DEVELOPMENT AND IMPLEMENTATION OF INTELLIGENT ENERGY MANAGEMENT SYSTEMS AND EDUCATION PROGRAMS TO OPTIMIZE RESOURCE CONSUMPTION ON UNIVERSITY CAMPUSES

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Abstract: *The article presents a systematic step-by-step approach to optimizing resource consumption on college campuses through the implementation of intelligent energy management systems (IEMSs) and energy efficiency education programs (3EP). The implementation methodology is discussed, highlighting the stages of evaluation, selection of IEMS, as well as their benefits, functionalities and challenges. We have also highlighted the types, benefits and made a number of recommendations aimed at providing energy resilience to university campuses. The major benefits of this approach are highlighted, including cost reduction, improved energy efficiency, increased awareness and responsibility of students and staff and building a modern and high-performing learning environment.*

Keywords: *intelligent energy management systems, SMART, resource consumption optimization, university campus, education, energy efficiency, best practices, combating climate change, resilience, sustainability.*

1. INTRODUCTION

The world faces a number of major challenges related to climate change and energy security. Population growth, industrialisation and dependence on fossil fuels have led to a significant increase in energy consumption and greenhouse gas emissions, which have a negative impact on the environment [1]. Energy efficiency has become a global priority and is key to reducing CO_2 emissions, fighting climate change and ensuring a sustainable future. Universities, as higher education institutions and research centres, have an important role to play in promoting sustainable practices and energy efficiency.

According to the Agency for Energy Efficiency and Environmental Protection, statistical data on the carbon footprint [2] for people in Romania is 3.85 tons, for the European Union it is 6.8 tons, worldwide we have an average of 4.79 tons. The target for 2050 wants the carbon footprint to be zero.

This paper aims to present an **intelligent energy management system** and **education programs** dedicated to optimizing resource consumption on university campuses. The successful implementation of these solutions will help to significantly reduce energy consumption, CO_2 emissions and operational costs, while increasing energy awareness and student and staff responsibility.

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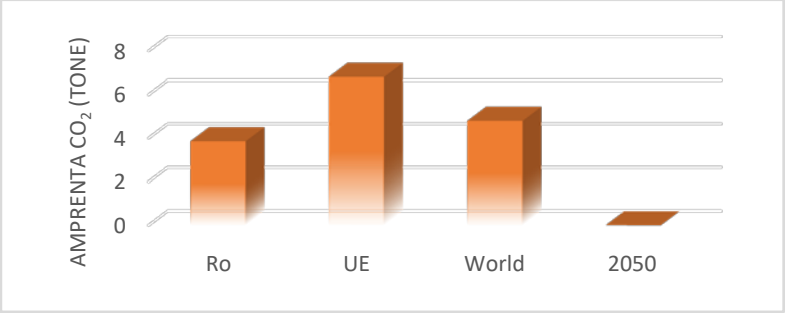

FIG. 1 Statistical data on the carbon footprint for people in Romania, EU, worldwide and target for 2050

2. INTELLIGENT ENERGY MANAGEMENT SYSTEMS (IEMSs)

Intelligent Energy Management Systems (IEMSs) are advanced solutions that use a combination of sensors, actuators, software and intelligent algorithms to optimize energy consumption on university campuses. For a better understanding of them, we will present the benefits, functionalities as well as the challenges of implementing and developing IEMS.

1.1.Benefits of IEMS

The implementation of an IEMS on university campuses can generate a number of significant benefits, with economic, environmental and social impact. Thus, we will point out the most important of these. **Significant reduction of energy consumption and costs** by values between 10-20%, generating significant financial savings. **Increasing energy efficiency** achieved by optimising energy consumption reduces the CO_2 footprint and contributes to combating climate change. **Improving comfort and quality of life** [3] results from the fact that an intelligent energy management system can contribute to improving thermal comfort and quality of life on campus, with staff benefiting from optimal living conditions.

A very important benefit, taking into account the fact that the staff involved is in the hundreds, even thousands of individuals, students, staff and auxiliary staff alike, is **the provision of a more stable and secure energy supply (energy autonomy)** that is expressed by reducing the risk of power supply interruptions and can improve the energy security of the campus.

