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An Integrated Approach to Energy Management

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Abstract – Energy is consumed everywhere and by everybody, in different circumstances and in different forms. Life itself is based on energy consumption, among other resources. The crisis human societies have faced since ancient times forced us to identify and use better ways to manage energy. A similar but increasingly aggravating situation humanity is confronting at current times, especially when discussing resources availability correlated with climate change, global economic difficulties or the war in Ukraine, and their impact on energy availability. Starting the 1st industrial revolution, organisations, businesses especially, started searching for ways to improve the use of resources and energy, as well as ways to store energy for longer periods of time. Increasing diversification and complexity of technologies lead in time to increased availability of energy as critical resource for human activities but, also, exposed us to various risks directly or indirectly brought by modern technologies. A strong change of paradigm in energy consumption and energy management must be made with respect to the entire life cycle of energy units, to maintain or improve our current lifestyle in the context of the crisis we are facing now, and we are prone to face in the foreseeable future. In this perspective, we need to step away from localized, sectorial approaches of energy, and move toward an integrated and integrative approach of energy management, focused on 3 important pillars – behaviour (regarding regulations/standards), technology (ICT/ICS technologies), and education.

Keywords: Energy management, integrated approach

I. INTRODUCTION

All crisis situations (e.g., climate, energy, financial, the war at EU border, etc.) guide us to improve resources management and cost control, hopefully with better outcomes in terms of benefits to both, human society and the environment. Limited availability of natural resources, energy included, as well as profitability constraints, correlated with a growing acknowledgement of climate changes and other crisis we are confronting, lead to an increased focus on the need to reduce energy consumption and optimise technological processes to limit the impact of human activities on the environment (Mariano-Hernandez et al., 2021). Environmental education, environmental economics, or engineering, standardisation, interoperability, infrastructure consolidation, energy management, etc., are strong characteristics of the 4th industrial revolution, also known as Industry 4.0, leaning towards increased productivity and efficiency, improved products, and services, reduced consumption of resources, reduced wastes, improved reuse, and recycling. Tendencies in optimizing production processes and activities on a large scale were observed from the early stages of industrialisation and reached the current level over long periods of time, with important costs and consequences on the environment (Klaus Schwab, 2015). Many efforts were made to improve production and delivery workflows, to save energy and costs, to reduce the environmental footprint of human activities while increasing profits and maintaining an optimum level of benefits.

In this perspective, all processes managing production, transport, consumption, and recycling of energy units, to optimize activities and reduce energy usage fall under the concept of energy management system (EnMS). In 2015 the Directorate for Science, Technology, and Innovation – Steel Committee of OECD defined an Energy Management System as "a systematic process for continually improving energy performance and maximising energy savings. The principle of an EnMS is to engage and encourage staff at all levels of an organisation to manage energy use on an on-going basis." (Organisation for Economic Co-operation and Development, 2015). Even if it refers only to organisations, it represents one of the most comprehensive and easily understood definitions of an energy management system.

II. INTEGRATED APPROACH IN ENERGY MANAGEMENT

Until recent years traditional implementations of energy management systems focused on procedures implemented at organizational level to ensure

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conformity to different standards families, such as: ISO/IEC 9000 on quality management, ISO/IEC 50000 on energy management, ISO/IEC 14000 on environmental management). The standards do not apply directly to householding, or professional activities of consumers but still, the standards apply to them indirectly through the standardized functional and technological characteristics of the goods and services they purchase from the market.

The current outlook to energy management, focused on a sectorial, distinct approach, is no longer sufficient for the successful evolution of human society on Earth, and an improved and more reliable approach to energy focused on synergic understanding and integrative measures should be pursued. Thus, with respect to the technological advancements of our times, energy management cannot be approached any longer only from procedural perspectives, as one may understand from the provisions of the ISO 50000 family of standards, but need to deepen on the technological and educational layers more than the standardisation suite recommends at the time of writing. Also, though ISO/IEC 50000 standards are meant to be applied by legal persons (organisations, by their legal definition), their provisions are, as well, useful to common people in managing their homes and other infrastructures they use. Therefore, the present paper concentrates on the need to extend the classical perspective of procedural approach in energy management systems to an integrated one, capable to provide an adapted response from us as individuals but also as an entire society, to current energy and climate provocations the entire globe is facing.

