Data Collection & Innovative Solutions for Energy Management

PROF.DR. M.ZİYA SÖGÜT
ASSOC.PROF.DR. KORAY ÜLGEN
Ş.ŞADİ KARAMANOĞLU
SEDAT VATANDAŞ

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Introduction

Despite the development of smart management preferences in energy technologies in recent years, a significant potential has still been identified for energy efficiency measures that are economically advantageous by energy management in all business processes, with the application of energy efficiency brought by operational optimization and managerial responsibility. While individual users rarely have reliable or detailed information on the energy consumption of primarily energy-consuming machines or components, a trend towards energy monitoring solutions for greater transparency about energy use and the evaluation of energy efficiency measures is developing as a structural responsibility of energy managements. Collection and processing of consumption data, identification of energy consuming system components, definition of energy and operational data and related parameters have become valuable by energy managements. In addition, the development of awareness has come to the fore as one of the basic components for continuous energy efficiency improvement, which increases the awareness of individuals with consumer and business responsibilities regarding energy use. In addition, energy-consuming systems or machines are often operated without a standby function during operating processes, and energy is wasted to power peripheral components. The fact that operational business processes can be managed in this way can create an important energy efficiency opportunity.

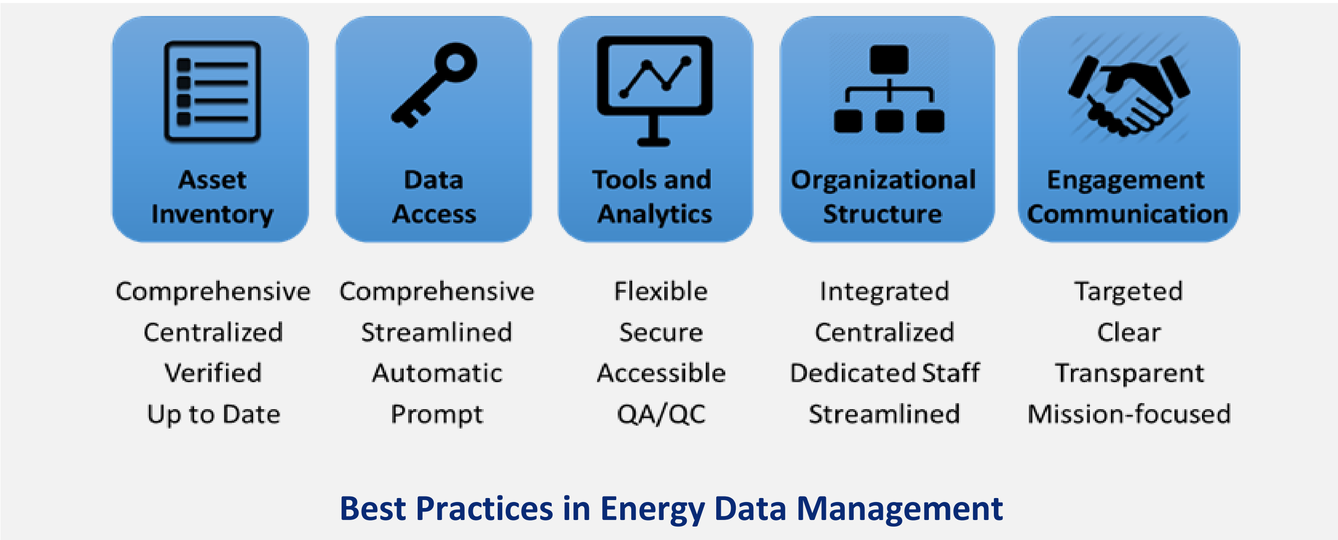

Fig.1 Best practices in EDM

Process definition is a very important step for energy managements for target setting, planning and administrative policies based on consumption data. Basic reliable analyzes of energy management elements in process management are handled from a statistical point of view. Energy data obtained from the energy efficiency aspect is primarily important to ensure relevance, accuracy, reliability, timeliness, punctuality, accessibility, clarity, consistency and comparability. In this context, the natural effect and continuity of data collection is an important gain by energy managements and increases with higher level of detail. However, the more detailed the data, the more useful it is for its manageability. Data control primarily gives clearer signals to users and policy makers and helps determine what should be prioritized. In energy management, the security and functionality of data and the way statistical analyzes are organized vary widely. Operational responsibilities require an effective data management model, together with the effective handling of data. In this context, the existence of standardized methodologies in energy management, together with effective data collection and management, shape the demand side of operational energy balances, the basic consumption of energy end use.

