

IMPROVING EFFICIENCY OF ENERGY USE IN CITIES – TOWARDS SUSTAINABILITY THROUGH MANAGING ENERGY AND CHANGING BEHAVIOUR –

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Abstract

The sustainability of the cities greatly depends of the way the energy is utilised and managed. Hence the energy management plays one of the major roles in achieving sustainable future of the cities.

The Energy Management System (EMS) on the level of the city based on applied human, organizational and technical measures provides and represents the excellent polygon for development of all needed skills and knowledge that are crucial for increase of energy efficiency and sustainability of the cities. The fully implemented EMS assumes that knowledge gathered through continuous energy management in the city is disseminated to the citizens, thus initiating the learning process and behavioural changes and expanding the potential of reduction of energy consumption from just the public buildings and utilities to the city as a whole. And potential for energy savings is up to 30 % of total energy consumption of the city.

Key words

Energy management in cities, energy analysis, behaviour change, monitoring and verification

Introduction

In an average EU country, more than 70% of population lives in an urban areas and more than 50% of total energy is consumed in cities. In this context sustainability of cities greatly depends of the way the energy is utilised and managed. Hence the energy management plays one of the major role in achieving sustainable future of the cities.

Being closest to places where energy is consumed and still having executive powers, local authorities more than ever have a pivotal role to play at reducing

energy consumption and energy bills in parallel with reducing local emissions. One of the possible paths to achieve this is introduction of Energy Management System (EMS) on the city level. EMS represents the specific set of knowledge and skills, based on organizational structure, incorporating the following elements: people with assigned responsibilities, energy consumption and energy efficiency monitoring procedures, continuous measuring and data gathering, data analysis, setting of targets and identification and implementation of energy efficiency improvement possibilities.

The relevant and accurate information, that is easily accessible, can guide decision makers to implementation of suitable policy and energy supply options. A set of adequately chosen and regularly monitored energy indicators, that reveal inter linkage between taken actions and achieved results, are excellent tool for evaluation of the real impacts of chosen policies. The indicators are not merely a data but rather they extend beyond basic statistic in order to provide a deeper understanding of the main issues and to highlight important relations that are not evident using basic statistic. If indicators are clearly defined and if their relations with certain effects are known, than through monitoring of the indicator change policymakers can easily assess the impacts of policy implementation.

Today the common practice in energy statistics is an analysis of the energy consumption trends on national level, which are then interpreted through set of chosen energy indicators. In most cases this aggregated way of energy data analysis does not give enough insight into appropriateness of chosen energy policies on the national level and for sure not on the local level. Thus in order to get more reliable information about real impacts of implementation of selected set of policies, or to get an insight weather they need to be adjusted, regular monitoring and evaluation of policy implementation on the local level is needed. In order to achieve this, the methodologies of local and frequent data gathering are required to enable identification of specific impacts and achievements of policy implementation disaggregated on the level of individual city.

In this article we will give an overview of typical energy systems in the city that is subject to an energy management and related energy analysis, including disaggregation of energy data to individual end use sectors. On an example of city of Sisak, we will present the establishment and achievements of the continuous EMS, including regular on-site measurement and monitoring of actual energy consumption. The EMS involves an IT infrastructure needed to gather the data, organisational modifications and methodologies to ensure continuous data monitoring, data analysis and at the end, the most significant,

change of the way the people behave – both, ones that are part of the EMS and ones that are responsible for energy consumption in public and residential buildings and for efficiency of public utility systems (water supply, street lighting, district heating, ...).

Energy systems in a city

In order to evaluate the efficiency of energy consumption in a city we need to monitor and measure energy consumption in a city on several different levels. For example to evaluate efficiency of energy transformation in the city we need to monitor types and quantities of energy entering the administrative border of the city, and then again entering the energy distribution systems of a city.

Figure 1 shows the shares of energy types entering the administrative border of City of Zagreb in year 2007. The total energy input in the city is 56.253 TJ (15.626 GWh), and to reach the end users the energy has to pass the transformation facilities and energy distribution systems.

Typically in a city there are several energy distribution systems that are subject to energy policies and that are the focus of EMS. Generally the energy distribution systems of a city are:

- Electricity distribution system
- Natural gas distribution system
- District heating systems

Additionally to the above numbered distribution systems the Water supply system can also be considered energy distribution system because large amount of energy is consumed for water treatment and supply processes.