In these perspectives, we are considering a 3-pillars approach of energy management focusing on behaviour pillar (also referred in the paper as the regulations and standards pillar), technology pillar (also referred in the paper as the ICT/ICS technologies pillar), and the educational one, each of them with their own functional and relational attributes. For its effective implementation, it needs to be applied on all social and economic sectors involving natural resources and/or pollution, adding upon the benefits of technology advancements, data usage, and modern education means, with respect to new potential risks brought by modern technologies to the safety and security of people, infrastructures, data, and the environment (Fig. 1).

An integrative approach to energy management, applied to all types of human activities leads to a systematic management of the life cycle of energy units – prospect, production, transport, consumption and (waste) recycling. While the entire life cycle of energy units is important, the consumption phase bears a heavier relevance due to the critical resource status of energy, the benefits it brings to people and the potential effect of its results on the environment.

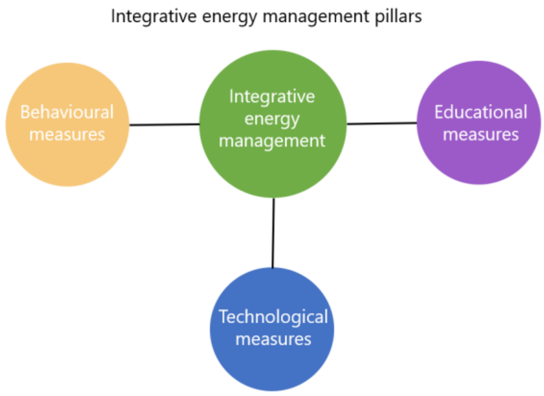

Fig. 1. An integrative energy management approach (IEMA)

Building on the traditional model of an energy management system (EnMS) based on procedural implementations, the paper focuses on the need to expand the traditional concept of energy management to an integrated and integrative perspective of a system of systems type, adding. The pillar of procedural measures and the technological one commonly addresses the organizational level in companies that build infrastructures, which create goods and provide services, while the pillar of educational measures mainly targets the beneficiaries of built infrastructures, equipment and services provided by the market.

This approach comes to build on the principles introduced in the classical implementation of energy management systems, similar to the integrative outlook brought by the present 4th industrial revolution, as highlighted by K. Schwab since 2015 (Klaus Schwab, 2015). Integrated perspectives over energy efficiency and energy management came into attention in the last years in many research papers on sectorial basis (Saletti, Morini and Gambarotta, 2022), (Tian et al., 2018), (Hu et al., 2022), (Liu, Jian and Jia, 2023), (Brandi, Gallo and Capozzoli, 2022), (Arab, Rekik and Krichen, 2023), (Mahmood et al., 2022), (Tan et al., 2023), (Wang, Zheng and Yang, 2023), (Viesi et al., 2023), but still need to get traction for a broader approach as proposed in the present paper.

As it is not the purpose of the paper to detail each pillar but to emphasize the need for an integrative approach of all 3 of them, in the following sections we will briefly review the meaning and influence of the pillars on energy management, based on a SWOT analysis on each pillar.

III. SWOT ANALYSIS ON AN IEMA

A SWOT analysis was performed to highlight several aspects considered on the opportunity to introduce an integrated energy management concept. The analysis is presented in a synthetic form, as follows:

Table 1. Summary on the procedural pillar.

Strengths	**Weaknesses**
• Compliance enforcement • Voluntary compliance • Common framework • Large scale • Consistency, sustainability	• Difficulties in enforcement process • Costly, time consuming • Challenging cybersecurity
Opportunities • Tighter regulations • Harmonized standards	**Threats** • Market pushbacks • Risks of ineffectiveness

Table 2. Summary on the (ICofICS) technology pillar.

Strengths	**Weaknesses**
• Performance improvement • Interoperability • Optimization • Real-time operation • Informed decisions	• Higher implementation costs • Difficult pace keeping with technology progress • Cybersecurity risks
Opportunities • Technology improvements • Informed decisions • Energy technologies integration • Improved energy units' life cycle	**Threats** • Difficult backwards compatibility • Difficult adaptation • Privacy concerns

Table 3. Summary on the educational pillar.

