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DECISION SUPPORT SYSTEMS FOR BUILDINGS ENERGY EFFICIENCY

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Abstract: *If we try to follow the introduction of energy performance rules in national building codes, buildings from today ages consume only half as typical buildings from the 1980s. If we refer to today's buildings, they are responsible for energy consumption in Europe, about 40% and carbon dioxide emissions, 36%. Currently, about 34% of buildings in Europe are over 50 years old and around 74% of the building stock is energy inefficient. At the same time, if we refer to buildings that are in a degradable state, only 1% of them are renovated every year. If we renovate existing buildings, we can lead to a major reduction in energy and investments in energy efficiency can stimulate the economy at a high level, especially in construction industry, because we can see that they are responsible for 9% of gross domestic product and directly for almost 19 million jobs and can reduce energy consumption by about 5 percent and also reduce carbon dioxide emissions by 5 percent. This paper presents several benefits and particularities on the use of support decision systems and for increasing energy efficiency in smart buildings with the help of renewable energy technology.*

Key words: *smart buildings, efficiency, energy consumption, support decision systems, renewable energy technology, onomy, construction industry.*

1.INTRODUCTION

Within the European Green Deal, the European Union is setting itself the very ambitious objective of being the first block climate neutral by 2050 and is already following the plan to achieve it. At writing time, the Proposal for a European climate law to ensure a climate neutral European Union by 2050 is in public consultation since 4th of March 2020 [2]. In 11 of December 2019 the European Commission publicly presented the European Green Deal [3] and, in 14th of January 2020, the European Green Deal Investment Plan and the Just Transition Mechanism [4]. As about 40% of energy consumption goes into buildings, the building and renovation sector presents a high importance for the European Union and its Member States, and needs to be addressed at all level to ensure sustainability in construction and administration of buildings, and also conformity with the ambitious objective of climate neutrality by 2050. Even though climate changes are global and EU plans are at a Communautaire level, measures must be taken locally at the lowest level possible, on each building in each locality within the EU.

The administration of a building is a continuous process that requires many decisions on all kind of aspects related to that building, from the structural integrity of the construction, to aspects like utilities management, energy consumption, waste collection and management, heat, interior or exterior illumination, etc. All these decisions were taken, until recently, only by human personnel based on proper training and professional experience, legislation and necessary information collected by directly inspecting the building. Some decisions can be taken based on historical data, while others require current data for an informed, good decision. Most of the decisions were correct, especially based on regulations compliance, professional expertise and centuries of common practices in buildings administration. Starting the last quarter of the previous century technology allowed us to automate some of the processes, such as those related to infrastructures administration, production processes, etc. As technology evolved, we are now able to completely automate, and even manage in complex information systems, most of the processes involved in building administration, especially those concerning energy management.

Modern society is based more and more on the usage of communication and computer technologies, and decision support systems are state of the art technologies, implemented in all aspects of the society, like business management, infrastructures management, utilities provision, information management etc.

EEB or, more specific, Energy efficient buildings (about new constructions or renovated existing buildings) this can be defined as buildings which are designed to provide a significant decrease of the energy need for heating and cooling that, in the end, will be chosen to heat or cool the building [5].

When we think about buildings, we can say that are an important part of our daily lives and we stay part of our time in them - at work, at home or during our spare time.

Even if we mean about hospitals, homes, libraries, workplaces or other public buildings- the built environment is, however, the single largest energy consumer in the EUROPE and, also, one of the biggest carbon dioxide emitters.

In these days, approximately 75% of the building stock is represented by energy inefficient. This means that a large part of the energy used goes to waste, but such energy loss can be in a great way minimized by using smart solutions and energy efficient materials when we are constructing new houses and improving existing buildings.

The EU's total energy consumption is reduced by 5-6% just renovating existing buildings and, also, lower carbon dioxide emissions by about 5% [1].

2. BUILDINGS CHARACTERISTICS

2.1. Smart buildings for eco-living

Many scientists have focused their research to improve technologies, of we refer to virtual sensing, artificial intelligence in the smart buildings sector, improving life quality with smart houses, detecting information of human behavior using to assisted living, maintaining environmental in a healthy way, and preserving natural resources[5].

