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Defining an intelligent information system for monitoring and verification of energy management in cities

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Abstract

Improving the efficiency of energy consumption (EC) is a central theme of any energy policy. Improved energy efficiency (EE) meets three energy policy goals: security of supply, competitiveness and protection of the environment. Systematic energy management is a body of knowledge and skills based on an organizational structure that links people with assigned responsibilities, efficiency monitoring procedures and continuous measurement and improvement of energy efficiency. This body of knowledge must be supported by appropriate ICT for gathering, processing and disseminating data on EC, EE targets and information. Energy Management Information System – EMIS is a web application for monitoring and analysis of energy and water consumption in public buildings and represents inevitable tool for systematic energy management. EMIS software tool connects processes of gathering data on buildings and their energy consumption, monitoring consumption indicators, setting energy efficiency targets and reporting energy and water consumption savings.

Project Intelligent Information System for Monitoring and Verification of Energy Management in Cities (ISEMIC) will distribute EMIS software tool in region (BiH, Slovenia and Serbia).

This project also has a goal of improving a software system for utilizing EC measurements, both from smart meters and traditional measurement devices and subsequent data processing and analysis to facilitate, upgrade and eventually replace the currently used energy management system for public buildings in Croatia. ISEMIC will enable use of smart meters within an energy management for the first time in BiH, Slovenia and Serbia, along with an analytical part which enables intelligent estimation of energy consumption based on multiple criteria.

EMIS/ISEMIC will enable:

- Continuous updating and maintenance of a database of information on buildings;
- Continuous entry and monitoring of consumption data for all energents and water in buildings;
- Calculation of consumption indicators by user-selected independent variables entered in the database data and via preset parameters;
- Monitoring and target setting for energy expenses and energy savings for building and groups of buildings;
- Report creation according to user preferences or templates.

The tool can be applied in all countries where project partners come from.

The paper will outline the inception phase of the project, planned developments and methodology and context of application in cities and counties in BiH, Slovenia and Serbia.

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. These way best practices are demonstrated, enabling knowledge dissemination amongst citizens and promoting energy efficiency improvements in private homes and business.

In the residential and service sector, information on energy and water consumption is commonly only provided on a monthly or bi-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.

2. 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.

During ISEMIC development research was especially directed on:

- Introduction of the concept of Energy Consumption Centers (ECC) for monitoring and verification of energy management in cities by enabling entry of different configurations of meters within a building or groups of buildings (i.e. campus, large hospital complex);
- Introduction of advanced regression analysis for energy consumption data in order to define energy and water consumption baselines;
- Introduction of algorithms for detecting patterns and outliers in energy data and possibility of documenting reasons for exceptions;
- Introduction of data verification and oversight routines for energy management – supervising users (i.e. energy management officers in cities) use the software to intelligently detect outliers and bands of variability regarding consumption to determine optimal consumption of individual types of buildings and/or consumers;
- Introduction of the Cumulative Sum (CUSUM) method for monitoring change in energy consumptions and control of energy efficiency improvement progress.

ISEMIC is finally developed in July, 2011. Main server used for project needs was installed on the computer located at FER-ZVNE. ISEMIC web application is installed on the server; it can be accessed by following the link: http://161.53.66.25:8080/IsemicIntro/ and by click on the project logo, homepage of the ISEMIC web application is opened.

Project partners agreed measuring equipment will be installed in each participating partner institution. Purchase of smart metering equipment and establishment of smart metering infrastructure is in

conduction after which a pilot run (data collection from bills, smart meters and traditional measurements, their storage and analysis) can be started.

2.1. Users and user roles in ISEMIC web application

Five different user roles are provided in ISEMIC application; the system is designed in a way that can support an unlimited number of roles, but these five mentioned roles are preconfigured (Table 2.1.1.):

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

One user can have different roles on different objects.

Table 2.1.1. Role characteristics

Roles	SA	EA	EM	U	G
Managing tables (table administration)					
Editing categories of objects					
Creating database backup					
Defining new energent and water distributors					
Changing constants on monthly bills					
Deletion of monthly bills					
Creation of new buildings					
Correction and deletion of new buildings					
Users level managing					
Creating new users (only lower levels)					
Correction and deletion of new users (only lower levels)					
Consumption input (daily, weekly, monthly)					
Correcting wrong consumption input					
Entering building general, construction and energy characteristics					
Data verification and monitoring roles of lower levels					
Determining consumption indicators and consumption limits for alarms					
Entering documents and photos					
Consumption monitoring (global)					
Consumption monitoring (local)					
Remote reading monitoring					
Login to application					
Printing reports					
Printing graphs					

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

Main function of EA is creating new lower levels 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 reading. 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.