Strengths	**Weaknesses**
• Easier, large-scale adoption • Improved awareness • People empowering • Sustainable, responsible culture	• Long application time • Difficult resources availability • Illiteracy obstacles
Opportunities • Sustainable mindset • Continuous learning • Wider audience with Internet	**Threats** • Difficult scalability and effectiveness • Resistance to change

1) Strengths:
   a) On the regulatory/standardisation pillar:
      i) Facilitates compliance enforcement for legal actors (organisations, by their legal definition) to energy efficiency and environmental management regulations, standards, and codes.
      ii) Facilitates voluntary compliance for small legal actors or other persons interested in energy efficiency and environmental management.
      iii) Provides a common framework for implementing, measuring, and monitoring energy management practices.
      iv) May be applied at larger than national scale, for signers of international treaties and agreements.
      v) Promotes consistent and sustainable energy management across industries and sectors.
   b) On the ICT and ICS technologies pillar:
      i) Enhances the performance of energy management systems.
      ii) Facilitates technological interoperability and integration between different technologies, with different purposes.
      iii) Facilitates the automation and optimization of energy management systems.
      iv) Allows real-time monitoring and control of energy consumption.
      v) Supports informed, data-driven decision-making processes in organisations, to improve their energy efficiency.
   c) On the educational pillar:
      i) Facilitates a general adoption of energy efficiency and environmental management principles on a large scale.
      ii) Improves awareness and understanding of energy management concepts.

   iii) Empowers people to adopt energy efficient practices and act for present and for future generations.
   iv) Promotes a culture of continuous sustainability and responsible energetic behaviour.
2) Weaknesses:
   a) On the regulatory/standardisation pillar:
      i) Legal compliance and regulation/standard enforcement may be challenging to some actors, considering regional/national regulations, market development level, or general climate conditions.
      ii) Updating or adapting regulations and standards to keep pace with technological advancements may become expensive in terms of cost and time, especially for smaller private legal persons.
   b) On the ICT and ICS technologies pillar:
      i) The initial investment costs for implementing ICT and ICS technologies may be high.
      ii) Technological advancements may be too fast for interested actors to keep up with.
      iii) The fast rhythms of cybersecurity threats and vulnerabilities identification may raise important challenges especially for private legal persons in ensuring a sufficiently robust cybersecurity environment.
   c) On the educational pillar:
      i) Widespread adoption and behaviour changes may take time to effectively manifest on the market.
      ii) Ensuring the availability of comprehensive and accessible educational resources can be challenging.
      iii) Illiteracies rates, especially in disadvantaged communities, may act as important obstacles.
3) Opportunities:
   a) On the regulatory/standardisation pillar:
      i) The increased focus on energy efficiency and sustainability creates opportunities for tighter regulations.
      ii) Collaborative efforts between governments, industries and other stakeholders may lead to better globally harmonized standards.
   b) On the ICT and ICS technologies pillar:
      i) Technological advancements offer strong opportunities for private actors to further improve technologies and energy management.
      ii) Better data may translate into better, informed decisions for policy makers.
      iii) Integration with smart grids and renewable energy sources can optimize energy consumption and reduce dependence on fossil fuels, facilitating an improved environmental management.
      iv) The entire life cycle of energy units may be improved and friendlier with the environment.
   c) On the educational pillar:
      i) Integrating energy management into formal education programs can foster a sustainable mindset from an early age.
      ii) Continuous learning for adults can be a source of future benefits in terms of energy management.
      iii) Promoting or education campaigns and initiatives may use social media tools to reach a wider audience and facilitate faster acknowledgement and behaviour change.
4) Threats:
   a) On the regulatory/standardisation pillar:
      i) Resistance or pushbacks from industries in the application of regulations or standards that can be perceived as burdensome or costly.
      ii) Inadequate estimations on resources of market actors and enforcement capacity may undermine the effectiveness of regulations or standards application.
   b) On the ICT and ICS technologies pillar:
      i) Too rapid technological advancements may lead to backward compatibility issues and the need for frequent updates or replacements.
      ii) Too rapid technological advancements may endanger private actors' capacity for adaptation, increase costs and lead to slow technologies adoption.
      iii) Potential privacy concerns about personal data collection and use may increase public skepticism and social movements against technology.
   c) On the educational pillar:
      i) Limited resources or funding for energy education programs can hinder their scalability and effectiveness in both children's education and adult continuous learning.
      ii) Overcoming the resistance to change among certain individuals or communities may prove challenging.