Stimulating innovation is one of the most important benefits, decisive for university institutions and can be exploited in three major directions:

- **development of innovative energy solutions** by facilitating testing and implementation of innovative energy solutions on campus [4] - The Faculty of Power Engineering within UPB collaborated with a photovoltaic energy company to develop an intelligent solar energy management system;
- **creating research opportunities:** data collected by IEMS can be used for research in the field of energy efficiency and development of renewable energy sources - Transilvania University of Brasov, within the Institute for Research and Development (ICDT) has created a research center [5] dedicated to the development of smart energy solutions, with the support of data collected by IEMS;

- **preparing students for an alternative career in energy:** implementing an IEMS can facilitate students access to new development opportunities.

1.2. Examples of IEMS functionalities:

By analyzing the capabilities and benefits of IEMS, a series of functionalities can be extracted and exploited that can be scaled at the level of the entire university campus.

Collecting, monitoring and analyzing real-time data from various sources (buildings, installations, equipment) to identify areas with high consumption and develop optimization strategies. With access to data and their interpretation, **automatic control and prioritization of consumers** can be achieved to adjust energy consumption according to needs, using sensors, actuators and intelligent algorithms. Also, having information on network behaviors and habits, **demand forecasting** can be achieved by using predictive models to predict energy demand and optimize resource production and distribution.

The integration of renewable sources allows facilitating the integration of renewable energy sources (solar, wind) into the campus energy system, with substantial benefits (energy autonomy and bill reduction) for the campus. **Storing surplus energy** by deploying energy storage solutions (in batteries or as heat) to manage surplus energy produced from renewable sources and use it during peak consumption periods, or when solar source, for example, is no longer available.

1.3. Challenges in implementing a IEMS

Debates on switching to renewable energy systems bring to the table actors for and against alike. Thus, for the successful implementation of an IEMS, it is extremely important to understand, assume and meet the characteristic challenges. We have identified and highlighted four essential elements necessary for the implementation and development of IEMS. **Strategic planning** that includes defining specific objectives, identifying the necessary resources and establishing a detailed implementation plan, customized to the campus layout area, with the particular orientations and inclinations of the roofs of the buildings. Also, close **collaboration** with the active involvement of all stakeholders (university administration, students, staff, energy experts) is essential for the success of the project.

An essential component is **initial investments** that can involve significant costs for the purchase and installation of equipment, as well as for software development and staff training. For this aspect, it is essential to identify non-reimbursable or low-co-financing financing, such as those provided by the Ministry of Energy [6]. **Continuous monitoring** of system performance and regular **evaluation** of the results achieved are essential to optimise the functioning of IEMS and demonstrate benefits.

3. ENERGY EFFICIENCY EDUCATION PROGRAMMES (EEEP or 3EP)

These programs can be the key to a **sustainable future** on university campuses and beyond, as this is where future trainers develop, those who once in society, besides being specialists, develop leadership. **Energy Efficiency Education Programs (3EP)** are not just a necessity [7], but a crucial investment in the future of our planet. Implemented on university campuses, they become catalysts for change, cultivating an energy-conscious and responsible generation.

1.4. Types of 3EP

Following our research, we identified several types of 3EP, each characterized by specific elements and ways of addressing the target audience. We have made a selection of them addressed to the 18-25 age segment, characteristic of the period of attending

university courses. In order to achieve the 3EP goals, we present the selection made with specific promotion modalities and characteristic examples:

Awareness campaigns can be achieved by informing students and staff about energy issues and the importance of energy efficiency [8]. Also, the use of various communication channels (leaflets, social media posts, seminars) to disseminate information and promote a culture of energy efficiency.

A characteristic example can be represented by organizing an awareness campaign with the 3R slogan "Reduce, Reuse, Recycle" which would lead to a significant increase in awareness of energy issues among students [9].

Courses and training programs can be achieved by developing specialized educational programs to provide knowledge and practical skills in the field of energy efficiency. Also adapting programs to different needs and levels of knowledge (students, administrative staff, technical staff). We have identified one of the important players on the sustainable energy market that offers information and specialized courses [10]. Moreover, the company developed a partnership with the **Faculty of Power Engineering** in which they launched a program of specialization courses in the field of energy efficiency for engineering students, which contributed to the training of qualified specialists in this field [4].