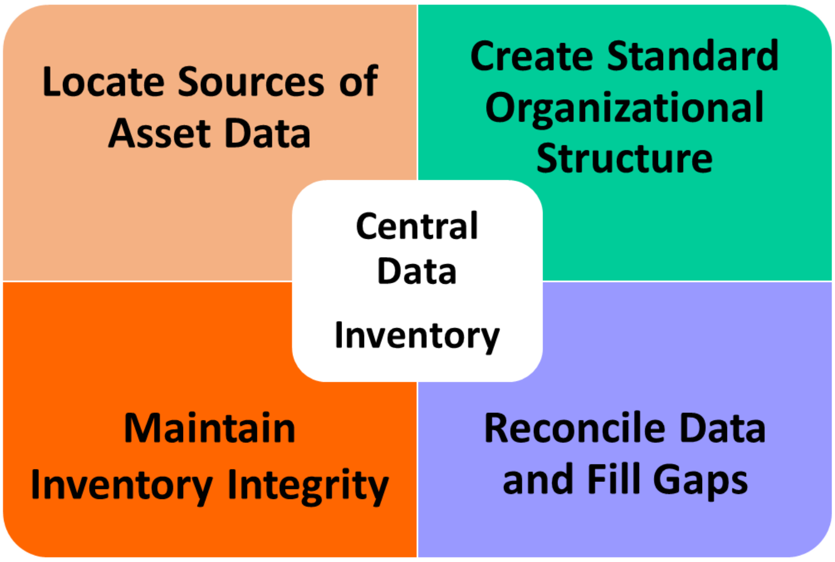

Fig.2 Data framework and ınventory

It operates a comprehensive data infrastructure for energy management data control and operations. According to the type of building, important traceable energy users are included in the data inventory as basic inputs. However, developing energy efficiency indicators requires more disaggregated information than energy balance. These indicators ideally express an operational relationship to end-use energy consumption for each energy user. In this context, a comprehensive framework for energy efficiency indicators is needed, paying attention to the main objectives, depending on the available data. Developed in this context, this report presents a review for data collection and management and a framework for possible innovative approaches. It covers detailed information regarding energy indicators, taking into account each user for the final use of the building. While this structural level may mean higher data collection requirements, it represents the desired level for monitoring energy efficiency progress.

Energy Efficiency and Data Collection Management

Energy management includes a managerial organization in corporate processes. In this context, it has the responsibility of data collection, processing and management, together with the energy management managerial capabilities to be developed. Despite the multifaceted advantages of data management in energy, energy efficiency and efficiency of processes, efficiency measures cannot be taken immediately. Even in market economies where costs are immediately reflected in prices, energy efficiency investments are implemented rather slowly in industry and other sectors. This is even more so in underdeveloped countries. The main reasons for this situation can be summarized as follows;

a. The slow reaction to price changes, the prevailing opinion that existing businesses are working efficiently,

b. The complexity of energy efficiency investments, the inability to rely on the proposed new equipment, and the undesirable disruption of production due to the necessary revisions,

c. Energy efficiency investments consist of many small investments,

d. In recent years, due to the worsening economic conditions, insufficient resources have been allocated to new investments,

e. Emphasis is placed on increasing production rather than improving efficiency, and senior management does not pay enough attention to energy savings.

In addition to these reasons, energy efficiency studies in industry also face technical and financial obstacles. Moreover, sometimes technical, financial and economic obstacles overlap. Factors such as not knowing the appropriate technical facilities according to the facility characteristics, lack of expert staff in energy management, lack of measurement and control instruments create technical barriers and delay energy saving efforts. Financial barriers are capital shortages, high interest rates, and the lack of simple medium-term financing for energy-saving equipment. These barriers are often more serious in developing countries than in industrialized countries. Generally, facilities that have lost their economic characteristics in today's conditions, or campuses within the existing building stock, are quite common. These facilities remained as facilities that consume too much energy according to cost criteria and could not keep up with technological developments. Many technical processes require energy to be converted into another form, which often results in significant conversion losses.

Energy efficiency is one of the fastest and most economical ways to affect the environmental performance improvements of a building. For this reason, it has become inevitable to provide continuity, quality and low cost in energy inputs in buildings where energy inputs are high.

Considering the additional financial burden that energy will bring on the business, the need for energy management shows itself. The efficient use of energy and the reduction of energy costs with an effective energy management will both prolong the use of these energy sources and provide economic savings. Figure 3 shows the associative linkage of an energy management process.