Based on the aspects highlighted by the SWOT analysis performed on the integrated energy management approach, some conclusions can be drawn:

An integrated approach to energy management, consisting of 3 pillars – the behavioural pillar (also referred in the paper as the regulatory/standardisation pillar), ICT and ICS technologies and educational measures –, provides significant potential to improve energy efficiency, sustainability, and care for the environment. Identified strengths include establishing clear regulations and standards, enabling effective monitoring and control through ICT and ICS technologies, as well as promoting awareness and behaviour change through educational initiatives. These strengths provide a solid foundation to promote energy efficiency practices and care for the environment. However, a series of challenges need to be addressed as well. Compliance and enforcement issues can arise due to differences in regulations or standardisation measures of governments, while high initial investment costs and cybersecurity risks may become important obstacles to an integrated approach of energy management. In addition, achieving widespread adoption and behaviour change through educational measures requires long-term commitment and availability of resources. Technological challenges, in terms of compatibility, interoperability, technology generated risks or privacy need to be considered as well.

The increased focus on energy efficiency and sustainability creates a favorable environment for stricter regulations and harmonized standards. Technological advancements offer opportunities to improve energy management systems, integration with smart grids and renewable energy sources. Integrating energy management into formal education programs and leveraging digital platforms can reach a wider audience and facilitate behavior change. However, it is essential to be aware of potential threats. Industry resistance, limited enforcement resources, compatibility issues, cybersecurity risks and privacy concerns may alter expected progress. Furthermore, low availability of resources and resistance to change may pose serious challenges in approaching an integrated energy management.

In conclusion, an integrated energy management approach has substantial potential to improve energy efficiency and sustainability. By capitalizing on strengths and opportunities, addressing weaknesses, and mitigating threats, stakeholders can work together to create a more sustainable and energy efficient future. Collaboration between governments, industries, educational institutions, and communities will be the key to the successful implementation and promotion of the integrated energy management approach.

IV. OVERVIEW OF THE BEHAVIOURAL PILLAR

The first, and most accessible pillar we need to consider when discussing energy efficiency in all its aspects, is the behavioural one. Considering that among the main triggers of common people's behaviours are rules and norms applied in the society - known under the legal designation of policies, regulations, and standards –, the pillar will also be referred to as the regulation and standardisation pillar. Thus, behaviour management manifests, in this situation, mostly through regulations and standards on energy management applied mainly to legal and private persons (Fig. 2).

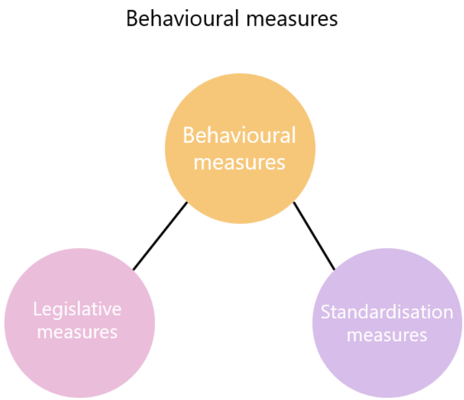

Fig. 2. Behavior management pillar.

The regulation layer is closely dependent to each country's strategic approach on global market positioning, natural resources exploitation, energy production and usage, waste management, acknowledgement of climate crisis, and the impact of environment protection measures on its economy. A rising level of interest in energy management and climate change is shown by all nations, each of them facing different kinds of challenges according to their positioning, climate, and landscape. In this perspective, relevant global or regional agreements were signed by many countries, an appropriate example being the 2015 Paris Agreement signed by more than 120 countries around the globe (United Nations Climate Change, 2018). Thus, despite the differences between national legal frameworks, all nations show strategic interest in solving issues related to energy management and the environment, to provide a stable foundation for all economic sectors development. Classical examples are the construction and the automotive sectors, which are some of the most economically performant and resource consuming sectors. We must note the fact that all developed nations and trade blocs implement, or plan to implement similar strategies and regulation packages, in a common effort to reduce human activities' influence on the environment and limit climate changes.

