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MODULE BASED DIGITAL STRUCTURE OF ENERGY MANAGEMENT INFORMATION SYSTEM

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Abstract: *This paper presents research for analysis of the structure of Energy Management Information System (EMIS) that enables effective measurement, planning and decision making management of energy use and costs. The goal of this paper is to present modular structure of EMIS as a digital tool. As a performance management system, its designed and implementation is dependent on the site and facility, therefore its features vary regarding needs. Despite that, EMIS has shown as beneficial, trough enhancing productivity and efficiency and by those providing gains for each consumer, as individual or as enterprise. The futures, modules and steps for development and implementation, as well as phases in operational cycle of EMIS are analyzed.*

Key Words: ***Data, Modular structure, Energy Management Information System (EMIS), Performance***

1. INTRODUCTION

The socio-economic development has been a major factor for the rapid increase of energy consumption inducing a major concern for the sustainability of the progress. Energy sector is facing uncertainty in prices, both of electricity and carbon, energy infrastructure, economic crisis and most importantly the energy resource quantity in order to satisfy the fast-paced increasing electricity demand. According to many researches World Energy Council, the energy consumption is projected to increase approximately 40-45%, by 2050, varying regarding different scenarios [1].

In order to sustain the life on this planet an energy planning, organization, controlling and conservation is urgently needed. Therefore, Energy Management (EM), as integrated solution for measuring, controlling, adjusting and matching supply and demand, is a key to costs decrease and energy saving. . EM as concept started evolving since the first oil crises 1973. Since then sufficient data is collected and can be analyzed, which leads to reliable sources of the structure and benefits of EM.

EM is a circular process that begins with metering the energy consumption and/or production and collecting data. Quantity and quality of data is of high importance, as the shorter the interval of measurement and the more detailed the data is the more precise calculations, predictions can be made. Also patterns can be extracted and the waste of energy can be spotted which will contribute to more energy efficient planning. After quantifying the data and analyzing opportunities for energy savings, planning and implementation should be performed. However, this is an ongoing process which requires regular inspection of the system in order to keep up with the current technologies and developments that might present a new opportunity of improvement [2].

For energy management, as represented at Figure 1, in order to provide the expected improvements an efficient flow of data is essential. Therefore Energy Management Information System (EMIS) should be the fundamental tool implemented within the Energy Management System itself [3][4]. EMIS is an interactive system for storing, analyzing and representing energy data, inducing energy performance advancement.

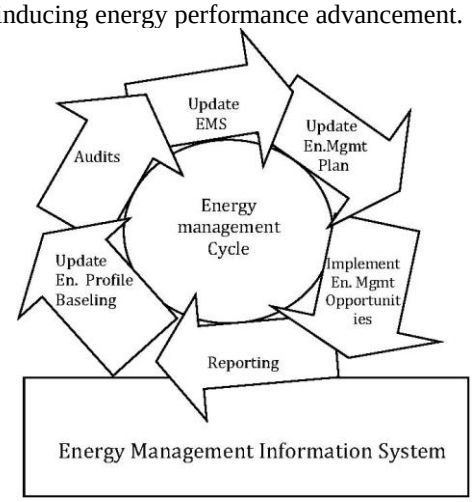

Fig.1. *Energy Management [3]*

As a relatively new tool for energy saving, EMIS has a high potential for research especially due to its relevance in improving performance and productivity.

However due to the aforementioned reason sources are limited. EMIS uses synergy of information, integration and innovation to help in the overall improvement of a business, simultaneously reducing the footprint of an enterprise. For in-depth analysis of EMIS few reports and papers were considered for relevant [5][6][7].

In general, the researchers agree on the benefits EMIS can provide. However, as expected, the development is differently defined depending on the area of work. Differentiation exists among implementation recommendation as most of the information systems need adjustments and customization, making each system unique and therefore carrying different features. Most of the resources available show that EM has been most popular in smart buildings [5][7][8] and smart grid technologies as most benefits can be received in these areas. On one side the buildings energy management is mostly researched by companies involved in designing and development of such systems and state agencies, whereas smart grid technologies is widely examined by the industry and academics providing in-depth research and reliable results due to instantly realized benefits as well as detected potentials for improvements.