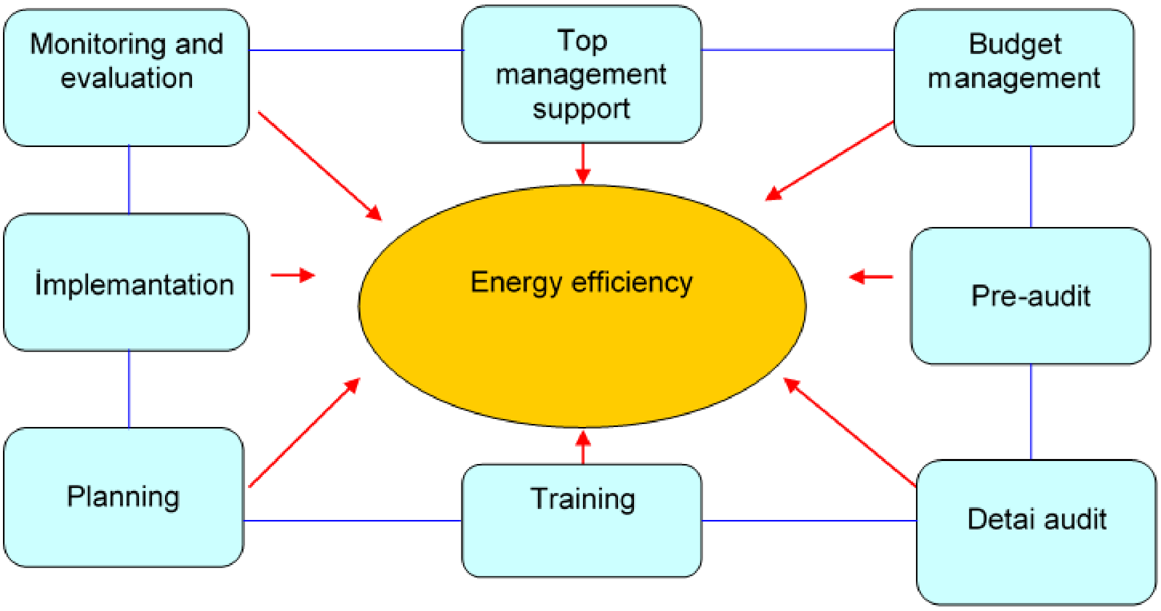

Fig. 3 Enerji efficiency management framework

Studies on energy management or efficient use of energy in buildings consist of various stages. These are:

a. Preparation of preliminary energy saving study

(1) Energy scanning (Data collection, processing and evaluation)

b. Management and staff support

(1) Management and Staff support and contribution

c. Energy saving design and regulations

(1) Arrangements that can be made in order to use the systems that can be used with maximum efficiency by making use of the researches made in the market based on the data

(2) Energy saving cost and recycling times

d. Monitoring and evaluation.

In this part of the study, the necessary energy screening was carried out by the energy management organization in an industrial establishment in order to prepare a preliminary energy saving study. This scan covers the stages of collecting, processing and evaluating the energy and production data of the enterprise.

Methodology of Energy Audit

Production costs in a structure include the sum of raw materials, labor, operating and energy costs. Generally, energy is simply included in the total production costs and is not considered as a separate item. Although energy costs sometimes constitute a part of the total production costs or service costs, and sometimes a very important part, depending on the nature of the building, this situation is often ignored by the managers of the building. Creating energy scanning is the first and important step for successful energy management in buildings. For this, the consumptions and indicators to the functional structure of the structure should be converted into tables by taking the data on a monthly basis. According to these charts, necessary calculations are made and energy analysis graphs are produced. These graphs are prepared for all parts of the structure. These graphics provide a comparison between consumption and production.

Thanks to this comparison, the energy policies to be applied are determined, that is, the points where savings can be made are analyzed. The savings that can be made are calculated with various calculation methods. The units used in these energy calculations are generally taken as tons for the amount of fuel, kWh for the amount of electrical energy, and tons for the amount of production. As a result, the aim of the energy screening to be made is to achieve the best results in energy savings by using correct data and appropriate solutions.

Energy Audit

In the first step of the energy scan, energy and production data are collected. At the stage of data collection, first of all, data collection strategies should be determined. To this end ;

a. The naming of the generation with the types of energy to be collected data

b. Determination of energy and production points to be measured

c. Determination of measurement types (such as measuring instruments) and periods (at least 10 - 20 sets of data must be obtained)

d. Measurement period and data collection method and place (at least 10 weeks for weekly measurements, at least one year for monthly measurements) should be determined.

Energy consumption can vary from week to week or month to month, depending on many factors. These are divided into two as,

a. Specific Variables

b. Controllable Variables.