Aspects related to influence of different sectors' regulatory frameworks on energy sector has been for many years subject to research papers, few representative examples being: (Hamza and Greenwood, 2009), (Li and Sun, 2020), (Bellini and Bonoli, 2018), (Zhou and Wang, 2022), (Kott and Kott, 2018), (Kott, Mrzyglocka-Chojnacka and Kott, 2019)..

Regarding the standardisation layer, the most important family of standards to consider when discussing energy management is the ISO/IEC 50000 series. The first one in the series, ISO/IEC 50001, is the procedural standard globally accepted on energy management, being focused on standardising procedures and behaviours in organisations, with the main objective to reduce energy consumption and increase efficiency, using procedural implementation of energy management systems (EnMS). An energy management system implementation in an organisation stands on two essential pillars: management commitment, and personnel contribution. Immediate, as well as long term results of ISO 50001 energy management system implementation one will observe, are improved monitoring of consumption, better usage of energy, and optimised workflows, all of them leading to better management of energy inside an organisation, improved cost control and increased revenues on every consumed energy unit. The latest version of the standard is ISO/IEC 50001:2018, and contains the "requirements for establishing, implementing, maintaining, and improving an energy management system (EnMS). The intended outcome is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance and the EnMS." (International Organisation for Standardisation, 2018).

While ISO 50001 deals with the implementation of EnMS in organisations, ISO 50002:2014 specifies the common requirements for energy audits regarding the energy performance of the organisations that implement or have implemented ISO 50001. Also, as standard provisions clearly state, it is applicable to all types of organizations and all forms of energy. ISO 50002 defines an energy audit as a "systematic analysis of energy use and energy consumption within a defined energy audit scope, in order to identify, quantify, and report on the opportunities for improved energy performance" (International Organisation for Standardisation, 2014). Tthe standard defines energy efficiency as a "ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy" (International Organisation for Standardisation, 2014).

An intended compatibility is easily observed between ISO/IEC 50001 and ISO/IEC 14001 – the baseline ISO standard on environmental management. This perspective facilitates voluntary compliance with both standards, and emphasises awareness on the relation between resources consumption, wastes, and the impact of human activities on the environment, with a deeper focus on energy management. Due to their common aspects, we expect ISO 50001 and ISO 14001 standards to drag each other's adoption and get hand in hand wide acceptance by the market. While both standards had, so far, a very limited impact at global level – with about 19000 ISO 50001 certified organisations, and less than 313000 ISO 14001 certified organisations as highlighted by ISO in a 2019 survey (International Organisation for Standardisation, 2022) –, important efforts need to be taken by advanced nations to support wide acceptance and adoption by most market actors, in terms of investments, stimulus, technology, standardisation and planning.

Aspects related to provisions above were already analysed in detail by authors such as (Ofori et al., 2023), (Daddi et al., 2022), (Andersen and Bams, 2022), (Ikram et al., 2020), (Johnstone and Hallberg, 2020), (Johnstone, 2020), (Mosgaard and Kristensen, 2020).

We should emphasize that both families, ISO/IEC 50000 and ISO/IEC 14000 contain several standards, with much wider applicability in terms of energy and environmental management in human, professional activities.

Conformity with ISO 50001 and ISO 14001 represents a voluntary choice for organisations, not an obligation, even if some of their requirements are already in the common sense (e.g., turning of the lights in unused rooms, adapting air conditioning settings to weather and indoor conditions, turning off the engine or air conditioning in unused vehicles, etc.). Thus, it is to be expected that many organisations will comply entirely or partially, but not necessarily certify to any of ISO/IEC 50000, ISO/IEC 14000, or even ISO/IEC 9000 global standards families. Therefore, common measures that may be adopted to reduce energetic consumption without a formal certification include better indoor climate control, more efficient lighting solutions (LED, presence sensing, etc.), turning off equipment outside working periods, optimising workflows, improving logistics, etc.

The baseline standards ISO/IEC 50001 and ISO/IEC 14001 are adapted to all types of organisations interested in a systematic approach to energy and environmental management, they are not intended for direct application by common people. Still, everyone may find inside principles and methods to apply in their own environments, thus making ISO 50001 and, eventually, ISO 14001, a general guidance set largely applicable to energy and environmental management measures, instead of formalized standards targeting only legal persons. Another aspect worth emphasizing is that the standards apply indirectly to all persons through the functionalities and limitations of technologies for energy distribution and consumer usage, technically making everyone subject to regulations and standardization. Behavioral pillar measures apply to all members of a state, subject to the national or sectorial regulations and standardisation.