2. DEVELOPMENT AND IMPLEMENTATION OF EMIS

Energy consumption which, as above stated, is substantially increasing due to the economic growth and technology development, has two parties involved in each transaction: supplier and consumer. Supplier side, involving both the supplier of energy and the supplier of goods and services that consumes energy has need for energy management, as their incentives are led by higher profits. Since the governments have engaged in working on the climate change issue, regulations regarding energy efficiency have been introduced, which influences the suppliers in their management of resources they deliver.
The demand side requires economic and behavioral analysis in order to create a solution that can help the reduction of energy consumption in the shape of demand response initiatives. An integrated information system can manage both sides reducing the demand and improving efficiency.
Energy management information system has its prime role to support the energy management as part of the overall strategy of the organization. The system should be developed regarding following factors [3]:

- Particular site, type of facility.
- Processes and plant involved, if it is industrial facility, the type of plant gives energy intensity and needs.
- Cost of energy, potential savings.
- The urgency of the information necessity.
- Capital availability, for investment in development, implementation and maintenance of EMIS.
- Existing infrastructure: meters and instruments, equipment existing on site will influence the capital investment amount.
- Monitoring and control systems.
- Data bookkeeping, historical data has very important role in future planning.
- Data analysis and reporting systems, the communication in the company and information flow.
- Existing management systems, how the company is managed influences the path of development of EMIS.

Mainly, for multi-site organization, for example, more sophisticated systems are needed, requesting higher capital investments and time as well as costs associated with monitoring. As for a smaller organization the system can be simpler and less comprehensive.

In order the EMIS to be successful in decreasing the energy consumption and improving the procurement, the development should be performed regarding the features stated below. Based on the features the elements as components of EMIS will be considered as follows.

2.1. Features of EMIS

Generally, the information system should ensure data flow and storage safety, quality insurance, by recognizing gaps and outliers by that mistakes, metering, mapping, verification of changes. Furthermore, EMIS should be able to give clear visualization of energy profiles and perform portfolio benchmarking defining the best practice. Additional features EMIS importing or exporting of data according needs as well as calculation of returns on investment and performing financial analysis [7][9].

2.2. Modules and elements of EMIS

An intelligent energy system should have three modules, each technology presented and integrated:
1. Flow network, representing connected transport components that enable the movement of matter or objects such as air, electricity, water, packages, containers, people etc.
2. Sensor network, which is a set of devices that measure and report status or condition such as temperature, pressure, location, speed etc.
3. *Data network*, which is owned or manage and has integrated metering system that reports on its use [3][8].

Therefore, basic elements of EMIS are sensors, instruments, data infrastructure and software tools (marked red on Fig. 2).

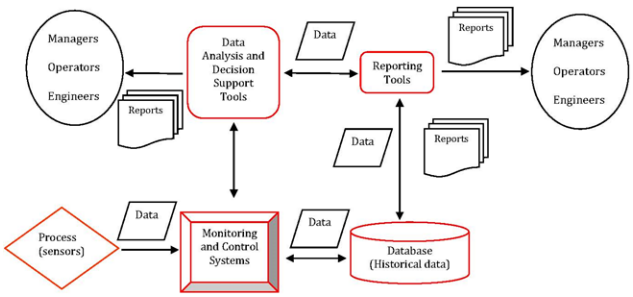

Fig.2. *EMIS elements [8]*

Commonly, the corporate IT system can be used to network the *data infrastructure* for process monitoring and management, enabling consolidation of data and functioning as a unified system.

Sensors and Instruments (meters, for energy use and measuring factors influencing the energy use) are connected to the monitoring and control systems (for example SCADA). Within the system *software tools* proceed with data analysis, reports and decisions as well

as storing data in the data base for further use. Software tools offer modular based customization of EMIS, according to application and user needs.

