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ŽELJKO TOMŠIĆ **IVAN GAŠIĆ**

zeljko.tomsic@fer.hr ivan.gasic@fer.hr

University of Zagreb Faculty of Electrical Engineering and Computing

GORAN ČAČIĆ

goran.cacic@undp.hr

United Nations Development Programme – Energy Efficiency Project in Croatia, Zagreb, Croatia

ENERGY MANAGEMENT IN THE PUBLIC BUILDING SECTOR – ISGE/ISEMIC MODEL

SUMMARY

This paper introduces Intelligent Information System for Monitoring and Verification of Energy Management in Cities (ISEMIC) web application that connects processes of gathering data on buildings and their energy and water consumption, monitors consumption indicators, detects any anomalies or irregularities in time, sets energy efficiency targets and reports energy and water consumption savings. ISEMIC enables use of smart meters within an energy management for the first time in the region, along with an analytical part which enables intelligent estimation of energy consumption based on multiple criteria. In the public sector are enormous potential for energy and water savings and thus a large area for ISEMIC web application implementation. ISEMIC web application is developed in July, 2011. Purchase of smart metering equipment and establishment of smart metering infrastructure on institutions of project partners responsible for ISEMIC web application development is in conduction after which a full pilot run will be started. The potential impact of this project is very large and it would be a great example how significant savings can be achieved by systematic energy monitoring and management provided by the use of ISEMIC web application.

Key words: Energy management, public buildings, energy consumption, smart meters, intelligent estimation.

1 INTRODUCTION

The role of cities is getting more complex due to growth of population, impact on climate change and the need to increase energy security. To meet these requirements, transformation of cities must be initiated in all resource management activities and critical infrastructures, beginning with improving the energy efficiency of public buildings. The role of energy management in achieving sustainable development of cities in the future is great.

Systematic energy management (SEM) in the cities is centred on alteration of human behaviour, changes in the existing organizational structures and application of technical measures to improve energy efficiency is a key prerequisite for the development of the skills and gain of the knowledge required for utilizing the existing potentials of enhancing energy efficiency and sustainable development in the cities. Fully establishment of SEM assumes maximizing the potential of achieving energy efficiency improvements in order to transfer the knowledge through the continuous process of energy management in cities to citizens, which would initiate the process of changing their perspective and behaviour.

The introduction of the SEM is nowadays unthinkable without the use of modern information systems and technologies and introducing advanced IT systems is the first logical step toward applying the concept of “smart cities”. The ultimate goal of introducing the “smart city” concept is achievement of environmentally friendly, efficient and sustainable urban infrastructure that will provide to citizens all necessary services in an economically and environmentally friendly way and additionally the life quality in the cities.

Today, in energy analysis and statistics is common practice of conducting analysis of energy consumption trends at the national level which are then adjusted to the level of individual cities. But in most cases aggregated approach to the analysis of energy data doesn’t give us good insight into the appropriateness and effectiveness of selected energy policies on the national level, nor on the local level. If we want to dispose with reliable information about the actual effects of implementation of selected policies at the local level, or if we want to get insight whether they should be corrected and adapted it is necessary to introduce regular monitoring of implementation and evaluation of the effects of conducted energy policies at the local level. The realization of this approach is possible only with the application of methodologies for continuous collection of key data in short and regular intervals at the local level in order to specific effects can be identified and achievements of the implementation of policies can be reduced to the level of each individual city.

2 ISEMIC WEB APPLICATION DEVELOPMENT

In the residential and service sector, information on energy and water consumption is commonly only provided on a monthly basis. Frequently the recipient of the information has no benchmark to assist in determining whether consumption levels are normal or excessive. There are two gaps or barriers which need to be addressed. First, there is a need for a system that provides higher-quality, more detailed information on a more frequent basis. Second, the system should have the capacity to analyze the information received and act on the parameters available to correct possible malfunctions. To overcome these issues, an integrated information system is required, enabling both entries of manual readouts (and accompanied by appropriate education of the staff in the building where energy and water is consumed) and reception of data from intelligent metering systems that capture real-time data.