2.2. ISEMIC web application structure

Below, application structure for SA user role will be short 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 2.2.1.

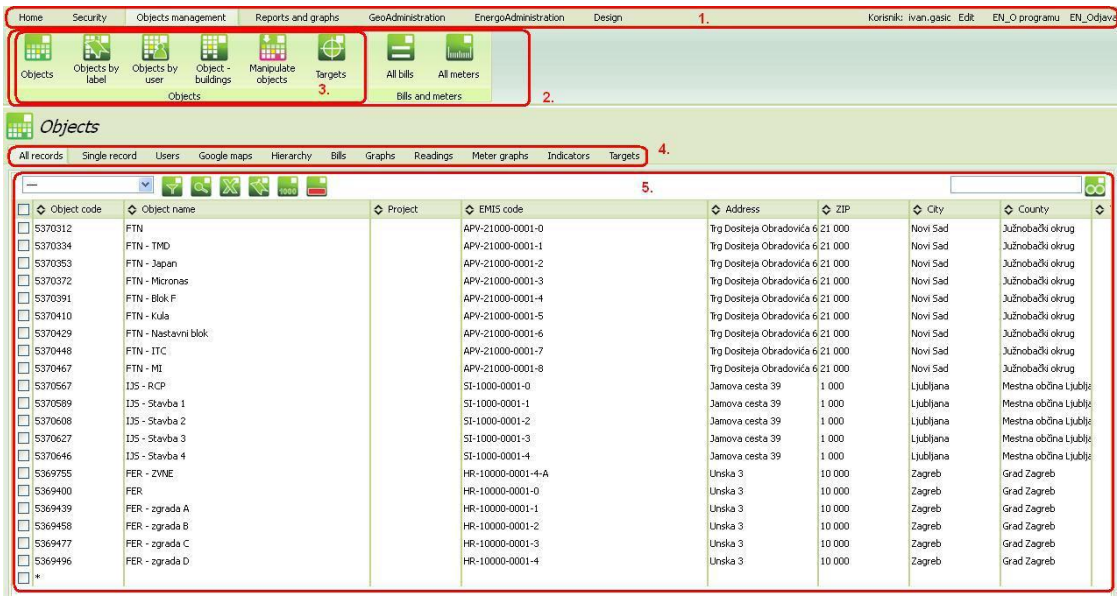

Figure 2.2.1. ISEMIC application outline

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

ISEMIC web application main menu bar consists of seven main application modules on the left side (Figure 2.2.1.): ***Home, Security, Objects management, Reports and graphs, GeoAdministration, EnergoAdministration*** and ***Design***. Each application module has 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 own corresponding workspace is opened (Figure 2.2.1.). In the right corner of the main menu bar are information about status and activities: ***Alarm*** (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).

Module ***Home*** consists of three working groups: *KPI – Key Performance Indicator*, *Messages* and *Alerts*. In the *KPI* working group it is possible to display graphically the execution status of given actions and graph by desired parameter (absolute consumption, relative consumption, CO2 emission and cost) for single energent for all objects the user has access permission. Within the *Messages* working group communication between users in the ISEMIC application is achieved. *Alerts* working group serves for defining alerts and assigning them to specific user (roles), objects, etc.

Module ***Security*** consists of two working groups: *Users* and *Roles*. Working group *Users* contains a list of all users. It is possible to update information and to assign roles to the selected user in the list as well as to see all inherited objects and roles and login user data (username, IP address, date and time of login and logout from the system) of selected user. Within working group *Roles* it is enabled to add new user role(s) and to see all users with selected role.

Module ***Objects management*** consists of two working groups: *Objects* and *Bills and meters*. *Objects* are the basic working group containing all information about objects for which the system user has access permission. It consists of series of working cards containing a detailed description of each object. In this working card it is also possible to add a new object and to set targets of specific energy consumption for one or more objects.

Figure 2.2.2. Graphs of entered bills for electricity

Working card *Bills and meters* contains an overview of all bills with associated data (e.g. bill number, energent, year and month of the bill, amount with the VAT, supplier, meter name, etc.). It also contains an overview of all meters with associated data such as meter name, serial number of measurement location, object name, energent, etc. In this working card the user is able to view graphically entered bills (e.g. Figure 2.2.2.) and edit or delete each bill.