2.3. Steps of EMIS implementation

Following the analysis of crucial factors, features, modules and elements, the implementation can be defined in 6 steps [3].

1. *Planning and creating a vision of effective EMIS* for energy saving, reduction of emissions, competitiveness, need for real-time fault diagnostics and by that quality increases. During this phase it important to define the needs of the organization it is intended for, and to simulate in order to assess the usefulness of the system
2. *Design of EMIS*, consideration of measurement issues and definition on type of measurement regarding the data needed. Performance measurement should be presented real time and person in charge should be involved in order to set achievable but aspirational targets that are evidence based. During this stage the level of comprehensiveness of data should be decided upon, as a trade-off exists between detailed data and cost.
3. Consider *integration into existing systems* is an important step as it can reduce costs of development and implementation. Also integration of EMIS into existing IT systems, means data acquisition can be done for all purpose and integrated all together, reducing the possibility for mistakes and inconsistency of data. Even integrated, certain adjustments and additional inputs and equipment will be required, which should be defined during this evaluation as it will influence in the decision of creating a new system or integrating in existing one.

Another important factor is integration and interaction of technology and people, as certain trainings might be required to encourage employees to share information and upskill them for the future use of the system. Communicating information can be an issue for certain people, as lack of awareness of benefits or fear of consequences can exist. Overcoming these issues is an important part of management tasks is a successful implementation is to be performed.

4. *Cost/Benefit Analysis*, commonly, is of extreme importance so that the project gets accepted. However, it is also hard to estimate the exact annual utility cost saving. Better estimations can be obtained if the organization can provide data on the areas of greatest energy use and potential saving as well as launching pilot project that can test and give more precise estimate.
5. Obtain *support from Decision Makers* is the final step of finalizing the initial version. In this stage the energy manager should present the project to senior management that is responsible for final decision and therefore approval. This implies that if the following stages were properly performed, and the management is skilled and informed as well as aware of the technology advances any company needs to undertake, the project of EMIS will be approved for implementation.
6. *Continuous control* of the performed activities and results to ensure proper implementation and prevention of any kinds of failures and mistakes.

3. OPERATIONAL CYCLE OF EMIS

EMIS consists of four basic repetitive phases [9][10]:

- gathering data,
- opportunities for action and changer,
- defining specific options,
- develop guides and control.

I. Data Gathering

Data are raw materials for forming information, which builds up the knowledge regarding a certain situation. Three categories of energy management data are defined [9]:

- Consumption,
- Cost, the most important factor of every organization, providing financial information
- Drivers, any factor influencing the consumption, can be features of organization`s activity that influences the consumption or certain conditions. Examples of drivers are: weather, hours working, hours of darkness etc.

The process of collecting data is usually very complex, depending on the number of points of collecting data, the method and frequency of data gathering.

Two *methods of collecting data* can be employed [9]:

 Collecting data from meters

In order to provide the data, meters and metering periods should be defined. Depending on the situation more than one meter is installed. The metering period, which represents the time between meter readings, is defined based on the needs of precise data. The collection can be performed manually, by staff, or electronically, based on electronic pulses which are proportional to the data collected.

 Collecting data from invoices

In the case where meters cannot be installed or the measurement point is on a remote location. In this case the information in the invoice should be correct; specifying tariffs with details included in order the right calculations of energy consumption to be performed.

Frequency of data collection is defined based on the needs of the system. Frequent reporting, therefore, is needed to capture anomalies in current flow, or energy spikes, which can indicate major (and expensive!) problems if left unchecked. It should be proper to allow problem discovering and solving on time, at least twice the frequency of fluctuations on energy in order to receive more clear data.