In this case, we can use smart devices which can provide us comfort, cost reducing and, also, healthy benefits, by using renewable energy and smart management components.

2.1.1. Solar Gaps

Reduce your apartment, home and/or business electricity bill by up to 70% with smart solar energy generating blinds. Solar Gaps [6] are designed to look like traditional window blinds but they have smart technology inside and covered with photovoltaic modules *(see Figure 1)*.

Benefits:

- energy generating,
- cost reducing,
- durable,
- do yourself installation, etc.

Fig. 1. Solar Gaps

The photovoltaic cells generate electricity to power devices, store in a battery and/or sell to your electricity company Once installed over a window (inside or outside), the smart blinds with built-in solar panels can generate up to 100W of energy per 10 sq. ft. (≈ 1 m2) of a window, which is enough to power 30 LED light bulbs or three MacBooks.

For example, a three-room apartment with four windows of 2 square meter (about 20 square feet) each facing south may be able to produce on average 7 kWh a day / 210 kWh a month assuming average daylight of 8.5 hours a day. In an office or retail space you can generate up to 10 times more.

To absorb as much solar energy as possible, Solar Gaps automatically adjusts the angle of the panels to follow the sun's position.

2.1.2 Solar Tape

Solar Tape [7] is an organic flexible solar cell foil with lined adhesive who can be transparent on the front or backside and can work as a solar sticker. Use your imagination for useful of solar tape. It can be used to window frames, glass, rods, window blinds, UAV drone / RC airplane wings, cabinets etc., wherever you would like or dream and where you might have a need for power.

The solar tape is more usually for solar energy integrators, sensor devices, hobbyists. PV (Photovoltaic) Solar Tape can also be applied like regular tape, this is simple because it is used a lined adhesive and functions as a solar sticker (see Figure 2).

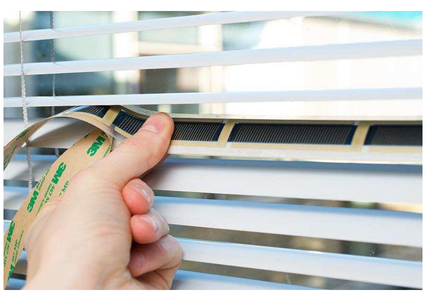

Fig. 2. Solar Tape

Fig. 3. Solar Window film

2.1.3. Solar Window Film

Whether you are at your home or at the work office, you will know all too well the issues and obstructions that sun rays can bring to an interior space. From window glare to overheating rooms, to damaging furniture, there's a substantial number of issues the sun can bring to both homes and workplaces alike. But where there is a problem, there is also a solution. Solar and energy control window film is the ultimate home and workplace accessory that's specifically designed to improve and enhance your everyday life.

This kind of Self-adhesive film are used on flat glass, polycarbonate and Plexiglas. The spectrum of the sunlight reflected limits the heating of the indoor climate Unwanted glare can be reduced, and this can make computer work more agreeable. Ageing of interior fittings and fixtures is delayed through the blocking of UV radiation (see Figure 3). The following benefits of these solutions have been identified:

- Reduced heating through sunlight in an efficient way;
- Low temperatures indoor;
- Air-conditioning used less often;
- Improved comfort in buildings for users;
- Can reduce glare by these reflective qualities and they are more comfortable for the light diffusion;
- Protects wallpaper;
- It works by blocking harmful radiation.

2.2 World energy consumption

The total energy produced and used by the entire human civilization. Is defined as World energy consumption [4]. This is Typically measured per year, and involves all energy harnessed towards humanity's endeavors across every single industrial and technological sector, from every energy source applied across every country and this does not include energy from food. World energy consumption has deep implications for humanity's socio-economic-political sphere, being the power source metric of civilization.