Specific Variables; It is the variable that determines the energy need according to the production amount of a part of the building. These variables are used in the standard equations used to calculate the energy requirement. Controllable variables are; These are the variables planned by the management to minimize energy consumption such as operating practices, system control, production planning and maintenance standard. In general, the standard equation is a line equation showing that the energy requirement depends on specific variables (service, production, etc.).

$$ENERGY(E)=a+bP \quad (1)$$

Here a and b are constants. P is the specific variable of that section. The type of standard equation that may be suitable for any given section depends on the number of specific variables and the relationship between energy and these variables. This equation(type a) is;

$$E = a \quad (2)$$

is the equation. That is, the energy consumption is constant and there are no specific variables for the section under study. In this case, the energy consumption of that section is initially fixed regardless of production. This type of equation is also a straight equation as (type b);.

$$E=a+bP \quad (3)$$

Energy consumption depends on one specific variable P (production). In this line equation, the constant a is the amount of energy that is not related to production. This equation (type c) is;

$$E= a + bPl + cP2 + dP3 + etc. \quad (4)$$

In this equation, energy consumption depends on more than one specific variable. These specific variables can be various variables such as P_1, P_2, P_3 production quantity, weather conditions, working hours, etc., or various types of products produced in the same department. The constant a is the energy consumption that is not dependent on production, which occurs under conditions where all specific variables are zero. The values of the constants b, c, d depend on the importance of the respective variables. After the standard equation is found, the targets are determined. While determining the standard for each section, the target should be determined at the same time. This target is an equation in the same form as the standard. It describes the improvement in the performance of that section. The role of goal setting is to provide the necessary motivation to improve productivity. There are basically three methods for goal setting:

a. Target based on best past performance
b. Simple percent discount
c. It is expected performance.

After the target has been determined in the building, a regular comparison of the expected energy use with the actual energy consumption values should be made in order to evaluate the performance. To do this, it can use specific energy consumption (SET) values. Specific energy consumption is defined as the energy used per unit service/product. For example, if a specific variable (production) is described in tons;

Specific energy consumption = Energy consumption (Energy Unit) / (Production Unit)

is expressed as.

The SET value is especially important in terms of monitoring the effect of various operating conditions on the service/production performances of the structure. An increase in the SET value indicates poor performance and an unnecessary increase in energy consumption. Actual, standard and target SETs are given in energy reports. These are calculated by taking the actual, standard, and target energy, respectively, and dividing these by the actual value of the specific variable. Standard and target energy consumptions are calculated using the equations found for each section. If non-production energy consumption is high; With the increase in production, it is possible to reduce the specific energy consumption. The amount of energy not dependent on production; Since it depends on the equipment capacities used, the current operating conditions and will remain constant because they are the same, the energy consumption per unit product will decrease with the increase in service/production. If it is; means a reduction in specific energy consumption. A second way to reduce specific energy consumption is; taking energy-saving measures, completing insulations, evaluating waste heat, combustion controls, etc. such as, in short, it is possible by increasing the efficiency in energy use.
As another evaluation method, plotting the cumulative total values (CUSUM) graph is also convenient to see the status of a facility. When this graph is examined, values with negative

slopes and areas in the negative zone indicate the times when the plant has a good performance, and the positive ones indicate the times of deterioration. To be able to draw the cumulative total values (CUSUM) graph, evaluation is made between service/production and energy data. For this, the standard equation is calculated using the least squares method. If there is no mathematical correlation between the data, the theoretical actual consumptions based on the detected target data are calculated. CUSUM graph is drawn accordingly.

Measuring and Metering

Given the complexity of the demand-side of energy systems, accurate energy consumption data for final consumption sectors are often difficult to obtain. Modelling stands as one important data source, providing estimates based on a range of input data and assumptions. The set of output stemming from models can yield stand-alone and readily available estimates or, as mentioned above, be used to complement/refine data collected through other methods, such as surveys and administrative sources. Modelling is not a data collection methodology in itself, but it is widely used across countries as a way to provide the best available picture of the energy use across different final consumption sectors. For this reason, it is included as the last method of this section.