Another crucial factor is the *data quality*, or the usefulness of the data. High quality data is most valuable asset, since bad data can seriously harm the business`s credibility and integrity. The core dimensions of data quality are: Completeness, Uniqueness, Timeliness, Validity, Accuracy and Consistency. Completeness of data stands for data without gaps and space for speculation, meaning that all available data has been collected. Data should not have any duplicates reported, so that the risk of assessing outdated information decreases. Furthermore, regular update of the database is to ensure all changes have been captured up to the date of analysis. Validation of data is performed to control for conformity to the syntax (format, range, type) that has been previously defined. Consistency is defined as

uniformity and reliability of repetitive events and accuracy stands for precision and exactness, if the data is good fit with reality [10].

II. Analysis and Opportunities spotting

This is a very important step of transformation of data into information and can be done on regular basis in order to plan and evaluate, and can be automated or can be done to investigate a situation. A factor that influences the data analysis techniques is the volume of the datasets. For example, the pattern of seasonal consumption is to be explored, monthly data is needed, but heating is not used all the 12 months. Therefore, a weekly data should be used, meaning the data volume is larger.

During this phase it is important not to cause "Paralysis by analysis", state of over-analyzing and not taking any action, leading to unplanned excessive costs.

To analyze data efficiently, various techniques exist, chosen according to the needed output [9]:

 Normalized Performance Indicators (NPI), kWh per square meter of floor area annually, adjusted for weather, operating hours etc., It is used usually for buildings energy performance in benchmarking process.

 Specific Energy Ratio, kWh per unit of output, used to express performance of industrial processes. It is also called the Specific Energy Consumption, and can be calculated as energy used divided by a production measure (driver)

 Current and Past Comparison, comparing energy performances

 Trend Line, expressing a direction of the biggest fraction of data points, energy use against time.

 Profiles, consumption patterns over specific time periods (daily, weekly, monthly, yearly), that can be compared with current or past profiles, average values in the profiles and control for different boundaries for the values.

 Contour mapping, 3D display of profiles

 Lines of best fit, line that best describes the data on a scatter plot.

 Control charts, having a central line for average and upper and lower line as limit lines defined from historical data.

III. Targeting the solutions, communication and implementation

Outputs from analysis are received in many forms from the System to be used for solving different issues. In order the process to evolve in efficient solution, the conclusion i.e. the output from the analysis has to be communicated, as depicted on Figure 3, transformation of information to action.

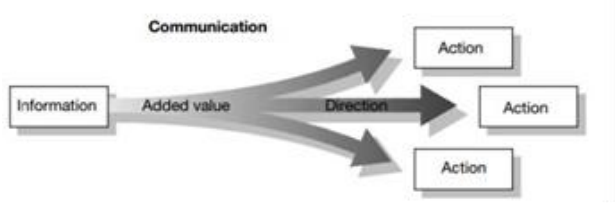

Fig.3. *Processing the Information into Data and consequently Action [9]*

The process of communication is divided into three categories [9]:

- Regular, as a report issued on time basis
- Exception, on a need basis
- Ad-hoc, as a result of requested investigation

To complete successful transfers of information it should be decided whose are the recipients of information and the exact information to which recipient should be delivered. Miscommunication can lead to implementing inappropriate or inefficient solution or ignoring a situation resulting in unnecessary costs and pollution.

Furthermore, communication too often can lead to information overload and decrease productivity, as infrequent communication can harm further actions.

To conclude, the right information is needed at the right time reported to the right person. Graphical representation of results is the best option of presenting and notifying, as it can be received as information in an easier and more efficient manner.

IV. Development of guidelines for further use and control

In order the System to function properly and the goals of its implementation to be achieved it is required to have the following [3]:

- Energy data that will help in improving the most affected areas
- Targets, must be regular reviewed and updated, take into account the influencing factors such as: outdoor temperature, operating hours, production rate, hours of occupancy etc), realistic but optimal and defined after a detailed research and monitoring of past experience and benchmarking. These targets should be communicated with the management and responsible to clarify any issues or misunderstandings in advance.
- Reports on the variation of the real data from targets, and the level of detail depend on the intended audience and their expertise.
- Training of the staff and team building so that no space for speculation and mistakes Is left
- Decision support providing a framework on decision making methodology and agreement to shorten and simplify the process of making a decision that tackles more departments/sectors
- Audited success, so to sustain motivation
- Motivation and Recognition, means rewarding systems and support from leaders.
- Benchmarking and best practices is always beneficial for the organization to measure performance in relation to other companies or sites and represents an excellent learning opportunity. It is important to compare practices that have similarities in activities, conditions and tackle similar markets.