Module ***Reports and graphs*** consists of three working groups: *Reports and graphs*, *Analyzer* and *Warehouse*. Working group *Reports and Graphs* contains a list of predefined reports and it is also possible to overview graphs of objects covered by a common label or graphs of objects sorted by the user. Reports are divided by the type in three groups which include reports of similar structure: basic data, certain object and object comparison. Report can be exported to PDF, XLS or Word format. Working group *Analyzer* provide defining specific analyzer to display on graph. Working group *Warehouse* serves for refreshing all data. Refreshing the warehouse is a procedure which automatically starts on a daily basis. Due to larger number of data in the database and many users accessing the application during the day, it is necessary to “liberate” central server resources in order to speed up its response for daily work. Therefore, all calculations and data preparation on the central server perform at the midnight when the system load is less. Sometimes it is necessary to update data in the warehouse immediately, without waiting for the midnight. For such emergencies the procedure can be manually started by clicking on the working card *Warehouse*. It is not recommended manually

starting the procedure for data refreshing when a large number of users work in the system concurrently because it significantly reduces the system performance and temporarily disables graphs drawing.

Module ***GeoAdministration*** consists of two working groups: *List of values (objects)* and *List of values (geography)*. Only SA has access to this module. Working group *List of values (objects)* contains a list of all possible object types, object type groups, types of users and building users. Here is possible to edit listed function buttons. Working group *List of Values (geography)* contains a list of all defined post offices, municipalities, cities, counties, countries, regions, weather stations and languages. Here is also possible to edit listed function buttons.

Module ***EnergoAdministration*** is a single working card and it contains a list of defined vendors, energents, units of measure, heating systems, cooling energent, refrigerant types, ways of cooling, fuel for heating/DHW, DHW mode and remote meter stats. In this working group editing of listed function buttons is possible. Only SA has access to this module.

Module ***Design*** consists of four working groups: *Translations*, *Administration*, *Design mode* and *Debug*. Working group Translations serves for translating all terms appearing in the ISEMIC web application to provide the application can run in multiple languages. Other working groups in this module are not important for displaying application possibilities and won't be processed here; they are important only to the developers of ISEMIC web application.

2.3. Data analysis in ISEMIC web application

Data analysis is the main advantage of ISEMIC web application and it will be briefly described below.

Manual inputs, as well as data entry through smart (remote) meters must pass the check procedures for the value and time consistency to be saved in the ISEMIC application.

Regression analysis is most often used for past energy and water consumption data analysis. For this reason it is implemented within ISEMIC application.

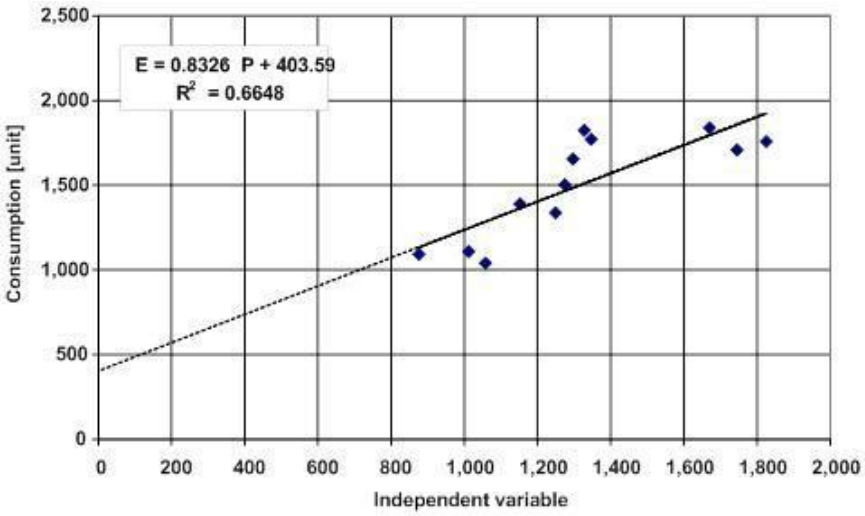

Figure 2.3.1. Relationship between production and energy consumption

Regression analysis 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 (Figure 2.3.1.). The relationship between production and energy consumption 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 ($y=a \cdot x+b$). If constant values (a and b) are calculated by the least square method the resulting line will go through the centre of data scatter and therefore is called a best-fit line. This line 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, i.e. energy. If correlation coefficient is equal to one, all data points will be exactly on the regression line. This will be the case of perfect correlation. The larger the scatter around the best-fit line, the smaller correlation coefficient (weaker correlation) is.