The Energy Management Information System (EMIS) is software developed in Croatia to help in implementation of energy management programs in public buildings, but it is implemented without any significant analytical engine for data analysis, as accent is put on creating a network of people regularly monitoring and manually entering consumption data in EMIS via the web. Also, there is no smart meter input capability in the system. These two missing features were the focal point of ISEMIC development. ISEMIC upgrades and improves the existing EMIS platform with new functionality for continuous collection, storage and analysis of data on energy consumption of buildings owned by a city, county or ministry. ISEMIC further implements a newly developed methodology for past energy consumption data analysis using regression analysis, least square method, best-fit lines, scatter trending, as well as setting and cascading targets using correlation analysis and risk analysis using probability distribution for planning improvement measures (Figure 1).

Alpha version of ISEMIC web application is developed and installed on server in July, 2011; it can be accessed by following the link: http://161.53.66.25:8080/IsemicIntro/.

3 ISEMIC WEB APPLICATION DESCRIPTION

Due to ISEMIC web application complexity and large extent of its possibilities only short description will be given in this chapter.

3.1 ISEMIC web application architecture

ISEMIC architecture has three levels (Figure 2):

- Web browser on the client side as user interface tool;

- Apache Tomcat as servlet container;
- Oracle database as data storage

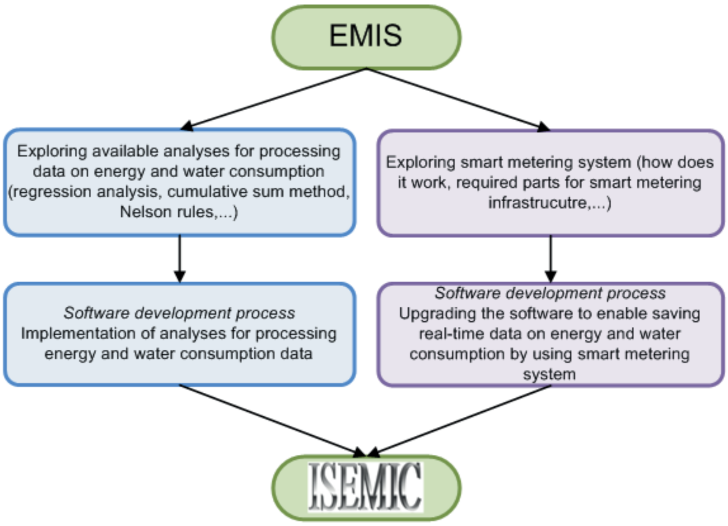

Figure 1. Upgrading EMIS to ISEMIC

Users connect to the application via http protocol (https for user identification).They are obliged to enter their username and password which aren't related to the database credentials.

3.2 Users and user roles in ISEMIC web application

Five different user roles are provided in ISEMIC; the system is designed in a way that can support an unlimited number of roles, but these five mentioned roles are preconfigured:

- System administrator (SA),
- Energy administrator (EA),
- Energy manager (EM),
- User (U) and
- Guest (G).

One user can have different roles on different objects.

SA can perform absolutely all operations in ISEMIC, but his main function is administration of whole application, from database backup to monitoring entered documents and photos.

Main function of EA is creating new lower roles (EM, U and G) and objects. He can edit and delete the information about roles and objects. Usually there is one or two person(s) on city, county or ministry level with this role. EA sets goals and limits of energy consumption and has the ability of deleting (false) entered bills. He also deals with data analysis, printing reports and graphs, remote reading monitoring, etc.

EM is a role whose primary function is oversight on certain part of the building. It can be a person in charge for energy, as well as the person in particular agency that requires data for specific data analysis.

U is a role primarily responsible for entering daily and weekly consumption readings. He also monitors remotely entered consumption data; enters monthly bills has the ability to change the wrong input, but not deleting entire bill. He can also edit object general, construction and energy characteristics.