4. ADVANTAGES AND DISADVANTAGES OF EMIS

Energy Management Information System should be a very important part of every successful enterprise and is a valuable asset of a company if managed appropriately. If used properly it will represent a basis for competitiveness by easing the communication, decreasing the linguistic, geographical, cultural gap

between countries. Furthermore, the IS is available at any time, making doing business more convenient and ensuring cost effectiveness and productivity boost.

Main purposes of EMIS are recording relevant data, analysis of energy consumption, calculation of energy indicators, recording undertaking energy efficiency measures, identification and development of energy efficiency projects, rising awareness and promoting energy efficiency. Therefore, if it is properly developed, implemented and maintained, the company can benefit from EMIS providing [3][11]:

- Early detection of poor performance, which can be done based on comparison of actual performance with targets and spotting deviations, enables identification of acute problems (excessive energy consumption and losses) as well as taking corrective actions
- Evidence of success, validation that actions that had been undertaken have been successful comparing to beforehand defined benchmark value which takes into consideration the external influences on energy use, such as production, ambient temperature, etc.
- The actual consumption of energy and the price of it.
- Support for decision making can help in a situation where a difficulty in decision making arises, and the support can come in different forms: guidelines, charts, systems etc based on knowledge-based systems or data mining
- Effective performance reporting, to ensure that the responsible are taking effective action
- Auditing of historical Operations, helping engineers and managers to learn from the past situations and perform better in the future
- Identification and justification of energy projects, the improvement investments can be easily justified and opportunities can be revealed.
- Support for energy budgeting and management accounting, historical relationships used for future budgeting. The data can reveal the true price of energy, product specific cost of energy, how the production volumes influence energy cost per ton of product
- Provides are based for project preparation in order to apply for funding.
- Energy data to other systems such as resource planning systems, scheduling systems, environmental reporting, management information systems, corporate systems etc.

However, EMIS has its downside as of security issues, unemployment and lack of job security (automation of certain activities previously done manually) as well as costs for implementation and maintenance. Since every method of gathering data has costs, choice should be made when costs of the method are equal or lower than savings potentially made with application of that data. Costs are also associated with user licence and trainings if needed. However, maintaining costs are usually the highest and should be considered when calculating. As mentioned, lot of work is processed automatically, performing task by computer that used to be done by people, causing job losses.

Security is one of the main issues, making the system vulnerable to security breaches and if not well protected, unauthorized individuals may have access to confidential data.

Furthermore, the system requires continuous work of operation in cases of manual entries, due to missing data and inability of importing a database. In the case of automatized data entries, the disadvantage, before mentioned disappear but the price of monitoring system increases.

In the end and very important the human factor is present and can influence in achieving the goal as of generating mistakes while working.

5. BARRIERS AND CHALLENGES

As still new and developing technology, the EMIS has lots of challenges to face and potential to improve, keeping pace with the extremely fast technology development[11][12].

The basis of the implementation and development lies in the understanding, vision and commitment as well as support of the management. If the management can spot the need of energy management in general and the benefits of information system to support it the development of the company is most certainly in the right direction. However, the benefits cannot be received immediately, therefore rejecting proposals for any kind of EMIS is more intuitive. Another reason for lack of support among managers is the failure of previous similar projects. For this and above mentioned reasons, the motivation between the management can be on a low level, usually transferred on the employees as well.

In the case of accepted EMIS project, it is crucial that well-defined company policies exist, explaining goals and objectives and easy-to-understand guidelines that will help the employees of every level understand the need and feel involved in improvement. Modularization and custom oriented structure of EMIS are crucial components for decision making, as well as system development and implementation. The policies and directives should be built on procedures connected to the modules in software solution that offers challenges to update according to technological and organizational changes.