City of Zagreb; 2007.
Total energy 56.253 TJ (15.626 GWh)

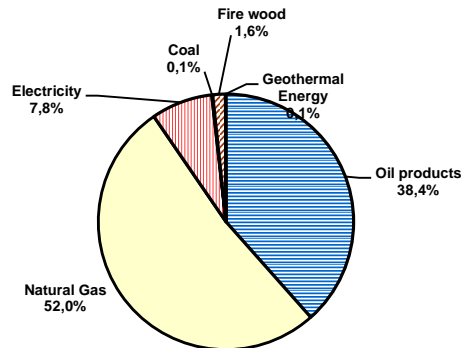


Figure 1 Shares of energy types entering the administrative area of the city

Figure 2 shows the shares of energy types that are entering the energy distribution systems of a city after passing through energy transformation facilities. The amount of energy entering distribution systems is 49.872 TJ (13.853 GWh), thus revealing the losses in the energy transformation process of around 11 %. **Figure 3** illustrates energy flow from administrative border of the city to distribution systems, and losses that occur during energy transformation processes. The efficiency of energy transformation processes can be improved through changes of facility management and through implementation of technical improvements in the facilities, and the EMS helps in identification of improvement possibilities and enables easy monitoring and verification of achievements after implementation.

City of Zagreb in 2007.
Total energy: 49.872 TJ (13.853GWh)

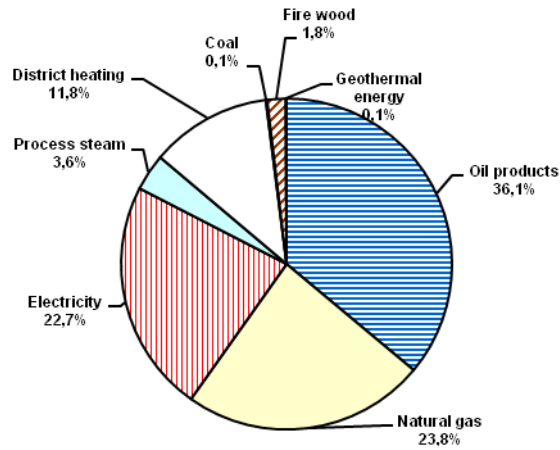


Figure 2 Shares of energy types entering the energy distribution systems

Energy flows in City of Zagreb in 2007.