G can only monitor the consumption of certain building(s) for which he is in charge and print reports and graphs on that building(s) or compare them.

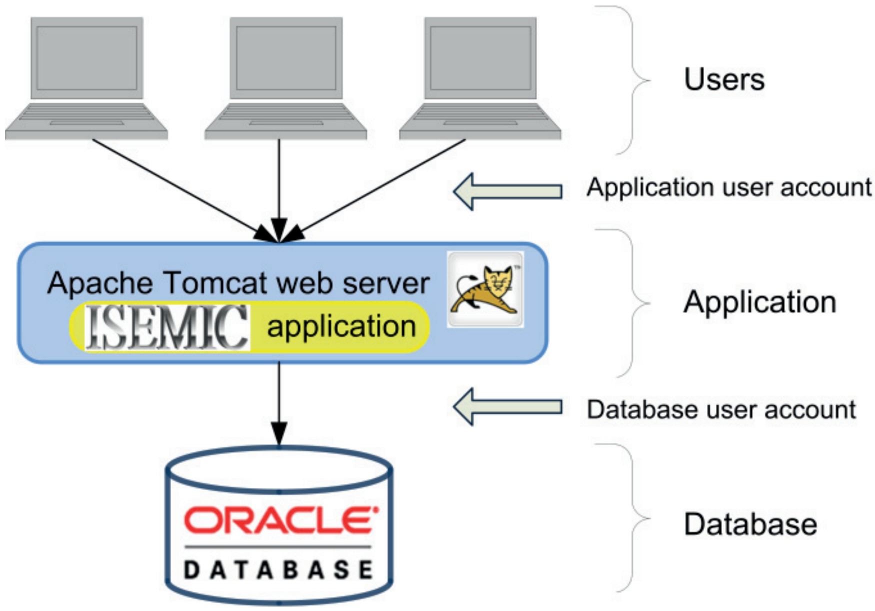

Figure 2. ISEMIC web application architecture

3.3 ISEMIC web application structure

Below, application structure for SA user role will be explained because it has embedded all possible functionalities developed in this project. Other user roles don't have their corresponding functionalities; they have reduced SA permissions. How much it is reduced depends on exact user role (EA, EM, U or G). ISEMIC application outline is shown on Figure 3.

ISEMIC web application main menu bar consists of seven main application modules on the left side (Figure 3): *Home*, *Security*, *Objects management*, *Reports and graphs*, *GeoAdministration*, *EnergoAdministration* and *Design*. Each application as its own menu bar – ribbon divided on working groups (which includes function buttons). Each function button has its own working cards ribbon and by click on desired working card its corresponding workspace is opened (Figure 3). In the right corner of the main menu bar are information about status and activities: *Alarms* (indicates the number of alarm messages), *Msg* (indicates the number of unread messages), *User* (user name of the logged in user), *Edit* (by mouse click on the label, a window for changing password and e-mail address is opened), *About program* (by mouse click on the label, a window with basic information about the parties contributed to the software development) and *Logout* (click to terminate the work in the application and logout).

3.4 Data analysis in ISEMIC web application

Data analysis is the main advantage of ISEMIC web application. Manual inputs, as well as data entry through smart meters must pass the check procedures for the value and time consistency to be saved in the ISEMIC. Regression analysis is most often used for past energy and water consumption data analysis. It shows how a dependent variable – energy consumption – is related to the independent one – for example temperature, by providing an equation that allows estimating energy consumption for the given temperature. The relationship between independent and dependent variable in most cases is in linear form which means that the relationship between the points in the graph can be approximated by a straight line and expressed by a linear equation. The resulting line will go through the center of data scatter and therefore is called best-fit line. It has a particular property – sum of the vertical distances of data points from the best-fit line is equal to zero. The correlation coefficient indicates how well a best-fit line explains variations in the value of dependent variable.

Within ISEMIC, cumulative sum (CUSUM) technique is used to track achieved savings.