The organization of **interactive workshops** and practical demonstrations facilitates learning and active involvement of participants. Thus, by addressing specific topics (such as saving energy in dormitories, choosing efficient equipment) through interactive and attractive methods, a significant change in student behavior is achieved. On November 10, 2023, the Press Office of **Ovidius University of Constanta** announced through a press release that the university organized an interactive workshop for students on renewable energy and energy efficiency within the university. The workshop on ways to reduce energy consumption in dormitories led to a significant change in student behavior [11].

The development of attractive and user-friendly educational materials (brochures, guides, online platforms) aims to facilitate the dissemination of information and promote responsible behaviour. It is very important to adapt the materials to different categories of audience (students, staff, teachers). We have identified a dedicated online platform with information on energy efficiency, educational resources and practical advice for energy saving [12]. Obviously, a very involved actor in promoting educational materials on climate change is the European Commission. It offers on the online website "Practical advice - Ideas for saving energy and protecting the environment, at home and at work" [13].

1.5. Benefits of 3EP

Once the types of 3EP are identified, their benefits become apparent. We mention the 4 most important benefits identified. **Raising awareness** achieved by educating students and staff about energy issues and the importance of energy efficiency. Awareness also leads to the development of a culture of individual and collective responsibility. **Behaviour change** achieved by promoting responsible behaviours in energy consumption, resulting in significant reductions in energy consumption and costs.

The development of practical competences and skills in energy efficiency helps prepare students for a career in energy. **Stimulating innovation** is identified as a major benefit of these 3EPs that aim to encourage the development and implementation of innovative solutions to optimize resource consumption. Supporting research and development in the field of renewable energy and energy efficiency is also a defining objective.

1.6. Recommendations for 3EP Implementation

In order to obtain the expected benefits, we have made a short list with some key milestones. The 5 recommendations, once achieved, increase the probability of obtaining the expected results. A first recommendation is the **needs assessment** carried out by carrying out an energy audit to identify areas with high energy consumption and establish priorities for the 3EP. It is also necessary to consult students, staff and other stakeholders to identify specific needs and interests.

Once the needs are identified, it is necessary **to develop a comprehensive 3EP program** with the inclusion of a variety of educational methods (awareness campaigns, training courses, interactive workshops, educational materials) to reach a wide audience and adapt the program to different categories of audience (students, administrative staff, technical staff).

Following the simulations of the theoretical model**, the implementation and monitoring of the program will be carried out,** ensuring the minimum requirements of the necessary resources (human, financial) for the efficient implementation of the program. Regular monitoring and evaluation of programme results is executed to identify strengths and weaknesses and make necessary adjustments (reactive feedback loop). In order to ensure the success **of the program, the assumed and active involvement of all stakeholders** is required, ensuring the active participation of students, staff, university management and other stakeholders in the implementation of the 3EP. At the same time, the creation of a dedicated 3EP working group to meet regularly to assess progress and take decisions ensures the coherence of the programme and the achievement of the expected objectives.

Full involvement and **use of available resources** to support the implementation of 3EPs, including educational materials, practical guides and funding programmes, ensures a climate conducive to achieving the objectives. Universities are recommended to collaborate and partner with non-profit organizations, government agencies and private companies to obtain support for 3EPs.

4. EXAMPLES OF GOOD PRACTICES AND SUCCESSFUL IMPLEMENTATIONS OF IEMS AND 3PE ON UNIVERSITY CAMPUSES

There are several approaches that can be implemented to increase the energetic efficiency of a building. For example, presence sensors (i.e. Passive Infrared (PIR) sensors) can be mounted in each room (laboratory, class room, other rooms with different functions). If presence is not detected inside a room, both electrical and thermal energy is saved:

- there can be mounted electrically actuated valves at most of the heaters in the rooms. If the presence is not detected for a while, these heaters are bypassed until somebody enters the room (i.e. two of three heaters can be bypassed when nobody is in the room). The central heating equipment will be always running, but the heating agent (i.e. water) will pass only through open heaters, and in this way, its temperature will decrease slower. Therefore the thermal efficiency of the rooms will increase with a minimum cost of electrical efficiency needed to read presence sensors and to actuate the valves.