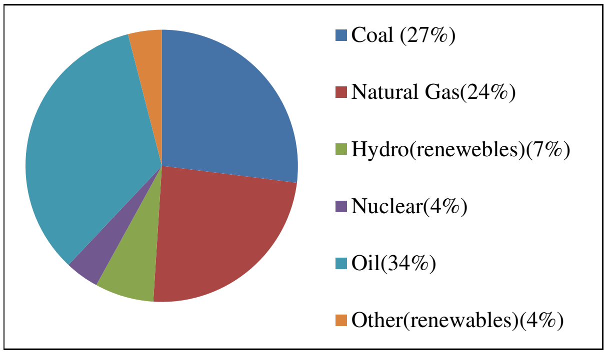

Fig. 4. World total primary energy consumption by fuel in 2019

2.3 World electricity generation

Studies made in 2016 reflected that the total world energy came from 10% biofuels, 5% nuclear and 5% renewable (hydro, wind, solar, geothermal) and 80% fossil fuels. In this period, from world energy generation like oil, coal, and natural gas continued to grow and, in this case, there had been increases that were in a higher level than te renewable energy. Using the figure down illustrated, we can see the growth in consumption of fuels like coal, natural gas and oil, also renewable sources of energy from this period.

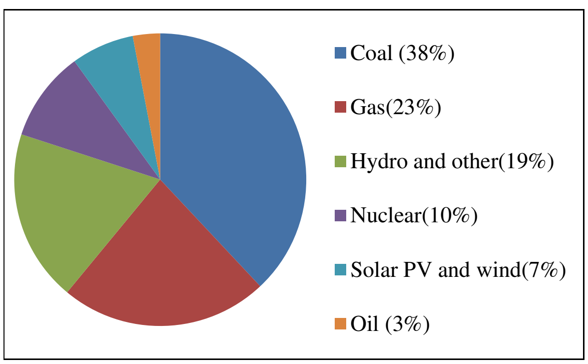

Fig. 5. 2019 World electricity generation

3. DECISION SUPPORT SYSTEMS FOR INTELLIGENT BUILDING MANAGEMENT

From a general perspective, DSS (or Decision support systems) are systems that bring together lot of information from a variety of sources, and this can make easier the evaluation of any kind of assumptions to specific models. In different words, these kinds of systems allow decision makers to access specific data around the organization as they need it to make different choices between alternatives [9].

Living beings are adapted to survive and take thousands and thousands of decisions daily, each time selecting only one from larger sets of possible alternatives, usually based on logic, knowledge, and available information. Survival itself, is based on the fittest decision in each context, from many others available. Even if it's about searching food, safety, or shelter, or it's about the reproduction process and the combination of genes in the chromosomes, survival and the entire activity of human race is based on the cumulative effect of individual decisions. Applying the same principle in process management area, decision support systems are meant to support humans and reduce making of decision, and the multitude of decisions needed to be taken repeatedly on different subjects, from many alternatives available.

As already mentioned, within EU around 75% of buildings are energy inefficient, increasing the energy consumption and the entire Union CO_2 fingerprint. To support the usage of new technologies, as previously exemplified, there is a clear need of intelligent management systems to reduce buildings' energy consumption and improve their energy efficiency.

Decision support systems (DSS) for energy efficiency in the building sector provide tools for building administrators to manage information about the physical infrastructures of the buildings, utilities and functionalities they provide to their inhabitants, as well as to manage the decision process regarding the infrastructure. These includes sensors installed in different areas in the building and tools to collect data from sensors, tools to analyses collected data and present information to automatic algorithms and human administrators and, in some cases, integration with tools to command changes and operations in field, where it is considered necessary. Data analyses is commonly based on historic data on the building, as well as current data from the sensing system. Common data collected by DSS for energy efficiency regards inventories of assets, inventories of functional elements, functional parameters and values, data about the environment, usually based on patterns already known to the system. More data concerns user preferences, behavioral patterns, artificial intelligence generated data on aspects like weather, climate, dangers, habits, etc.

From a functional point of view, simpler systems only collect data and present it to human administrator, leaving the decision and action to him. More complex systems collect and present data and can analyze it and proposing actions considered useful based on historic data and simple algorithms.