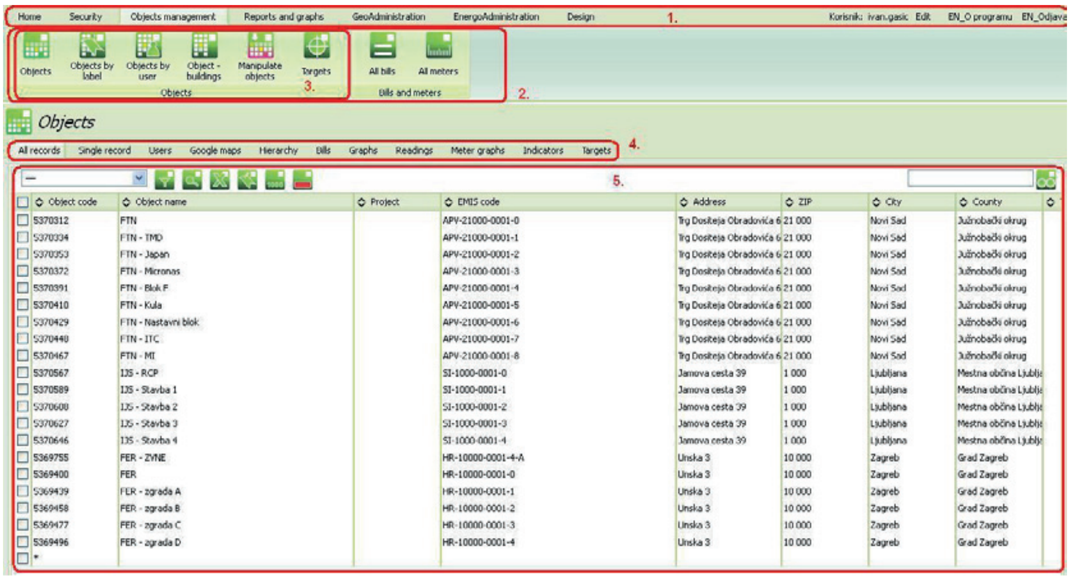

Figure 3. ISEMIC web application outline

1. Main menu bar
2. Menu bar – ribbon
3. Working groups (includes function buttons)
4. Working cards ribbon
5. Workspace

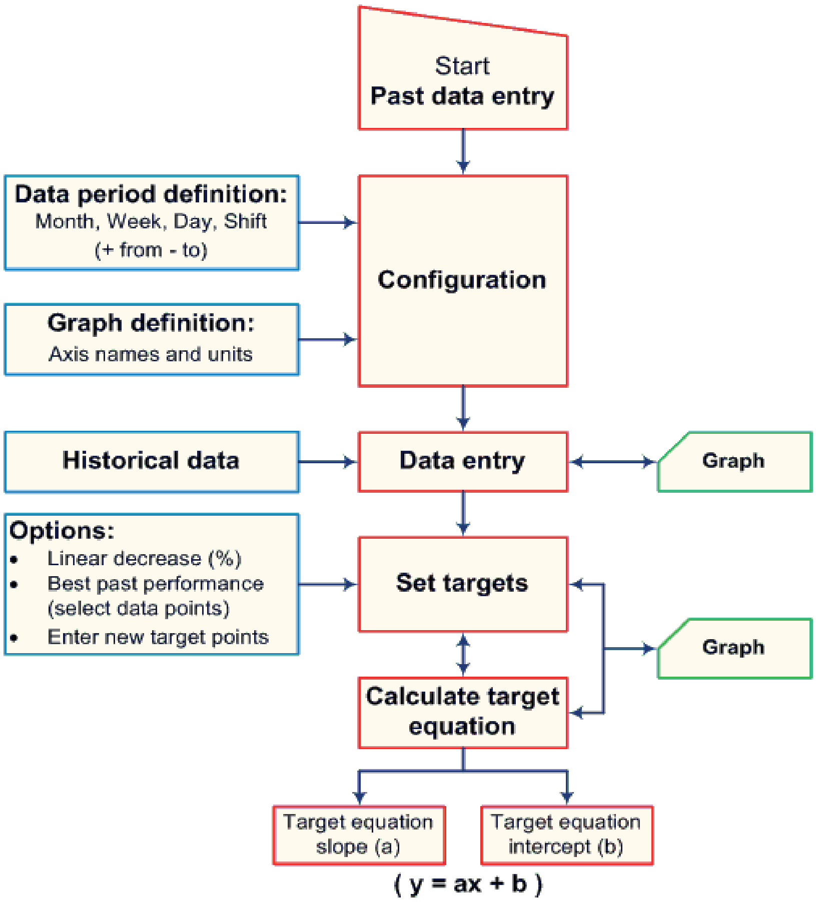

Figure 4. Procedure of setting energy efficiency targets

ISEMIC has the ability to review entered consumption and its monitoring according to the method called Nelson rules.

3.5 Setting energy efficiency targets in ISEMIC web application

The procedure of setting energy efficiency targets and their display on the graph is shown in flowchart on Figure 4. Goals can be set as:

- a linear reduction (percentage);
- a new line based on selected points of best efficiency or
- a new line formed on newly defined basis points.

As the result ISEMIC generates new target line equation.

4 CURRENT RESULTS OF ISEMIC WEB APPLICATION IMPLEMENTATION

Energy and water consumption data of building complex belonging to Faculty of Electrical Engineering and Computing (FEEC) are entered from bills during period from 2007 – 2010 into the ISEMIC and some of the obtained graphs are presented below.

The first graph (Figure 5) shows the share of each energent in total cost with tax for each year. Next three graphs (Figures 6,7 and 8) show electricity, heat and water total consumption of whole complex of FEEC for each year. It is also possible to view total cost with tax, monthly consumption and monthly cost with tax for each energy sources.

Last graph (Figure 9) shows monthly CO_2 emission during period from 2007 – 2010 caused by electricity consumption. It is also possible to view monthly CO_2 emissions caused by consumption of other energy sources.