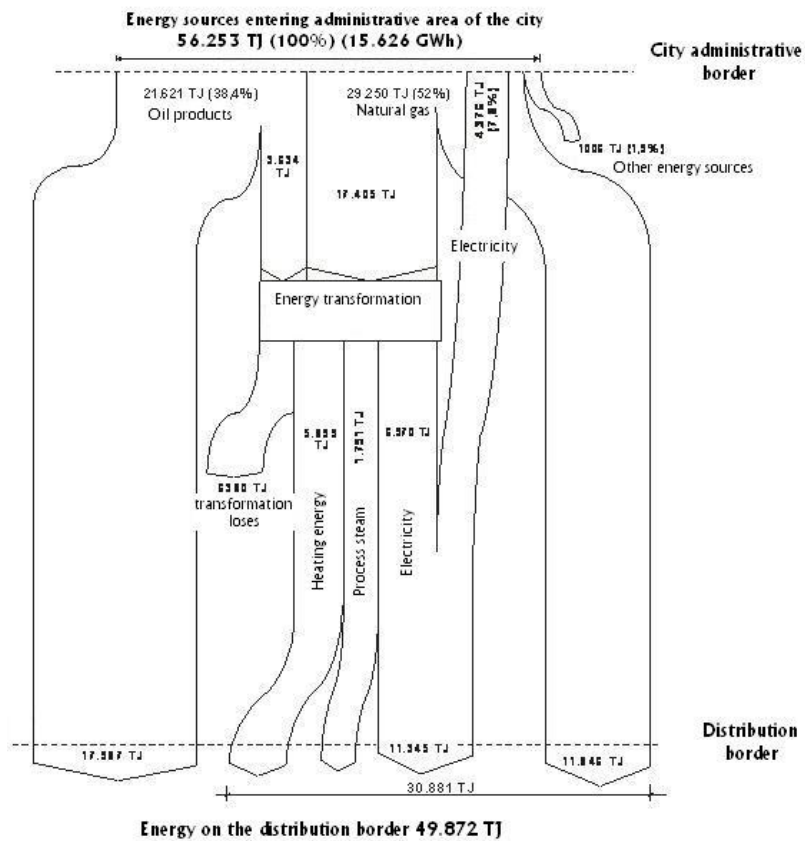


Figure 3 Efficiency of Energy transformation

The efficiency of the distribution systems is also influenced by management of the system and its technical state. **Figure 4** illustrates the energy flows in distribution systems of the city of Zagreb in year 2007. The amount of energy entering the distribution system (supply side) is 30.881 TJ and to the end users (demand side) 28.909 TJ is delivered, giving the losses of distribution system of around 6 %.

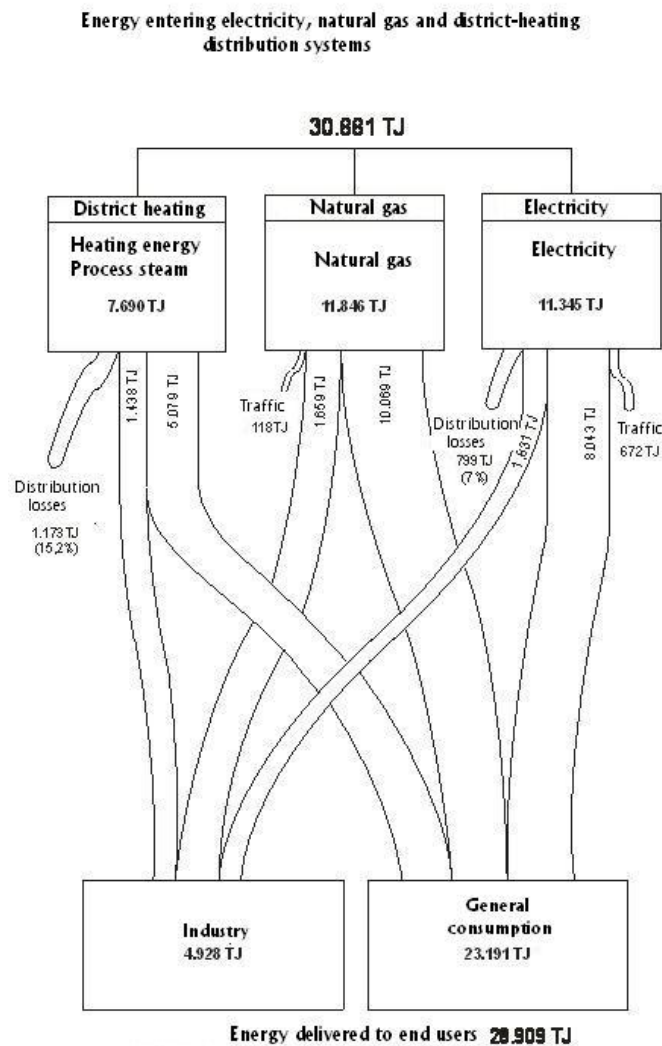


Figure 4 Efficiency of distribution systems

The demand side of an energy system is typically divided into following energy sectors:

- Building energy sector
 - i. Domestic (Households),
 - ii. Commercial (private services)
 - iii. Government (public services)
- Transport (Traffic) and,
- Industry

Figure 5 shows the shares of energy consumption for City of Zagreb in year 2007 divided by energy sectors.

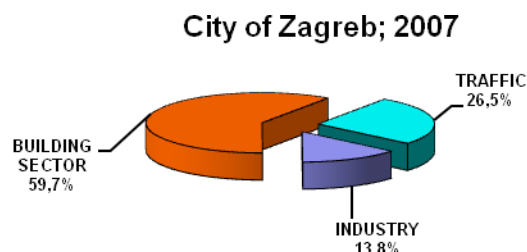


Figure 5 Shares of energy consumption by energy sectors

The above presented energy data represents general statistic that gives overall insight on the aggregated level of energy flows in the city. In order to analyse the energy trends in the city in a way that provides good insight and understanding of the driving forces of energy consumption and impacts of introduced energy policies, the energy data analysis needs to be detailed enough to show fine connections between different influencing factors. To achieve this, energy consumption measurement and energy data analysis needs to be performed regularly, specific set of energy efficiency indicators has to be defined for each of the energy system and baseline energy consumption needs to be established to enable clear target setting and evaluation of achieved results.