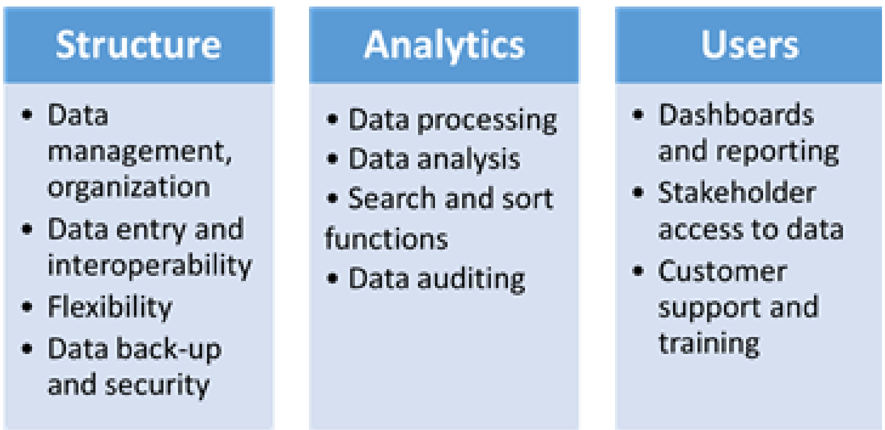

Fig.4 Data tool and analytics

In a broad sense, a model is a tool for analysing or investigating some aspects of the real world. It is usually a quantitative method, system or approach which applies statistical, economic, financial, or mathematical theories, techniques and assumptions to process input data into estimates. There are typically three parts to a model: inputs, in the form of data and assumptions; a processing component, often through calculations; and outputs (Department for Transport UK, 2014). The main steps of modelling include: establishing a comprehensive framework, setting the assumptions required, inputting data, running the model, validating the outputs and assessing the results. The quality of the generated outputs is critically impacted by the quality of input data and the validity of the assumptions. Historically, the two main approaches used to model end-use energy and monitör energy efficiency are the so-called “top-down” and “bottom-up”. Such nomenclature is a reference to the position in which data inputs are hierarchically placed compared to the whole system. Grubb et al. stated that the top-down approach is associated with an economic paradigm, while the bottom-up approach is associated with an engineering paradigm – therefore it is many times referred as to the engineering approach.

Top-down models typically estimate energy demand through aggregate economic indexes – such as GDP and price elasticities. Top-down models can not explicitly represent the technologies available, thus usually underestimating the potential for efficiency improvements. In contrast, bottom-up models represent technologies using disaggregated data but often disregard market thresholds, potentially overestimating efficiency improvements. With more detailed data, bottom-up models have a strong ability to model technological options, but at the same time they require a greater amount of input data, which makes them often significantly more complex. The strength of top-down models lies in the fact that only aggregate data are needed, which is more available and simple to obtain. Overall, the application of modelling approaches has key advantages, such as resource savings, reduction of respondents’ burden, quick results, and a complementary usage to improve survey results. Inherent risks include, for example, the use of default values from another region/country due to unavailability of local data (EUROSTAT, 2013). Attention must be drawn to the validity of modelling assumptions, to the quality of input data, and respective impact on the model outputs.

New Technologies in Data Collection and Their Implications

The importance of control technologies in energy systems and applications is increasing day by day. As change tools, new applications in technology management provide significant gains in operational efficiency. In this context, new technologies in energy applications offer different control managements primarily as digital applications. Especially digital ones of these technologies (such as sensors, connected devices, network equipment) are increasing their usage diversity as potential tools for data collection, management and analysis due to their control advantages in energy system applications. Today, while the opportunities created by digital technologies increase the amount of data in systems, innovative methods are also developing to process larger data volumes. But at the same time, significant opportunities have emerged in system inputs to fill existing data gaps. Especially in digital technologies, technologies such as smart systems and devices, cloud computing and artificial intelligence have enabled the collection and interconnection of important information from energy systems.