V. OVERVIEW OF THE TECHNOLOGICAL PILLAR

When considering the technological aspects of energy management systems in various industries or sectors, such as the construction, automotive or production sectors, the first thing we need to consider is the fact that an EnMS is a collection of ICT and ICS technologies and infrastructures designed to manage planning, monitoring, control and optimising activities for production, transport, and/or usage of energy units, while maintaining an expected and constant level of functionality and comfort for users. Waste management resulting from the usage of energy units is also of great importance, with an important impact on energy efficiency and environmental management (Fig. 3).

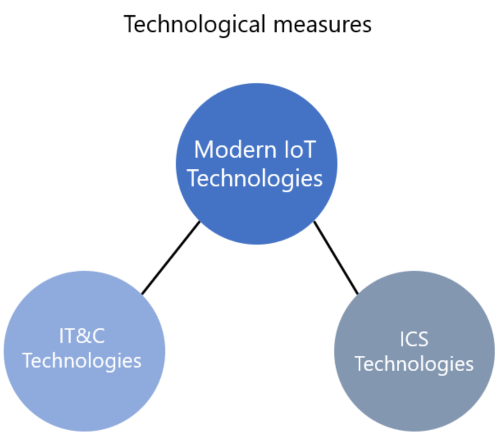

Fig. 3. Technology management pillar.

There is an intrinsic relation between the organisational and the technological perspective of an energy management system, better highlighted within the recurrent application of the PDCA (Plan, Do, Check, Act) improvement cycle. The output of one becomes an input to the other in a continuous loop, with measurable results in terms of reducing an organisation's energy footprint, a general reduction of consumption and waste, and increased productivity and efficiency. Thus, modern smart technologies provide improved control of energy use, stronger integration with means belonging to the behavioural perspective, and facilitate informed, better decisions on energy management by people and organisations.

Considering the multidisciplinary characteristics of modern technologies, with respect to the topic of the paper, we see as a certain fact that common or highly specialised technologies are used congruently in sectors such as construction, automotive, industrial, or agricultural production with the purpose to increase energy efficiency and reduce the impact on the environment. Among these technologies we find general engineering technologies and materials, fuels, materials science, ICS technologies (e.g., SCADA technologies, (Industrial) Internet of Things, data communications, data protocols, automatic control systems, sensor elements and actuators, data processing and visualization), ICT infrastructures (e.g., hardware infrastructure, software components, networking, and cybersecurity equipment) etc. The resulting level of technological integration means that an energy management system can be considered in an integrated perspective as a system of systems that operate independently of each other but controlled and correlated, exchange data with each other and possibly with a system central administration, resulting in an increased energy efficiency of a system (building, vehicle, etc.) while maintaining or increasing the level of safety, functionality and comfort to its users.

Another element that must be accounted for from a technical perspective in energy management systems, in addition to the effective application of planned measures through devices and technical equipment, is represented by the quality of the measurements. Data quality and their proper timely representation, generally regarded as data correctness, are some of the most important aspects in the digitalization field, valid in any field of activity. In all areas, including energy management and energy efficiency of physical infrastructures managed by EnMSs, data correctness must be ensured throughout their entire life cycle, depending not only on the result of the operational or historical processing of the data in question, but also on the decisions made by human decision-makers or artificial intelligence systems based on the available data. From a technical point of view, energy management systems may be regarded as control systems based on a mix of modern ICS and ICT technologies for monitoring, controlling, and optimizing energy consumption inside and/or outside a physical system/infrastructure, including the operation or usage of managed infrastructures. The use of data collections, their temporal sequencing, sensory and actuation technologies, combined with data calculation and analysis technologies, allow a more efficient use of energy, in all the forms energy may be found. Thus, this means that the performance and accuracy of an energy management system directly depend on the accuracy of measurements of the controlled parameters, and their interpretations. Changes in the technical, environmental or control parameters that may occur in the measurement or actuation equipment, result in data changes in the data storage, processing, and presentation system, directly influencing all human or automatic decisions regarding energy management. Electrical or electronic "noise" in physical measurements can alter energy management decisions in the same way.