For this purpose it is necessary to regularly collect the data on the level of end users of each energy sector, and that calls for well organised Energy Management System, including system of data measurement (DMS) and infrastructure of data gathering disaggregated to specific sectors. In following chapters the general EMS model focused on the building sector will be presented. The building sector was chosen while this sector is responsible for consumption of significant amounts of energy in the cities, for example, as shown in **Figure 5**, in the City of Zagreb this sector is responsible for almost 60% of total energy consumption.

Establishment of Energy management system in cities

The goal of establishment of Energy Management System (EMS) in cities is the development of the needed technical and organisational skills and procedures at the level of city councils in order to enable continuous and real time data

collection and energy performance measurement. The process includes organizational changes and introduction of an Energy Management Information System (EMIS). EMIS is an IT infrastructure that enables regular and centralised energy data gathering and analysis on different levels i.e. analysis on aggregated level of the city building sector or disaggregated to the level of individual buildings.

The ultimate goal of EMS is first of all establishment of continuous energy management that enables control of energy consumption in the buildings owned by the city, followed by identification and implementation of energy efficiency measures in the buildings, and finally the transfer of knowledge gathered through energy analysis to the citizens in order to initiate overall behavioural change that will result in energy efficiency improvement of entire building sector of a city. The basic concept of EMS in a city with clearly defined responsibilities of all involved parties is illustrated on **Figure 6**.

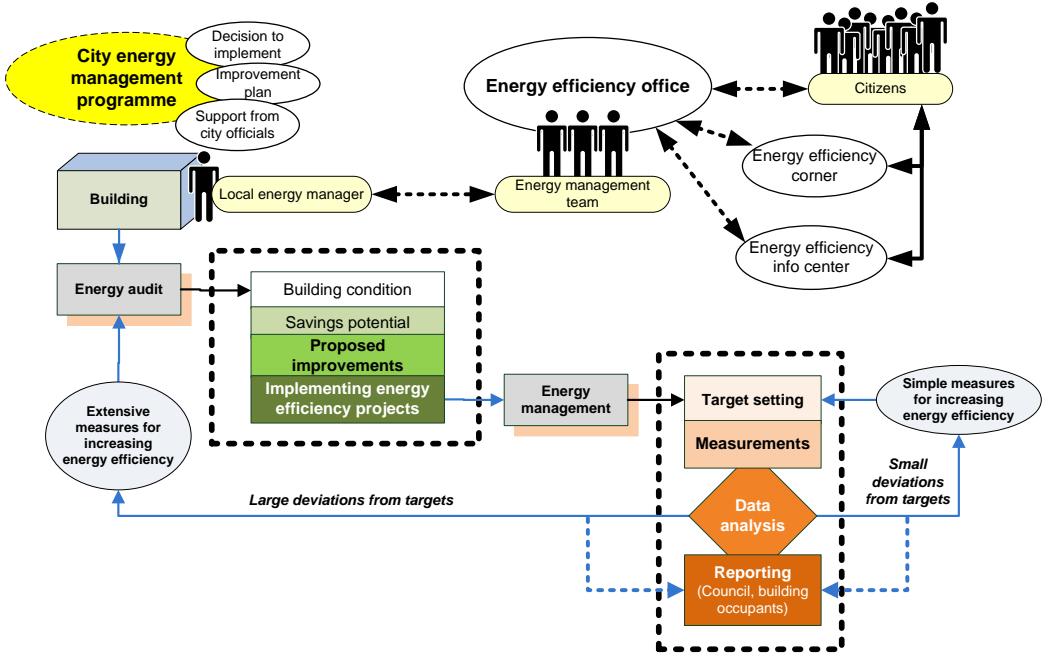


Figure 6 Basic concept of EMS in a city

The Local Energy Managers (LEM-s) are responsible for energy management and collection of energy consumption data disaggregated to individual buildings and regular data delivery to Energy Efficiency Office (EE Office) in a city, via established IT infrastructure.