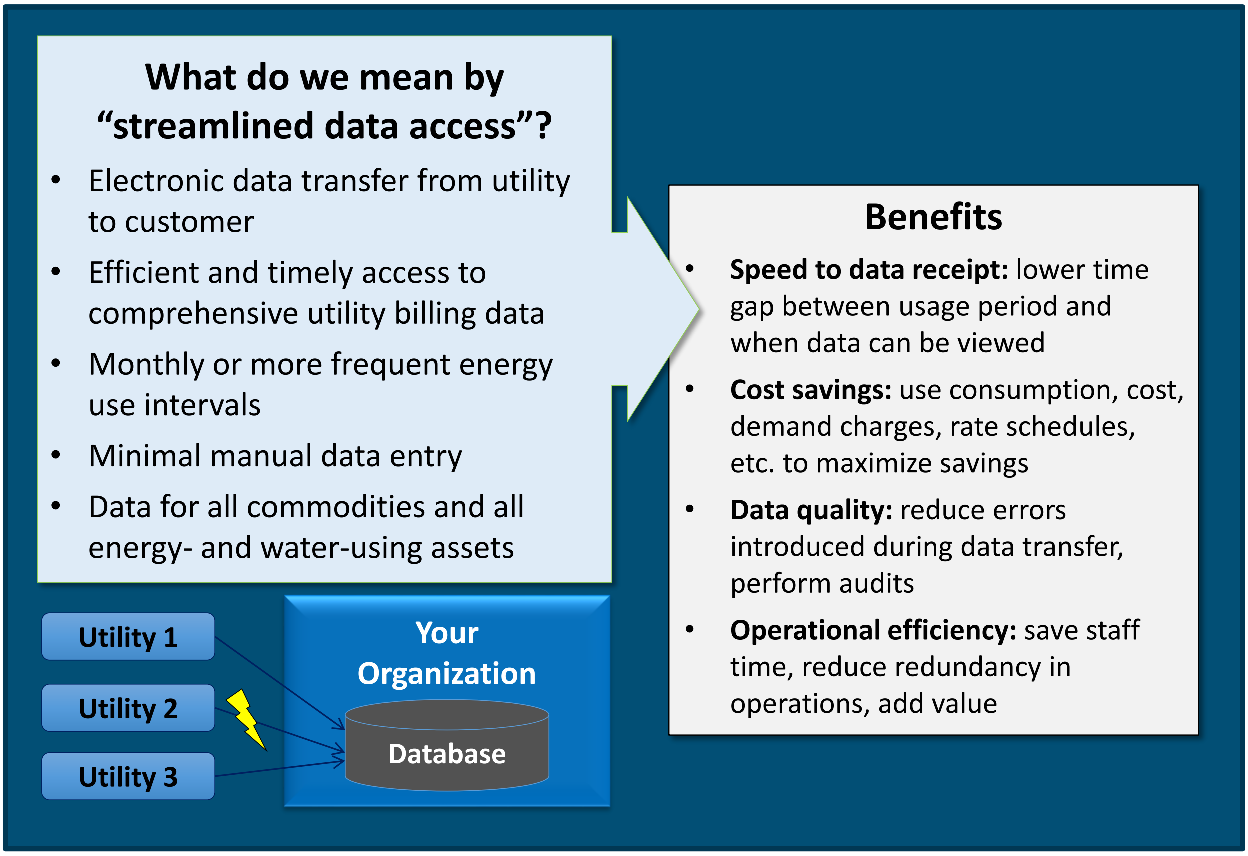

Fig.5 Streamlined data access

Digitalization means the expansion of ICT (information and communication technologies) applications across economies, including energy systems. It can be defined as the increased interaction between the digital and physical worlds (IEA, 2017). Continuous improvement processes in the applications of these technologies are shaped as a combination of three main factors. These;

- While advances in sensor technologies reduce costs, increased data collection volume due to improvements in storage capacities
- Rapid growth in advanced analytical computing combined with artificial intelligence techniques
- More connections and data transmission with lower costs in control technologies.

Demand management, digitalization in control management, collection, management and analysis of large volumes of data are the basic steps in shaping monitoring. In this framework, monitoring the progress of energy efficiency and process management provides an effective potential in this respect, and as a result, an important information potential emerges for policy making. For corporate governments, energy data has an important role in supporting and improving energy statistics. The quality, up-to-dateness and usability of data should be considered as an effective tool in improving or increasing efficiency. The collection of data, especially the end-use points, will create a manageable process impact for data management strategies.

The wider adoption of digital technologies for all system components today still sometimes presents challenges. For example, one of the main challenges is the proper structuring of the large volumes of data generated and their effective manageability. In addition, the social acceptance of new application systems (closely related to data privacy and security), high assembly and distribution costs, and regulatory procedural shortcomings of system components pose significant barriers to the wider applicability of new technologies. In recent years the building industry has become increasingly smart and connected, with smart building applications, mostly for enhanced safety and efficiency standards. With data flows in energy systems and components, data can be collected or produced properly, enough information for a very large and accurate amount of deep learning infrastructure. Therefore, it enables better analysis of the energy efficiency of control models or tools in smart buildings. This will provide an environment for the collection of accurate and detailed disaggregated usage data, which refers to the limitation of traditional methods used or to monitor users' preferences in terms of both space and time for comfort conditions (Allström et al., 2017). In short, for smart building systems, digitalization developments in both residential and commercial buildings focus on heating and cooling end-uses powered by smart thermostats and sensors (IEA, 2017).

Indeed, for smart buildings, system components such as smart meters and smart lighting (see the relevant sections under New technologies and their potential role in data collection for more details) are also important considerations. Data collection for these system components is ensured with innovative methods and a high level of detail. Digitalization in buildings is expressed as "building energy management systems, especially for smart building applications (IEA, 2017) and these system components support the improvement of corporate data collection systems. Undoubtedly, the ongoing digital transformation in energy systems and technologies and the increasing big data flow, sectors And it opens up countless opportunities across end uses.However, while providing system conveniences, this digital advancement highlights data security problems such as new system vulnerabilities, issues that need to be carefully considered (UNIFE, 2019). , data collection or availability can be evaluated together with the obligation to comply with data privacy regulations and laws. For this purpose, leakage risks and security threats need to be well understood and carefully managed (Singh et al., 2014).

The role of new/digital technologies is seen as a fundamental issue in energy management. In particular, better analysis and evaluation of data are considered in three main categories. These are data collection, data management and data analysis. While the boundaries between these three categories are not always clear, a technology can be used for more than one purpose. They examine key factors and technologies that reveal new possibilities or risks for each of these applications, focusing on the level of energy end-use and the working potential of energy efficiency indicators. Although new technologies focus on data collection as system components, it shows that there may be overlaps with some applied methodologies, especially administrative resources and measurement/measurement.

