• Increasing the efficiency of energy consumption of the plugs by eliminating or minimizing their consumption as long as there is no human presence at the workplace.

• Improving the energy consumption of air-conditioning, cooling/heating system depending on summer or winter schedule.

• Improving the energy consumption of electrical lighting systems depending on natural day lighting and the human presence at work posts.

The detailed structure of the components of the SIMENERG system is as follow:

Level 1: Field elements:

• Presence detectors: for detecting presence / absence of human operator at the workstation.
• Closed window detectors (magnetic contacts) are used to control the air conditioning.
• Humidity and Temperature detectors: are used to control the air conditioning. 8 are installed in existing climatic chambers on the 4th floor of the building;
• Single-phase meters for single phase active power: the meters work separately and record the energy consumed on each post; data are entered manually in the server at the end of each calendar month;
• Twilight Detectors
• CO2 Emission Detectors: It is used to measure the amount of CO2 from work spaces, halls and values are registered into the database server for testing purposes. Required: 2 pcs.

Level 2: Programmable Logic Controller – PLC

Functions performed by the PLC:

• The measurement of analog signals (4 ... 20mA) or digital (+ 24V = 1 / 0V = 0) corresponding to the technological parameters of the field transducers;

• The conversion of measured signals into digital signals;

• Transmission of the processed data in the equipment room and receiving input data;

• Sending commands to the field actuators.

NOTE:

Both the capacity of CPU and runtime support software with 2048 tags make it possible the extension of the program application in the entire pilot building.

Level 3: Monitoring

To monitor the energy consumption of the functional model SIMENERG, a server is required to achieve real-time monitoring of consumption of the building network, to allow analysis of data recorded in the system and to make system audits.

Power supply from renewable sources The functional model provides power from renewable sources for at least the following components: PLC, server monitoring, temperature and humidity sensors, presence sensors.

This was taken into account as renewable energy sources help reduce global CO2 emissions being green energy sources, non-polluting, protecting the environment, being one of the objectives of the European Union which states that by 2020 the emissions reduction to be 30% for $CO_2$. Power supply for all field elements, PLC and peripherals is provided by a 3000W solar system (consisting of photovoltaic solar panels 250W, 12V DC battery / 250Ah - 8 pcs, current regulators on each system, 48Vcc inverter / 230Vac, 50Hz, AAR equipment).