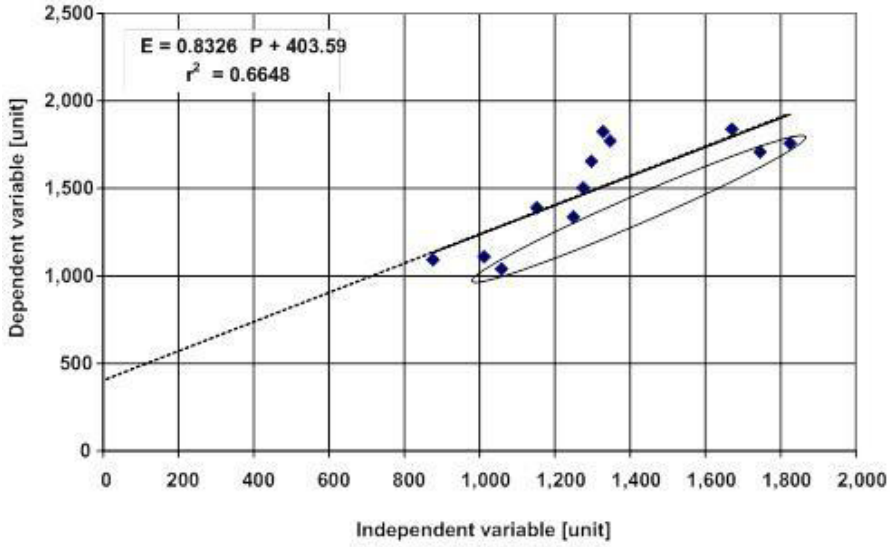

Figure 2.3.2. Identifying baseline for energy performance evaluation

It makes good sense for energy performance assessment to take best-achieved performance as a reference for evaluation and as a target for future performance (Figure 2.3.2.).

Within ISEMIC, actual savings are defined as the consumption or costs after the improvement, taken from the agreed baseline consumption, which would be the case if projects of efficiency improvement weren't implemented. All other factors remain constant. Baseline consumption is expressed as a baseline equation, which is calculated from the agreed data set for baseline consumption (regression analysis).The equation of energy consumption calculated from past consumption data is E'. Measured energy consumption is E_m.

$$\text{Energy savings} = E_m - E'$$

If the result from the above equation is a negative value, it means that the energy efficiency is improved because the actual consumption is lower than the consumption from base equation which is calculated with the same independent variable.

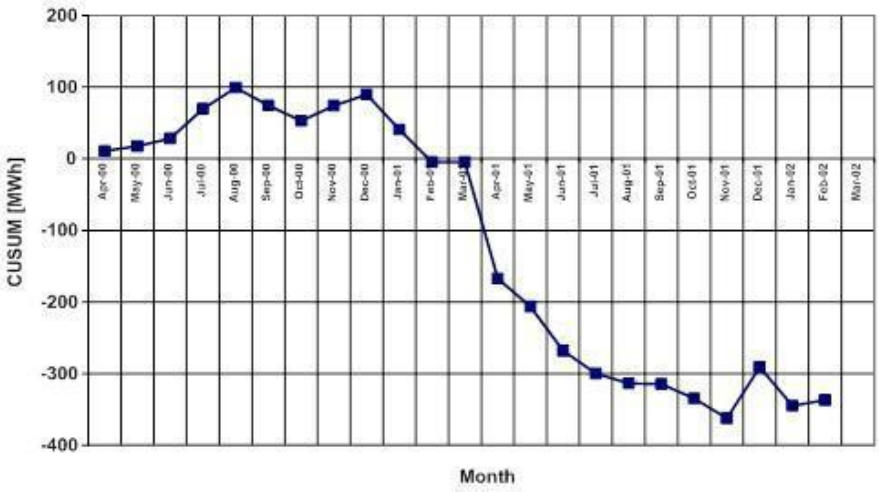

Figure 2.3.3. CUSUM graph

ISEMIC calculates energy savings in the same way every day/month/year, and adds the daily/monthly/yearly savings. Cumulative sum (CUSUM) presents accrued differences for each

day/month/year, and is calculated by adding the accrual from the previous day/month/year (Figure 2.3.3.). CUSUM graph expresses savings at any time and enables a direct comparison with the target amount of energy that should be saved.

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

3. Innovative aspects

Web application ISEMIC 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 improvement;
- 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.

4. 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 of all project partners. 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. 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.

REFERENCES

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[2] UNDP (group of authors), 2011, Technical specification of ISEMIC web application