Smart devices

Smart appliances or devices are increasingly a feasible option for households to enhance comfort, security and energy management. The Internet of Things (IoT) has led to an increasing amount of smart devices available in the market. Those devices hold the potential of providing consumers with real-time energy consumption data and energy cost information, as well as helping utilities to understand and anticipate customer behaviour. According to Lobaccaro et al. (2016), systems and new feedback initiatives that enable visibility of energy resources to households must require a combination of well-designed programmes that successfully inform, engage and motivate users; in summary, data collection, data processing, data representation, and control/interaction capabilities. Besides, data can be displayed to the user both through direct and indirect feedbacks. While the former represents the data collected typically in real-time, the latter are derived from post-processing tasks, for instance energy audits and enhanced billing (Lobaccaro et al., 2016).

Data management

In this paper, data management refers to the methods/ tools used for processing and structuring the data (for example deleting null entries, adding/removing fields in databases), as well as data storing and retrieval, without including an in-depth analysis. It can also refer to a specific platform or software that enables these processes to take place. Defining good quality data is a complex and broad task, regardless the sector. According to EUROSTAT (2003), data quality assurance follows six criteria:

i) accuracy, how well the data depicts the reality;
ii) coherence, whether the different flows from the data collected are consistent among themselves;
iii) timeliness, if the reference period for the data is the latest possible and not outdated;
iv) relevance, how do data fit in the purpose;
v) accessibility and clarity, how easily users can access data and understand it; and vi) comparability, the extent to which data is comparable (definitions), for example across countries.

Countries usually define their own frameworks for quality assurance and validation of the data collected, which may vary significantly.

Database management systems

Organisations are facing new challenges in recording, updating and tracking their data on an efficient and regular basis. After collection, a proper data management becomes imperative before proceeding to a subsequent analysis. New technologies may also have a role to play in this context. Database management systems are nowadays crucial to qualitatively store and treat data.

For instance, linking end-use data with its metadata, describing the definitions of the data series, as well as the relationships and links within the database. A useful database management system allows not only for entering new data, but also for updating existing data and correcting irregularities within a given dataset. An efficient database must be able to bring stored data into a format that would allow for further display and interpretation. These management systems can embed plausibility and quality checks to support the improvement of data quality. As an example of the importance of database management, it has been raised the need for a central database of Energy Performance Certificates (EPCs), in order to obtain representative data at national level that is good quality, comprehensive and comparable (see box below). EPCs have been widely implemented across countries, constituting an invaluable source of data on buildings' energy performance. This makes available a large amount of data on the theoretical energy performance of buildings for key end uses (e.g. heating and cooling) – it cannot be considered proxy to energy consumption data, as the real consumption depends on additional factors such as occupants behaviour. However, it can be a useful input to derive actual consumption.

Smart Buildıngs Concept

The concept of smart building includes energy, gas and water consumption, all meter systems connected to household appliances, electric vehicle charging infrastructure that both consumes and generates electricity with alternative sources such as solar panels, and all system flows and other connected devices such as entertainment, health and home security. The building concept that manages in a holistic structure is briefly called a smart building. This system structure, the combination of devices, the data they provide, and the control actions they activate form a system integrity in the smart home services structure.

Smart homes manage multidirectional system flow and will include multi-connected device structure. These are energy system components, renewable energy systems, vehicle chargers, control actuators; personal health and home environment sensors; entertainment consoles; and images. Data from these devices can be easily exchanged to support a range of smart home services. Examples include local and remote home energy management, security monitoring, wellness monitoring, and sharing of Internet and entertainment content. This type of system management provides better control infrastructure over their environment by accessing a variety of context and situation sensitive applications and these services contribute to people's comfort of life. Unlike Mrvcut home systems, smart systems contain many different connections. While the first controls in smart building systems had a limited structure, today, with the change in technology, very different preferences or control schemes have been produced depending on the comfort demand.