The Energy management team (EE team) is responsible for regular analysis of collected data individually per building, in cooperation with LEM-s, and aggregated analysis for entire building sector that is monitored through EMS. The process of continuous data measurement and analysis provides relevant indicators that are needed for identification of measures that will lead to the

increase of energy performances of monitored public buildings and public utilities, and identified energy efficiency measures are constantly implemented. Additional responsibility of EE team is dissemination of knowledge gathered through energy analysis to the citizens through different educational and promotional instruments such as Energy Efficiency information centres (EE info centres) and Energy Efficiency corners (EE Corners) with the goal of initiation of behavioural changes that will lead to improvement of energy efficiency in household sector.

The process of knowledge gathering and transfer of the knowledge from EE offices in cities to the citizens and provision of essential information feedback from the implementation level back to the decision makers on national level in order to initiate policy adjustment is illustrated on **Figure 7**. The information feedback provided through EE offices is essential for accurate and objective analysis and evaluation of achieved results and identification of needs for adjustment and adaptation of energy policies being implemented.

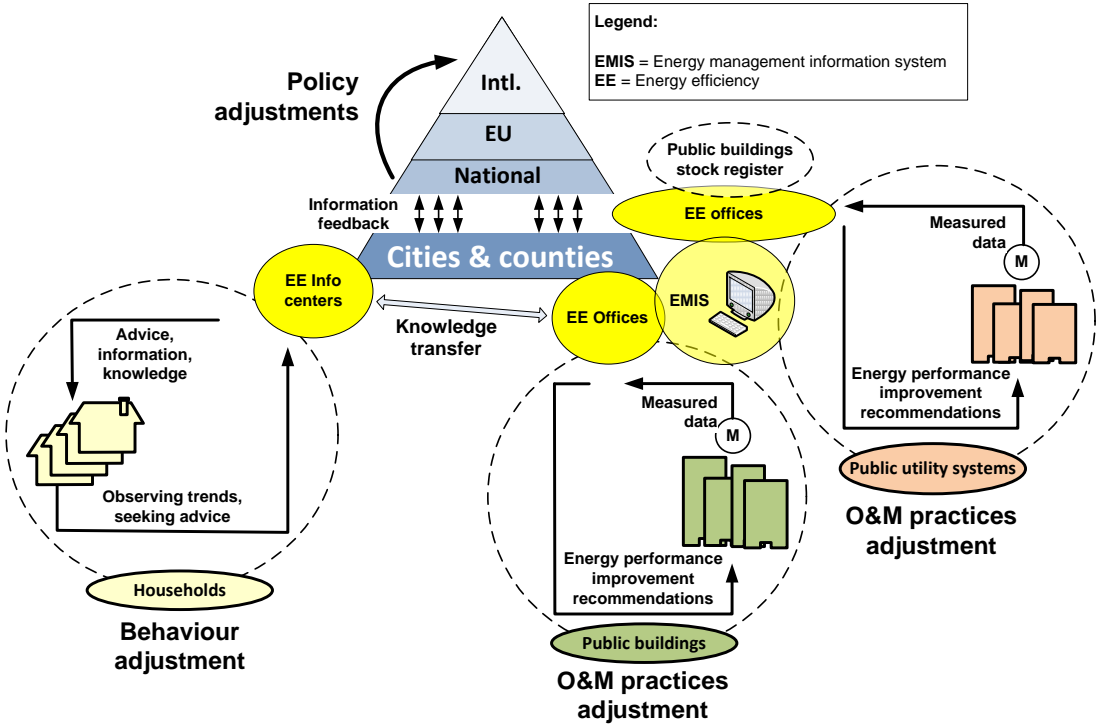


Figure 7 Learning loops and knowledge transfer as part of EMS

Results of Pilot project of EMS implementation in Croatia

Pilot project “Introduction of sustainable energy management in the City of Sisak” has started in 2006, and the full implementation lasted for one year. It was implemented as a part of UNDP/GEF project “Removal of barriers for energy efficiency in Croatia”,

City of Sisak in numbers:

Area: $\approx 420 \text{ km}^2$

Inhabitants : $\approx 50\,000$

Energy costs: $\approx 1.350.000,00 \text{ EUR}$ (for buildings and public lighting)

The process of pilot project implementation included establishment of EE Office, education of EE team consisting of two persons, implementation of energy audits of building stock owned by city in order to identify potential energy efficiency (EE) projects, installation of EMIS and setting up of operational procedures in city organisation needed for continuous energy management and energy consumption data gathering.