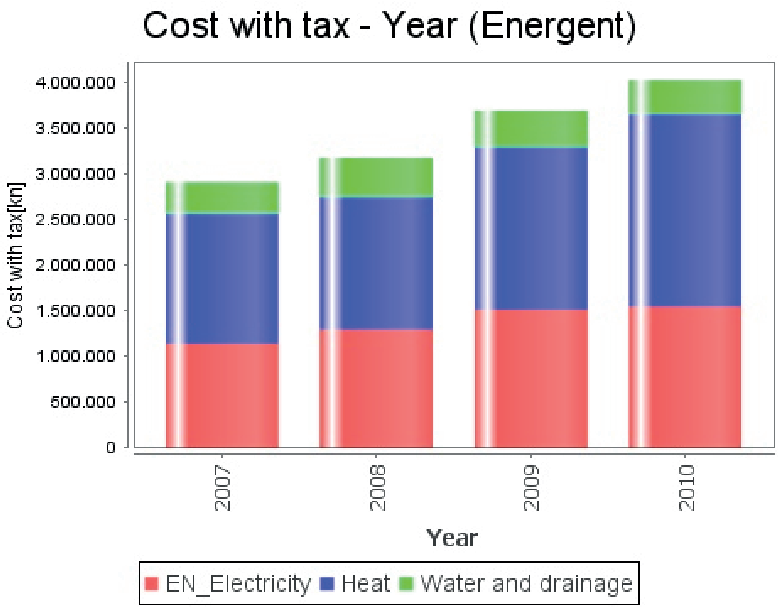

Figure 5. Share of each energy source in total cost with tax

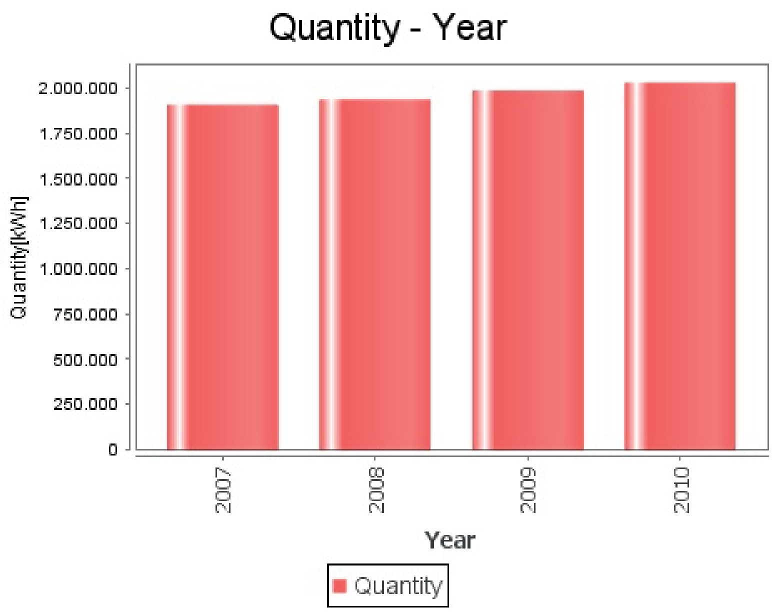

Figure 6. Electricity consumption for each year

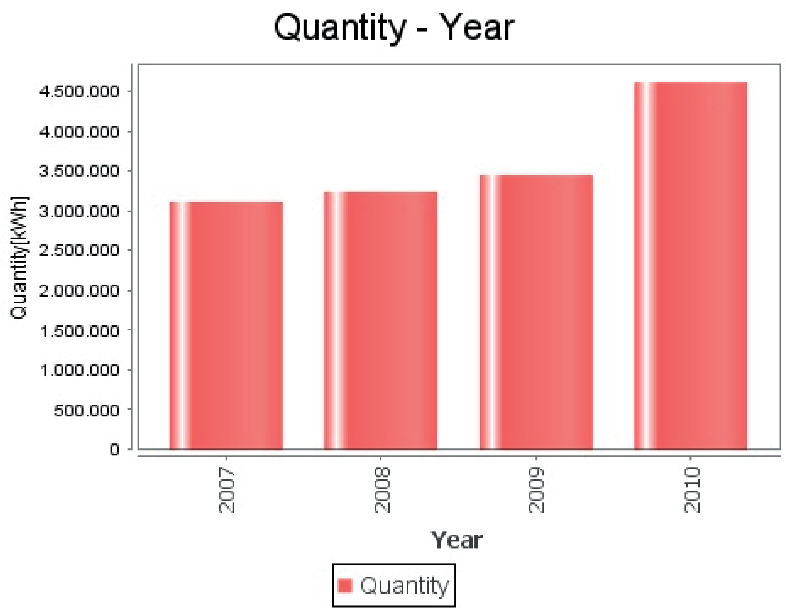

Figure 7. Heat consumption for each year