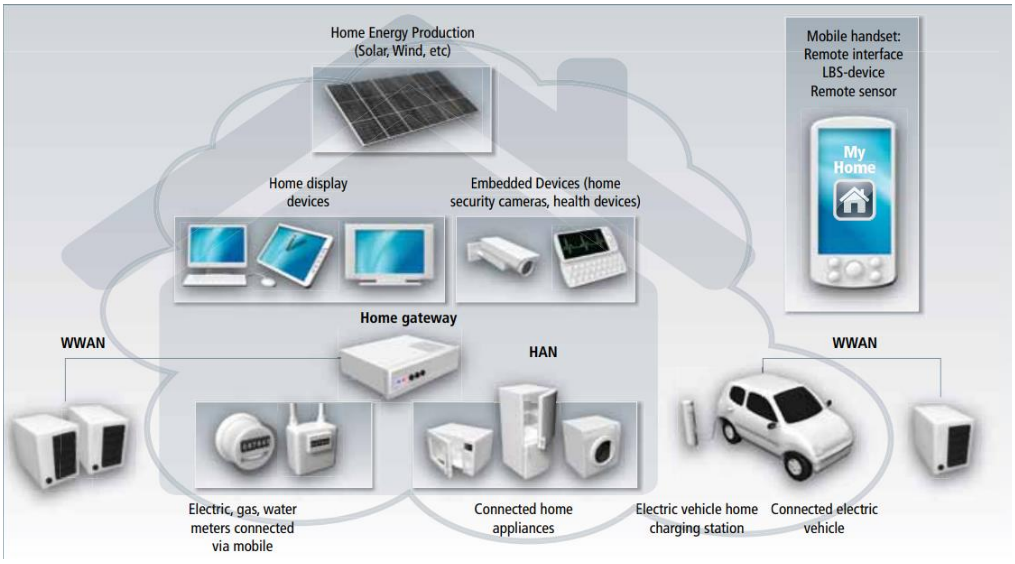

Fig. 6 Smart Home Service[1]

The smart home concept can also be seen as a technological process that is constantly developing and growing with a structure related to demand today. It incorporates many new technologies with many target aspects such as comfort, safety, sustainability and environment that affect people's quality of life. In today's classical home technologies, single-stage or single-use features of self-study or automation devices create a limited use in all system solutions. However, smart system components and control management of various devices define a home automation system that connects applications to all data and creates control difference. In this context, forms and methods have been developed to change the lifestyles of people in smart buildings with artificial intelligence options such as smart and controllable internet of objects. Although energy demand and measurement is considered the primary goal of homeowners, energy efficiency and energy and environmental sustainability stand out as key components. As a matter of fact, smart meters, building energy management systems and assisted living systems have all become a part of smart building solutions for such buildings. BEMs have the capabilities to regulate the use of household appliances and the charging of electric vehicles according to the time of day or dynamic electricity prices. Gas, electricity and water sensors will also be able to provide advanced analytics in their monitoring and management to enable users to be more effective and efficient based on demand management.

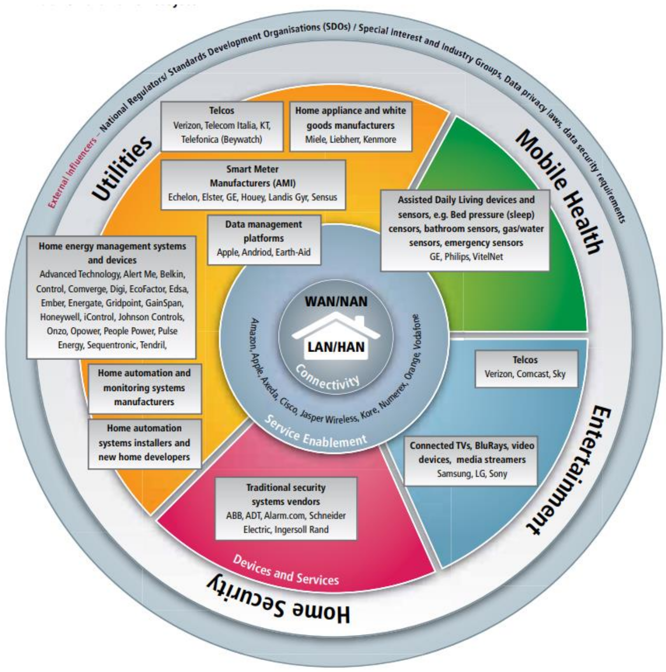

Fig.7 Smart Home Ecosystem[1]

The concept of smart building has developed as a framework for change along with multi-government. An effective smart home system and structure is usually the direct concern of users' demand management, to bring together many control management and packages. In the smart building concept, the main input in the success criterion is change. In this context, together with all the components; In the smart building concept, the development of critical technologies and tools to drive change in service providers is a necessity. In this context, smart building systems; It shows the development of different ecosystems and operational management system structures with these system components. In addition, smart buildings of the future will shape technologies and standards that can coexist. Most importantly, it will aim at continuous improvement, with a framework that will evolve as a structural framework with a continuous impact of change on the size and direction of the service segment.

[1] GSMA, (2020), Vision of Smart Home The Role of Mobile in the Home of the Future, https://www.gsma.com/iot/wp-content/uploads/2012/03/vision20of20smart20home20report.pdf

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