The results of 2 years of work of EE office are following:

- Established continuous energy management and data gathering through EMIS
- Following energy audits 10 EE projects were implemented (2 in 2007, 8 in 2008), and 7 new prepared for realisation in 2009. The investment in 10 implemented projects was 1.220.000,00 EUR, achieving 200.000,00 EUR financial savings in two years (70.000,00 in first year and 130.000,00 in second), and 250 tonnes/Year reduction of GHG emissions.
- Organisation of dozen educational workshops for citizens with themes such as insulation of buildings, reconstruction of heating systems, use of RES etc. that increased interest of citizens for EE.
- Provision of co-financing for reconstruction of heating systems in multi-apartment buildings for citizens with the goal of energy consumption and GHG emissions reductions.

The successful implementation of EMS in Sisak and achieved significant positive impacts resulted in start up of replication of the established model of EMS in other 90 others Croatian cities and counties (72 out of 127 cities and 18 out of 20 counties).

The crucial part for successful implementation of the project was continuous effort invested in information dissemination, education and development of needed skills at all levels of city administration, thus enabling gradual process of learning, recognition and acceptance of energy management and continuous energy performance monitoring and improvement in city buildings and institutions as a necessity.

The success of fully implemented EMS in a city is envisaged through continuous monitoring of energy consumption in public buildings and public utilities and regular analysis of available data. Through the process of further dissemination of gathered knowledge and experience the gradual process of overall learning and change aimed at reducing the overall energy consumption in a city by 20-30% is started. Accurate data analysis and calculation of suitable

energy indicators that enable objective assessment of achieved results play the key role in EMS, and Energy Management Information System – EMIS is used as crucial tool for this analysis.

Energy management information system - EMIS

EMIS is a specialized software application which is used as a basic tool for continuous energy management in buildings. EMIS enables update and maintenance of databases of general, construction, energy and other data that define the overall state of a particular building, the application is programmed to be accessible over the Internet enabling simple and continuous data input from any building with an existing internet connection. Data on energy consumption (e.g. natural gas, extra light heating oil, firewood, thermal energy, electricity) and water consumption can be entered in EMIS manually, through web interface or in advanced versions through establishment of general acquisition systems (GA Systems) that collect the energy consumption data and send it to EMIS, or through utilisation of Smart meters. The concept of EMIS in buildings with manual or automated data input is illustrated on **Figure 8**.

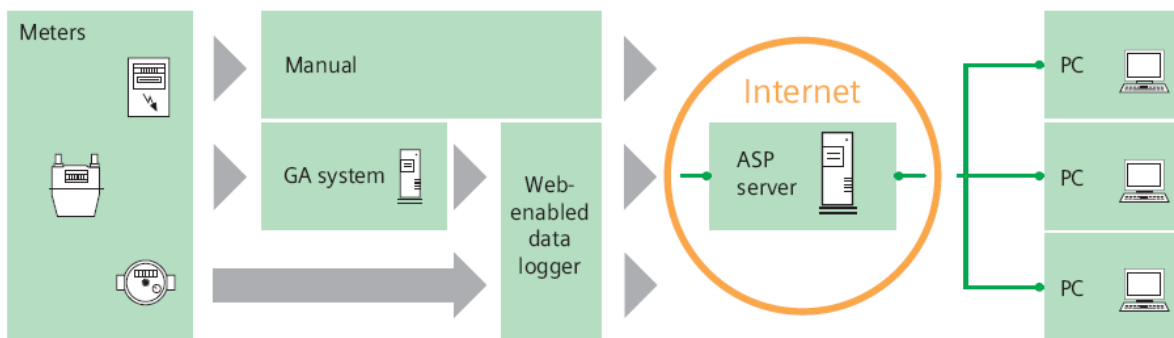


Figure 8 Illustration of an EMIS in buildings

The important feature of EMIS application is numerous possibilities of processing, analysis and display (graphical or in table format) of gathered data through set of predefined energy reports and energy indicators that facilitate energy analysis of particular building or group of buildings.