Considering the long history of ICS technology applications, the subject was comprehensively covered in scientific papers in the last 40-50 years. The last decade marked the transition from traditional ICS technologies to (Industrial) Internet of Things, also covered extensively in scientific papers. Still, some subjects like those related to reliability, cybersecurity, remained constant in time independent to the economic sector, as may be seen in papers such as (Lun et al., 2019), (Li et al., 2019), (Dong et al., 2022), (Li et al., 2019), (Sándor et al., 2019), (Fitz, Theiler and Smarsly, 2019), (Oks et al., 2019), (Asghar, Hu and Zeadally, 2019), (Bharathidasan et al., 2022), (Georgiadou, Psarrou and Askounis, 2023), (Sanders, Bronk and Bazilian, 2022), etc.

In optimization, aspects related to data transmission are subject to similar conditions and constraints. As well, constraints regarding cyber security of energy management systems need to be pondered carefully, due to its impact on the ICS/ICT systems, data, the managed physical infrastructures, or the people using them. The usage of artificial intelligence technologies also presents new challenges from induced controlling and privacy perspectives, which need to be managed in the future, including the ethical use of artificial intelligence.

Similar aspects on the impact of data quality in smart environments were covered by many scientific papers, such as (Sha and Shi, 2008), (Canto et al., 2015), (Morewood, 2023), (Koziel et al., 2021), (Kim et al., 2022), (Bi et al., 2022), (Alwan et al., 2022).

In addition, the impact the continuous digitization and the miniaturization of electronic components and equipment have in the design and implementation of energy management systems is expected to make the share of automatic energy management systems grow continuously. As well, the technological mix of ICT and ICS technologies, the use of advanced sensor technologies and actuators such as modern SCADA or (I)IoT technologies, cloud computing or artificial intelligence technologies will lead to a general increase in energy efficiency and better control over consumption.

The increased use of smart devices in day to day professional and domestic life rests itself on a few pillars. Among them, the growing technological complexity of production and services' processes, improved functionalities, technological accessibility, energy consumption and security – physical and cyber security. Aspects related to soft functionalities, accessibility, presentation, or physical security might be handled by users, based on easier learning processes.

Instead, aspects regarding hard-coded functionalities, technological complexity, energy efficiency and cybersecurity are most of the time hardwired in the equipment and provide no real control to users. In this perspective, energy efficiency and cybersecurity of smart equipment and systems must be carefully pondered at both, manufacturer, and user levels, to ensure the optimizing of risks and a reduced energy footprint while maintaining the appropriate level of functionality and design of products and services.

Therefore, they need to be approached at a technological level by the manufacturers, and at a behavioural level by users, based on policies, regulations and standards enforced by governments. A third option considers a common, integrated approach, using optimizing management methodologies and systems. To better facilitate these approaches common, easily accessible procedures, functions and tools must be in place for all users, providing intuitive and easy to understand functionalities and interfaces.

An additional impetus is currently given to the increase of energy efficiency in all possible ways, by the energy crisis and the war launched by the Russian Federation in Europe due, on one hand, to the medium and long-term impact on the availability of energy resources and its effect upon the basic needs of mankind as well as, on the other hand due to the negative effect on the environment and climate changes that will further limit the ability to satisfy people's needs on large scales, beginning with their basic ones (water, food, home, security).

On the opposite side, we must highlight the fact that increased use of electric and electronic technologies, especially old and obsolete technologies, leads to increased levels of energy consumption, if not carefully pondered. However, it is highly expected that the digitization process of automatic processes in energy management systems will continue in an accelerated manner in a way that maximizes the benefits for energy systems at the expense of the negative impact on consumption and the environment.

In addition, considering specific markets trends such as the accelerated migration to electric means of transport, thus generating a growing pressure on national and even global energy systems, energy efficiency becomes increasingly important in today's world.

VI. OVERVIEW OF THE EDUCATIONAL PILLAR

The third pillar to consider in an integrated approach of energy management, the educational one, must increase public knowledge in energy management and its societal and environmental consequences to common people and youngsters, supporting actual efforts to reduce human impact on the environment while maintaining energy availability as strategic resource. As well, awareness and educational activities should facilitate future efforts on reducing energy consumption, optimizing activities, and developing new, innovative technologies aiding in achieving the proposed purposes (Fig. 4).