The most complex DSSs can also take decisions and apply them on the physical infrastructures based on complex algorithms and actuator systems. Automatic decisions need good algorithms implemented in the system, depending of its desired complexity, and may be based on historical data (e.g. start lighting at night), other defined criteria (e.g. recognize entrance of new inhabitants), or intelligent decisions based on artificial intelligence (e.g. automatic control of physical infrastructure, alert on intrusion of not recognized people etc.). The development of modern control hardware in the last years and the big process time constant allows the implementation of more complex control strategies that can use detailed dynamic models for building [10].

As technology permits more and more improvements in this area, there will be an important switch from simpler systems to more complex ones in buildings management processes, with modular facilities and benefits for inhabitants, as well as buildings administrators.

It is important to say that in a predicting mode DSSs function more in feedforward loops, while in correction mode DSSs function in feedback loops, collecting data and bringing the destination system to a defined model.

As there is no general agreement and standardisation on an architectural model of a decision support system, we are considering a top level architecture of a DSS that includes 4 main functional components, and the general relations between them as presented in Figure 6, below:

- Knowledge base layer, the functional layer of components responsible with data storage. This is where models, data, information about facts, rules and assumptions are stored, aggregated and retrieved, in order to facilitate decision processes. Previous experiences, rules and axioma are stored here in various formats, depending on the destination and operation of the DSS.
- Data collection layer, responsible with the collection and transmission of data to upper layers. This is where actual data is collected from the sources by physical or virtual sensors and transmitted to upper layers. Data depends on the specific domain of application, as well as different formats and standards of representation.
- Processing layer, responsible with the data processing and preparedness for presentation or the decision process. This is where algorithms are found, and the processing is made upon current data, considering historic data, rules, axioma and requirements from the system or its human operator.
- Presentation layer, responsible with presenting data and information to human operators. As data cannot be read in its raw format and need to be presented in a human-readable format, this layer also transforms it for its operators.

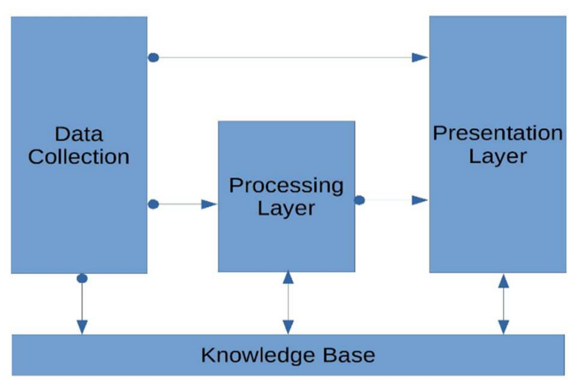

Fig. 6. Decision Support system, simple model and functional relations

As already mentioned, with no standardized and generally accepted model for decision support systems, the above proposed model may be regarded differently in other representations, or its layers may carry different names, structure or relations, with, overall, similar functionalities of the system. Still, it must be mentioned that some sectorial references may be found proposing minimal levels of standardization in liberalized markets.

In the construction sector DSSs may target different areas, with different functionalities satisfying different needs. While in the construction stage of a building, a DSS will target optimizations of work and processes like supply of materials and goods, work program, resources allocation, etc., for buildings in use a DSS will target maintenance activities such as energy management, utilities management, access and security, etc.

In the operation stage of a building, eventually inhabited by humans, the needs are more related to functional usage, comfort, pollution reduction, and other higher-level needs of data/information, decisions or, in some cases, even actions. Therefore, a decision support system will have to target and satisfy those needs by assisting its human operator, or by applying various actions through automatic means, where possible.

In more advanced DSS systems, the processing layer contains complex decision algorithms based on decision trees, machine learning, deep learning, or other artificial intelligence techniques. As well, in areas where physical measures need to be applied on field through automatic means, in integrated management systems information from a DSS may be used for modules containing actuator elements, generally in a dedicated, separate layer, responsible with the application of decisions in the physical, or virtual environments. In a feedback loop data is then retrieved by sensors and verified against known models by the DSS.