For every implementation to succeed a very important element is defining and allocating the responsibilities, accountability and authority between the human resources.

Furthermore, obvious element is the budgeting. Available budget is crucial. The initiator should have a good project elaboration and vision that can be transferred to the management or a funding organization (in case of external financial support). For the capital planning two basic types of costs should be accounted for: first cost (for new or replacement equipment) and life-cycle cost (operating efficiency of equipment and the pay-back period) which can be most influential in making the decision for implementation of such system.

6. ENERGY MANAGEMENT SOFTWARE

EMIS is relatively new concept and it has proved its effectiveness. Many companies have developed software that can be implemented or companies that offer custom-made solutions to adjust the system even more to the company`s characteristics and needs.

Below are shortly presented some of the most popular software among companies.

Energy Advisor [13], created by Emerson company manages energy consumption (Figure 4) and reports (Figure 5) and notifies for direction to reduce energy costs. It is convenient as it monitors equipment.

Fig.4. *Emerson Energy Advisor - energy consumption real-time representation [13]*

Fig.5. *Emerson Energy Advisor- reporting [13]*

Utilities Direct [14], offered by the company named the same, provides Energy Management and Metering, trough real time data shows energy consumption in 30 minutes intervals. It can be implemented in single-site or multi-site company, but it is focused on medium to large companies and larger energy consumers. One of the best features is the flexibility to adjust and switch to different suppliers as well as asset registration and invoice preparation tool.

Sap Energy Management Software [15], by SAP, which as a company creates different modules to increase productivity and by that to reduce costs, offers smart metering and analytics as well as demand side management tools. Its modules and features offer customized cost effective design of strategy that will comply to the environmental regulations. One of the biggest advantages is the integration with financial data in ERP of the company user and the development of the SAP system on a whole. Therefore, SAP can be beneficial for every company that uses SAP already and/or is able to adapt to the new interface.

Schneider Electric Power Logic ION EEM [16], created by Schneider Electric, focuses on integration of business and energy strategies, making it focused on financial gains and losses more than pollution reduction. This software has powerful graphics and models with visualizing solutions. Another benefit is the customization options as well as flexibility in integration and sharing data with other parties and systems.

eSightenergy [17], by eSight, focuses on small but usefull also for large companies. It is web-based software, making it easily accessible, user frendly and has options for pay-as-you-go. Companies can use it for billing, as it provides them with tariff details including one-minute interval variations.

Credit360 [18], used by Swiss Re and Barclay is concentrated on planning and forecasts promoting sustainability, as it helps the company reduce footprint without cutting into profit and except energy data, it also collects data on carbon emissions. Although it contributes in making the business greener, it does not improve business productivity as it would be expected.

JouleX [19] (Figure 6), as one of the leaders in IT, CISCO has designed an energy management software solution that monitors, analyses and controls energy usage and according to their sources contributes to reduction of energy costs to up to 60%. Offering flexibility and remote control as well variety of tools of adjustment and reporting. Though very useful and popular, it is more convenient for large data centres and heavy server loads.

Fig.6. *CISCO Energy Management Software [19]*

7. SMART GRID AS EMIS

As energy management enables increase of energy efficiency, Smart Grids are an EM solution to reduce both households and industries electricity consumption and enable Demand Side Management. Smart Grid is a system that provides more electricity to meet rising demand via advanced infrastructure that enables electricity demand management in a reliable, sustainable, secure and economic manner [20][21]. This system provides both supplier and consumers with valuable information which is beneficial for both sides. Smart Grids evolved due to the increased popularity of distributed generation, as they help the deployment and integration of solar and wind in the grid (Figure 7).

To enable the precise monitoring and control the Smart Grid as energy management information system has to possess the following features [21]:

- Monitoring

It is of high importance to record data frequently, in the intervals of approximately 15 minutes on daily, weekly and monthly level. Shorter intervals, as above

explained, can show more variability, and by that sending wrong signals. On the other hand, longer intervals would not enable precise future planning.