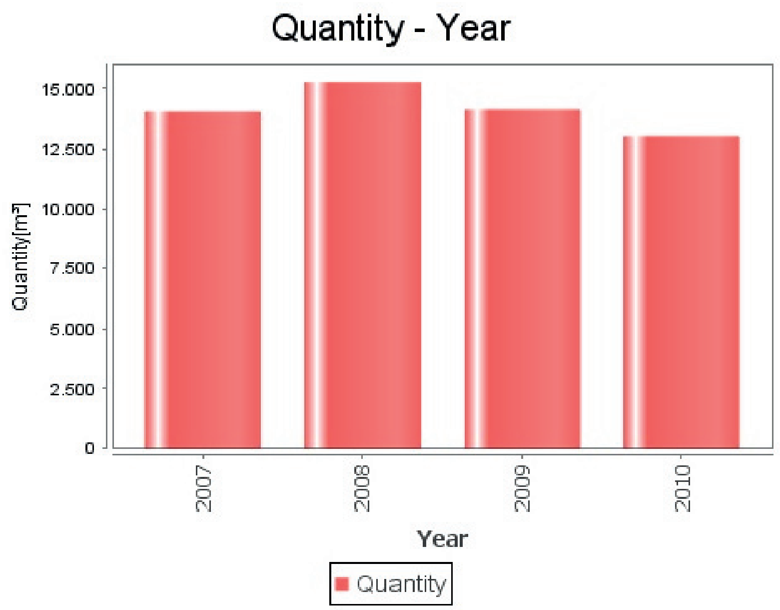

Figure 8. Water consumption for each year

Purchase of smart metering equipment and smart metering infrastructure is in conduction after which more grained energy and water consumption data will be available.