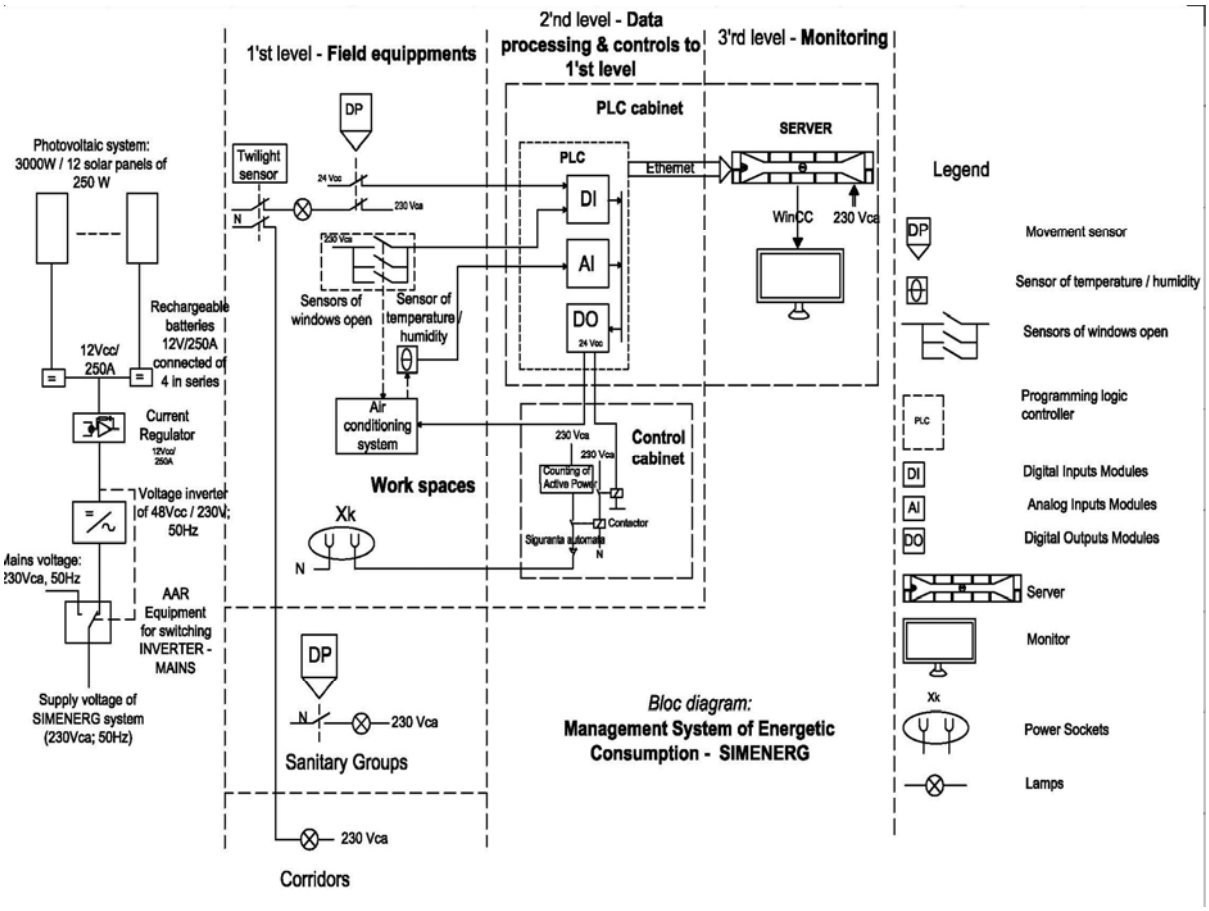


Fig. 2. Block Diagram of SIMENERG System

## 5. Results

The application was developed and tested in a 7 floors pilot building (for energy efficient lighting in the halls and restrooms on 7 levels) and in the 4th floor offices of this building (for management of lighting, heating and cooling, consumption of electric appliances).

In terms of the evolution of electricity consumption and CO2 emissions, the comparative analysis of the bill ENEL 2014-2013 on 4th floor / TD1 and TD2 sections of the building was observed following evolution:

*Table 1*

| Month | Energy consumption trend [kWh] | $CO_2$ Emissions Trend (2)x0,09 [kg] |
|---|---|---|
| *1* | *2* | *3* |
| October 2014 | - 1540 | - 138,6 kg |
| November 2014 | + 1920 | + 172,8 kg |
| December 2014 | + 200 | + 18 kg |

In October 2014 vs. October 2013 there is a total electricity savings (TD1 + TD2) of 1540 kWh in consumption of electricity and heat.

In November 2014 there is an increase of 1920 kWh in consumption of electricity per two sections vs. November 2013. The cause is electrical heating of the 4th floor (and the whole building) because during the month, the average outdoor temperature between the hours 18.00 to 6.00 didn't decrease below +100C for three consecutive nights and the gas heating system didn't start to work. In Nov. 2013 the building heating was gas heating. The same explanation applies in the month of December 2014 when the building heating was electrical heating instead gas heating.

## 6. Conclusions

The SIMENERG Management System of energy consumption is a system that can be implemented in public buildings using the existing components on the industrial market. Its extension can be done according with building architecture. The ENMAS program software is developed on a simple architecture with software modules, with access to various parameters that are configured by human operator and provides adaptive functional models in order to improve energy savings and consumer comfort.

The main benefits of the SIMENERG system implementation will be:

- Real-time access to information regarding various parameters (indoor climate, equipment consumption, energy saving, etc.)
- Online management of the process control system using intuitive graphical interfaces
- Reporting the current energy consumption and support of final consumer in energy saving actions
- The software application is adaptable and expandable allowing adding of new functions on user requirements
- Changing of consumer behaviour and improving of level comfort.

Using this system into a public building, important electrical energy savings can be obtained up to 30% per year, along with reduction of CO2 emissions.

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