The typical data and energy indicators that can be displayed and calculated by EMIS, for any particular building or group of buildings that are entered in the system are:

- Total energy consumption by energy type for selected time period
- Total costs per energy type for selected time period
- Total energy consumption of all energy types for individual object for selected time period (expressed in kWh and in units of supply e.g. m³ for natural gas, litres for heating oil etc.)

- Total costs per energy type for individual object for selected time period
- Cumulative energy consumption per energy type for selected time period
- Cumulative energy costs per energy type for selected time period
- Calculation and display of energy – temperature curve (E-T curve) for individual objects
- Specific energy consumption per energy type for individual object per m² of floor area, m³ of building volume, per persons working in building, per number of beds, etc.
- Comparison of calculated indicators with the set targets or chosen benchmarks for specific building type.
- Comparison of energy consumption of similar individual buildings or group of similar buildings
- Comparison of energy consumption of building for different time period (e.g. same month of different years.)
- Calculation of CO₂ emissions per energy type for individual object or group of objects
- ...

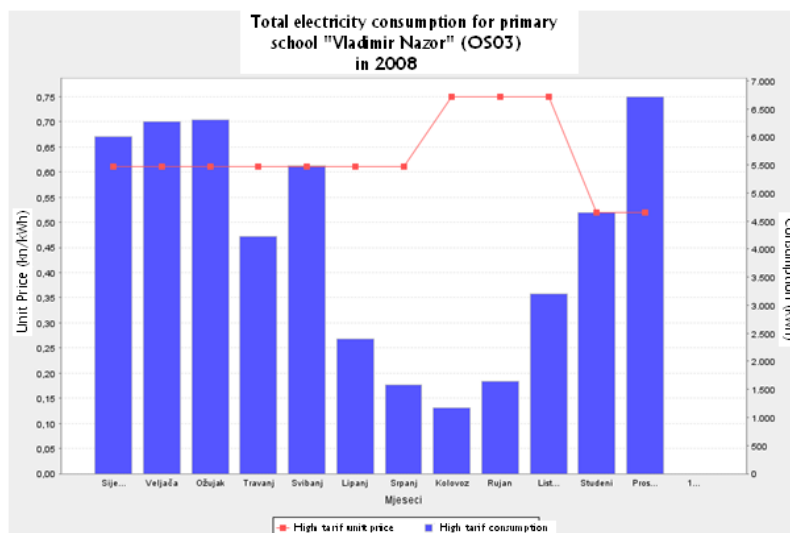


Figure 9 Example of data display from EMIS

The different indicators and data interpretation options that EMIS offers facilitate energy analysis and analysis of different factors that are behind the changes of energy consumption and related emissions of CO₂. The interpretation of energy indicators help to reveal key couplings between energy use and other influencing factors such as energy price, economic activity or implemented energy policies, thus providing insight that is crucial when evaluating the results of energy efficiency policies implementation, or when designing effective future actions of when monitoring and verifying achieved results after implementation of specific EE measures for individual objects.

Monitoring and Verification

Monitoring and verification (M&V) of achieved results is an important part of energy management. As the main goal of energy management is improvement of energy efficiency to the highest achievable level, than for individual object or chosen energy sector that is managed the results of implemented activities or energy policies need to be regularly monitored and verified.

The reduction of emissions of green house gases (GHG) is one of significant results of implemented EE measures that needs to be regularly monitored and verified. Analysis of the data related to M&V of GHG reduction is a result oriented process that clearly determines the emission reductions achieved by a certain project. Prior the M&V analysis the criteria and goals have to be defined, and through analysis the compliance with the predefined criteria and goals of the project is verified.

Every time M&V analysis is performed the expert should check accuracy, completeness, and consistency of all monitored data, the accuracy of data collection systems and monitoring equipment used, validity of any assumptions made during the project development phase regarding baseline energy consumption and emissions.

Basically, the methodology of M&V of GHG emission reduction consist of six steps: (1) determination of actual energy situation (consumption), (2) establishment of baseline consumption (base year), (3) determination of implemented EE measures, (4) implementation of EE project, (5) monitoring of the achieved results of implemented EE measures (new consumption), (6) calculation and verification of GHG emission reduction as the difference between emissions after the EE project implementation and baseline emissions. The conceptual methodology of M&V of GHG emission reduction is illustrated by **Figure 10**.