Real time metering of electricity consumption on a daily basis of whole complex of FEEC is currently established and connected with the ISEMIC. Next two figures (Figures 10 and 11) show daily electricity consumption for whole complex of FEEC in January 2011 and 2012. Red points represent total daily consumption during higher tariff, while blue points represent during lower tariff. It is expected real time consumption metering of other energents (heat and water) of whole complex of FEEC will be established in near future, as well as real time metering of energy and water consumption of individual buildings.

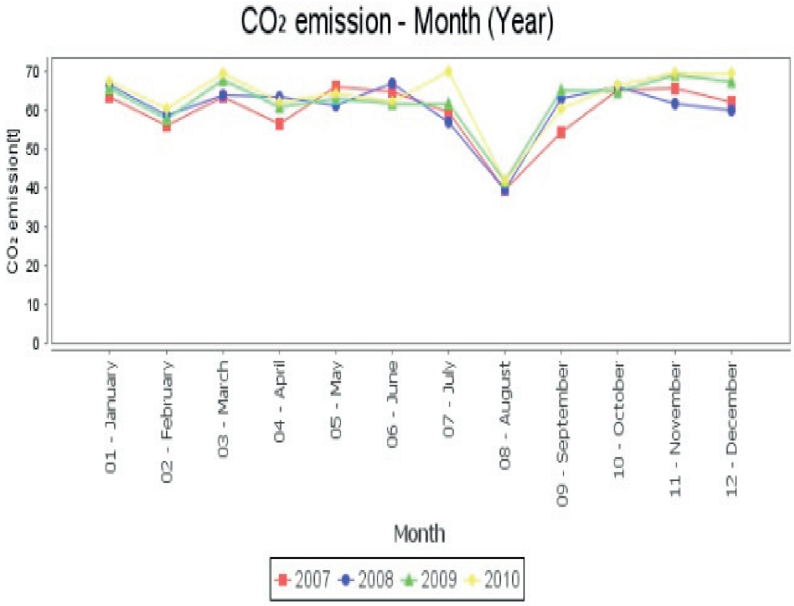

Figure 9. Monthly CO_2 emissions caused by electricity consumption

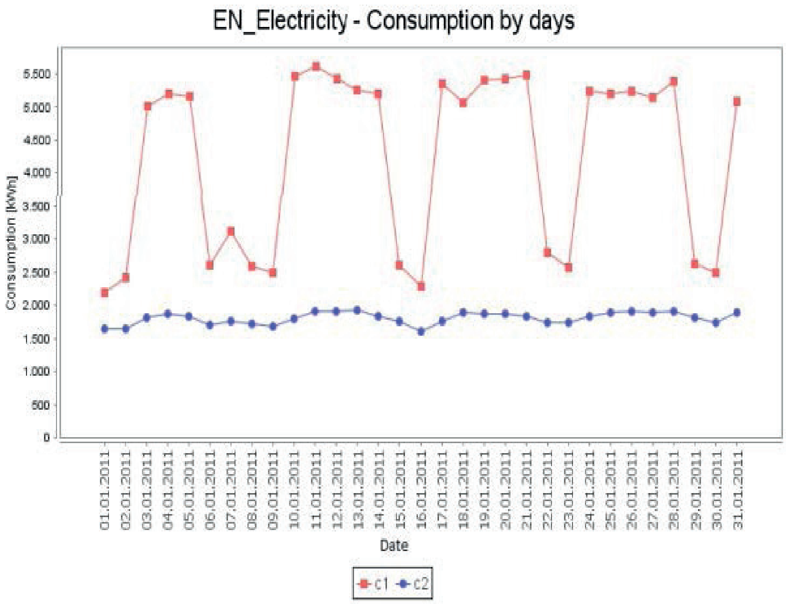

Figure 10. Daily electricity consumption for January 2011

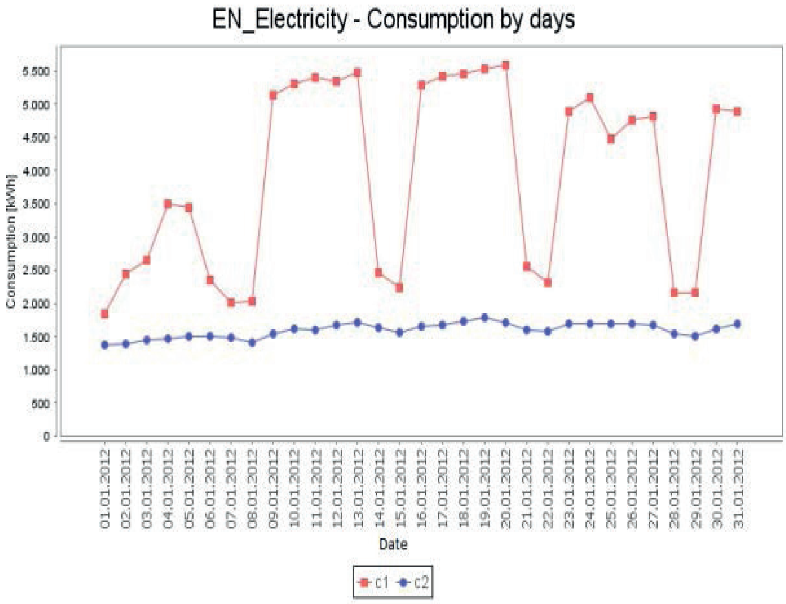

Figure 11. Daily electricity consumption for January 2012

5 INNOVATIVE ASPECTS

ISEMIC web application can become very important tool for energy management in public buildings. It will enable local and national authorities to lead by example and have a tool to help in proving positive effects of increasing energy efficiency and installation of smart meters.

ISEMIC creates added value in the following ways of presenting new, ready-to-use concepts:

- Interconnectivity with smart meters subsequent to creation of data bridges, which enables consumption monitoring on a daily basis or more frequently;
- Use of ICT for energy management in buildings as a service rather than a product (only an internet connection is needed);
- Use of algorithms that support expert knowledge and decision makers by discovering patterns of energy usage to identify waste, to find opportunities for change and to set targets for improvements;