- Affordability

The general idea of smart grid is to improve the lives of people by reducing the energy consumption and improving the sustainability of the electric grids and life needs in general. Therefore, system`s maintenance and configuration should be as simple as possible and not requiring professional help that would be costly. Also this system should require minimum energy to run, so that high running costs can be avoided.

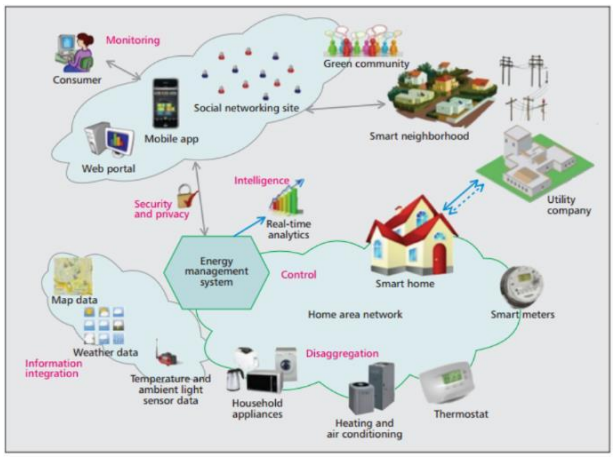

Fig.7. *Smart Grid as EMIS [21]*

- Availability and Accessibility

Accessing the data should be easy and simple, through devices as mobile or lap top enabling accessing from virtually anywhere.

- Intelligence and Analytics

As neither companies nor customers would like to waste time in analyzing and most of them do not have the expertise it is very significant that the system can perform intelligent measurements and predictive actions after examination and definition of usage patterns.

- Control

One of the main features should be enabled remote, programmable and automatic control to save time and avoid mistakes.

- Information Integration

Ability to integrate different type of measured data (energy, air quality, temperature, humidity, light etc.), historical data, as well as to import data from other systems for measurement or data keeping is of high importance so that the data can be directly analyzed and by that time could be saved as costs reduced.

- Disaggregation

Disaggregated data can be helpful in informing customers for the energy consumption of appliances or benefits of switching lightning or other appliances when not in usage,

- Cyber security and privacy

One of the biggest issues is security and risk of hacked systems. Most of the companies consider their data to be important and confidential; therefore the system should be secure and reliable to be attractive for both the supplier and the customer side.

Many systems have been developed with a combination of some of the features above mentioned. In general, Smart Grids have a huge potential of improvement following the emerging technologies, vast research etc. Great advancement will be achieved in the field of intelligence and machine learning, increasing the ability of the system to recognize user`s preferences, determine comfort levels and needs of a certain customer based on which it can undertake automatic actions. A very important emerging concept is Demand Side Management or also called Demand Response and therefore a crucial feature of smart grids, understands influencing consumer to reduce or reschedule their consumption. This results in stabilizing the general load profile, reducing peak hours and by that prices but also, very imprint for electricity suppliers and operators reducing the possibility of over loading the system and need for ancillary services.

Furthermore, one of the most popular technologies currently is home automation infrastructure which enables data acquisition, profiling, making decision based on profiles and undertaking actions. These systems have different features and the EM system should be able to integrate completely with the home automation system so that all the measurement, control and actions are interconnected and act cohesively. This feature is joint with mobility feature that each EM should be having. People are dependent on their cell-phones and expect to have all the necessities inside the memory if their mobile phone. Accordingly, EM should be controlled, monitored and handled via mobile application, taking care of security issues.

8. CONCLUSION

To conclude, the EMIS systems need to provide the users with easily accessible and operable interface as well as intelligence that will result in savings and profitability as it is the goal for all market participants. With application of modularization and customization rules for development of such software product as is EMIS, those advantages are achievable.

Driven by the needs of energy saving, EMIS is advantageous over passive systems of energy data recording as it gives real-time information, notifies, controls and handles the consumption. Above all it will reduce the pollution and enable sustainable economic and social development.

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