Taking into consideration the current technological level, costs and the climate changes, many resources are invested worldwide in methods and technologies to decrease the impact of the climate in the human activity, reduce the energetic consume, and improve waste management maintaining, at the same time, the level of comfort specific to our times. In this perspective, considering the European Union, as already mentioned billions of Euros were allocated in the 2014-2020 period by the European Commission to develop new technologies and improve existing ones. Climate changes will be of great importance in the following decades as well, for EU to achieve the proposed goal of climate neutral by 2050.

Considering the energy area in a building management, a DSS will have to have at least the following functionalities:

- management of utilities provisioning and distribution inside the building;
- management of heat installations;
- management of common lightning installations;
- management of private lightning installations, where appropriate;
- detection and eventual response measures on gases;
- detection and eventual response measures on fire;
- detection and eventual response measures on flooding in common and, where possible, private areas.

These functionalities may regard only data or information on the topics, or in advanced systems, actioning modules may use this data/information in applying human made or automatic decisions on the target system.

4. CONCLUSION

Energy efficiency became a very important factor in designing and building buildings, no matter their planned usage: residential, utilitarian, business, administration, etc. Many resources are currently allocated to develop new innovative technologies, and to improve existing ones in order to reduce humanity energy consumption that contributed, if not originated, the climate changes the world faces in the present.

New buildings need to be built already on energy efficiency principles, and renovated buildings must incorporate new technologies during the process. As well, old buildings need to adapt improved technologies and management systems to reduce their energy consumption.

On a case by case analysis, the decision on whether to renovate a building or take it down and build a new construction should be taken on criteria such as cost efficiency, advantages of the building and long-term environment impact. Analyzing the entire life cycle of a building, among the elements we found common to all situations defining the purpose and usage of a building in a modern society, we need to underline the need for a system to ensure the intelligent use of energy and utilities, adapted to inhabitants' day to day behavior.

The importance of management systems is recognized by the European administration at both, national and Union level. All Member States are having best orientation to introduce new technologies meant to reduce the energetic consume, reduce the CO_2 fingerprint and improve citizens' safety, while maintaining a high level of comfort for inhabitants. As well, at European level important funds are still available for R&D and business development on areas like green economy, blue economy, or environment protection. Of these, intelligent management of energy consumption is of great importance and presents new opportunities to achieve these objectives in the operation of the buildings and will strongly support the long-term visions aiming to reduce the impact of human activity on the environment. Therefore, the market of intelligent systems for optimization of energy consumption will increase in the following years, with a focus on artificial intelligence techniques and improved data management to support the automatic or human decision processes.

With technology also human needs evolve, new data sources are included constantly, and algorithms and equipment are getting smarter. This situation raises new challenges and new risks on technological, and methodological levels. As well, the impact of risks on human rights must be taken into consideration. Cybersecurity and personal data protection are getting very important in all aspects of decision support, information management, or infrastructures management systems, and need to be tackled with care in the following years.

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Sisteme suport de decizie pentru eficientizarea energetică a clădirilor

Rezumat: Dacă e să facem referire la clădirile din zilele noastre, acestea sunt responsabile de consumul de energie la nivel European, de aproximativ 40% și de emisia de dioxid de carbon, în proporție de 36%. În present, aproximativ 34% din clădirile din Europa au peste 50 ani și în jur de 74% din stocul clădirilor este reprezentat de energie ineficientă.În același timp, dacă facem referire la clădiri care sunt în stare degradabila, doar 1% din acestea sunt renovate în fiecare an. Dacă renovăm clădirile existente, putem duce la un număr major de reducere a energie și investițiile în eficientizarea energiei poate să stimuleze la nivel înalt economia, mai ales din domeniul construcțiilor, pentru că putem observă că acestea sunt responsabile pentru 9% din produsul intern brut și în mod direct pentru aproape 19 milioane de locuri de muncă și poate să reducă cu aproximativ 5 procente consumul de energie și de asemenea să scadă emisia de dioxid de carbon cu 5 procente. Lucrarea de față prezintă mai multe beneficia și particularități asupra utilizării Sistemelor de decizie support și pentru creșterea eficienței energiei la clădiri cu ajutorul tehnologiei energiei regenerabile.

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