- A streamlined, robust system of determining baselines of consumption using regression analysis on past consumption data, defining consumption targets and verification of savings using the CUSUM technique;
- System of accounting for exceptions on outlier values of energy consumption, which are commented by the technical person in the building as well as the city energy manager;
- Monitoring for changes in energy performance to evaluate the effect of improvements that have been made, to check whether consumption targets are being met and to provide evidence of progress towards improved energy savings.

6 CONCLUSION

It is expected that ISEMIC will improve energy efficiency in buildings, raise building users' awareness of energy consumption and utilize measurements from smart

meters. Examples from praxis show that introducing an energy consumption monitoring system raises employee awareness on energy expenditure, which leads to 5% of energy and water savings without any additional investments in energy efficiency measures. After full ISEMIC implementation and implementation of some simple energy efficiency measures it is expected that energy and water savings will reach at least 10% of current consumption expenses [5]. It would be a great example how significant savings can be achieved by systematic energy monitoring and management provided by the use of ISEMIC. After successful project finish it is expected that city, county or ministry will show higher interest to connect public buildings in their ownership with the ISEMIC web application and start systematic energy monitoring and management. Connection of private buildings with ISEMIC is expected in further future; with development of remote data reading systems and supporting IT infrastructure ISEMIC will have an important role in development of the concept of „smart cities“.

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