- similar with the approach above, there can be mounted switches to automatically turn off most of the lights in the rooms where human presence is not detected. Therefore, until the people are educated to be careful with saving the energy (various means of such methods of education are presented in the next chapter), this electronic system will help in electrical energy efficiency.

The presence sensors are only one option to monitor the activity in the rooms, and to increase the energetic efficiency. Hall sensors [14] can be also mounted at the windows (and possibly at doors). If the windows are opened for a longer period, some of the heaters can by bypassed, since the produced heat will be lost. When the windows are closed, the heaters can operate again at their maximum capacity.

Moreover, the rooms in the Universities can be equipped with temperature sensors. If the room is, in some point in time, into the direct sunlight, its temperature can highly increase, and it will be necessary to stop the heaters in that room.

In the same time, other rooms in the same building must be heated, since these are not heated by the sun. Therefore, the central heating system will operate permanently during the working time, but it will heat only the rooms that need it. Therefore, fewer resources to heat the water (or another heating agent) will be necessary.

There are examples around the world where Universities, by adopting different strategies succeeded to achieve important energy savings. For example, at Aarhus University in Denmark, it was decided to switch off all unnecessary indoor and outdoor lighting, considering the importance of energy saving against some visual effects which could exist. However the managers there considered to continue lighting areas in order to maintain safety and security of the building and of the personnel [15]. Also, at this University, they are running ventilation systems in a controlled way, for shorter times, according also with the indoor temperature and with the quality of the air. Other aspects were taken into account, like the closure of some rooms at night or in the weekends, in order to save the energy for heating and ventilation. By implementing different measures to increase the energetic efficiency, **Aarhus University succeeded to save 17% energy for heating and 16% electrical energy** in the winter 2022-2023 compared with the same period from 2019-2002. This University also has a performance in reducing its emissions, as a group of experts have shown in their studies [16].

Besides creating electronic control systems to avoid unnecessary loses of energy, the Universities must keep into account the thermal rehabilitation of their buildings. For example, University of Padua has adopted a plan to reduce the energy consumption, considering also “upgrading heating and cooling plants, replacing windows and doors, thermal insulation of roofs, replacing lighting fixtures and uninterruptible power supplies (UPS)” [17]. This University also has a consistent activity in increasing awareness for possibilities of energy conservation and sustainable clinical laboratories [18].

Obviously, all programmes and systems must be supported financially, and such major projects are often, depending on their scale, dramatically expensive. Therefore, it is recommended to write **projects that can compete for non-reimbursable funds** [19], as proven by the **University of Life Sciences** "Ion Ionescu de la Brad" of Iasi (USV), which will implement its **own photovoltaic plant** [20, 21]. The project amounts to a total value of over 4.8 million lei, funds requested and obtained through the call for proposals "Supporting investments in new capacities to produce electricity from renewable sources for self-consumption", launched by the Ministry of Energy, with financing from the Modernization Fund (FM). The investment plan is the installation of a generous photovoltaic system of approximately 750 KWpeak, made of over 1,700 photovoltaic panels, which will be deployed on 5,000 square meters. All these will be mounted on the structures of the institution's buildings, including the headquarters, canteen, university campus, and within the institution's Teaching Farm. Thus, it is desired not only to reduce the carbon footprint of the university, but also as an example of good practices in promoting renewable energy sources in the academic environment.

CONCLUSIONS

Intelligent Energy Management Systems (IEMS) are an effective solution for optimizing resource consumption on university campuses. The successful implementation of an IEMS can contribute significantly to reducing costs, increasing energy efficiency and combating climate change.

The successful implementation of 3EPs on university campuses requires careful planning, active involvement of all stakeholders and efficient use of available resources.

The benefits of 3EP are significant and can contribute to creating a more sustainable, efficient and energy-responsible university campus.

3EPs are an essential component of an effective energy management strategy on college campuses. Well-designed 3EP implementation adapted to the specific needs of each university can significantly contribute to reducing energy consumption, reducing costs and combating climate change.

The successful implementation of these solutions will help to significantly reduce energy consumption, CO_2 emissions and operational costs, while increasing energy awareness and student and staff responsibility. Smart energy management systems and energy efficiency education programs are essential tools for reducing energy consumption and CO_2 emissions on college campuses. The successful implementation of these solutions requires an integrated approach, with the active involvement of all actors in the academic environment

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