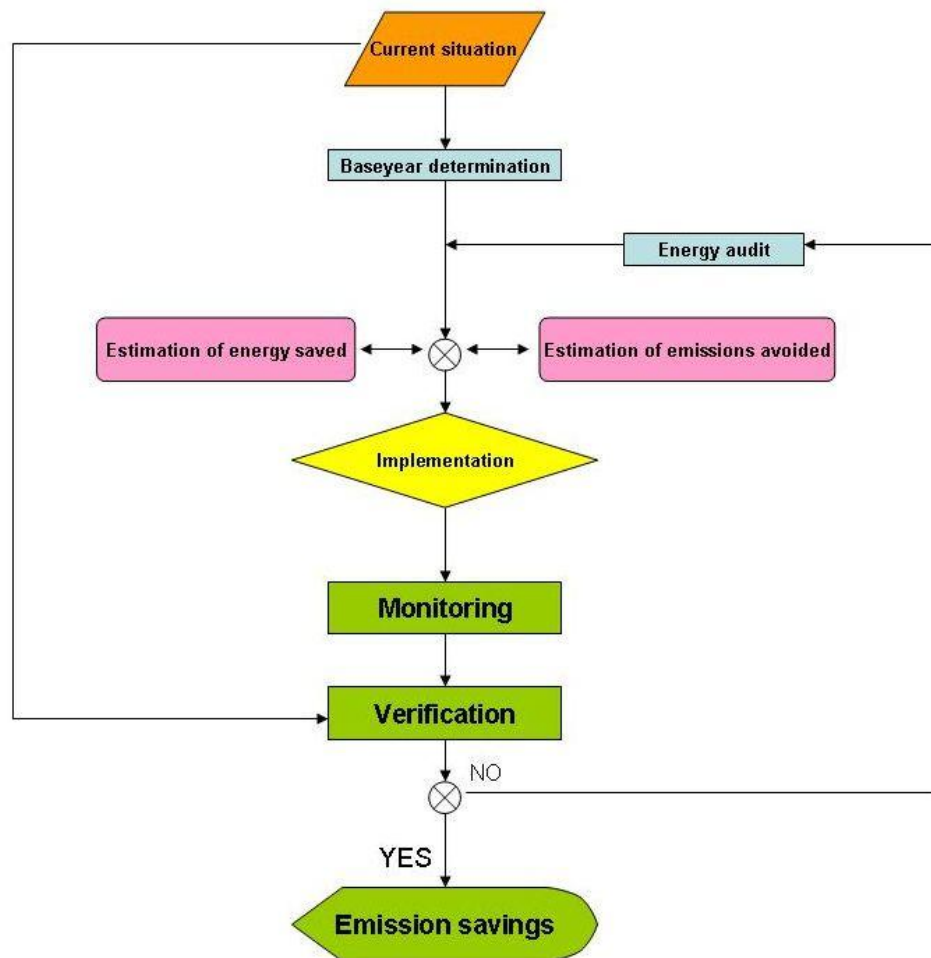


Figure 10 Conceptual methodology of M&V of GHG emission reduction

Conclusion

Until recently energy related decisions were made at the national level, but energy management at city level becomes a priority and important issue. Today local authorities, being closest to places where energy is consumed and still having executive powers, more than ever have to take a pivotal role to play at reducing energy consumption and energy bills in parallel with reducing local emissions, and they have to recognize that cities are not just part of the problem, but rather that they are part of the solution.

Having this in mind many cities are coming up with innovative institutional reforms to promote prosperity while minimizing inequity and unsustainable use of energy, and thus it is possible for cities to become centres of innovation and minimize their environmental impact through the energy efficiency and make our societies more sustainable.

The described methodology of implementation of continuous Energy Management System, based on applied human, organizational and technical

measures introduced, shows that it is possible to achieve behaviour changes through intensive learning loops, thus paving the way towards reduction of overall energy consumption of the city up to a potential of 30%.

The effectiveness of presented model of EMS has been demonstrated through implementation of pilot project in City of Sisak, where significant savings were achieved, and further replication in several other cities, where the result are to be verified. The successful replication of the model pilot project has shown that changes of behaviour regarding energy efficiency, energy consumption control, monitoring, control and management of energy consumption is achievable through a mix of continuous processes of education, motivation, encouragement to action and most of all through dissemination of gathered knowledge through well developed channels of communication.

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