In a traditional approach, still dominant in the research community and public literature(Kang et al., 2021), (Mitra et al., 2020), (Chen et al., 2021), (Guo et al., 2020), (Lu and Lai, 2018), (Pelenur and Cruickshank, 2012), (Vogel, Lundqvist and Arias, 2015), (Lia et al., 2021), (Fuchs, Aghajanzadeh and Therkelsen, 2020), (Majaty, Touzani and Kasseh, 2023), the educational approach in adult populations in developed countries manifest mostly in professional environments and is mainly related to the implementation of ISO standards on energy or environmental management. An increasing importance gets the component of environmental education in schools, which is expected to facilitate a greater level of attention and empathy to environmental problems, in mature ages. Although the component does not explicitly address aspects of increasing energy efficiency, it deals with aspects of reducing energy consumption with an impact on increasing the efficiency of the use of energy units, regardless of how they are manifested.

User behavior can have a significant impact on the energy efficiency of a building, vehicle or other types of physical built infrastructure and the effectiveness of an energy management system in managing energy consumption. Examples are at hand in this matter, such as users in a building using excessive lighting or air conditioning, unjustified use of electrical equipment or utilities.

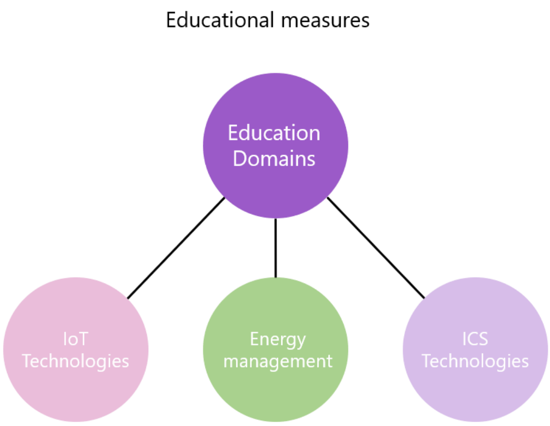

Fig. 4. Education management pillar

All these types of behavior lead to higher levels of energy consumption at infrastructure level with significant impact at community level (e.g., excessive, unjustified use of cold water or hot water in dry areas, excessive use of electricity during low levels of production, etc.) or the environment (e.g., large quantities of waste, household garbage, air/water pollutants, etc.). Users can also voluntarily reduce the efficiency of indoor air conditioning systems by using them when the air conditioning is not needed or by opening windows when the indoor air conditioning is on. Similarly, when users of a built infrastructure voluntarily and unjustifiably increase temperature settings, or when they do not turn off lights and electrical and electronic equipment that are not in use, an energy management system cannot achieve its energy saving potential. At the same time, in the case of smart EnMS systems, if the users of a building, vehicle or other type of physical infrastructure do not follow the indoor climate recommendations provided by EnMS, the system may not be able optimize energy consumption as effectively.

In addition to the technological mechanisms for adapting energy management systems to the way of occupying and using an artificial infrastructure, to overcome the high influence of user behavior on energy efficiency, it is important to first educate the occupants or users of physical infrastructures about the importance of efficient behavior from an energy efficiency the point of view and encourage them to adopt energy-saving habits. All ways should be used to transmit the message to common consumers, starting from the family and early school ages to mature adults' public information and continuous learning.

Thus, we appreciate that general aspects of increasing energy efficiency must be addressed systematically and consistently throughout people's lives. Relying only on commercial or government level demand response programs based on incentives or costs, it might not be enough to cover all aspects related to energy efficiency and, in strong correlation, environmental management. We also appreciate that demand response programs have a measurable impact only in their implementation period and with limited effect in the long term. Leaving a defining, prolonged impact on general habits of the population, in terms of increasing energy efficiency and reducing energy consumption, requires a much more comprehensive and longer approach to education.

As already mentioned, other aspects such as the level of knowledge regarding cyber security can influence the behavior of a user of energy management systems and can significantly alter their ability to optimize energy consumption and increase energy efficiency.

In uncorrelated ways, aspects related to education and its long-term influence on energy efficiency and energy management were subject to scientific papers for the last 30 years. Facts on these subjects may be found in papers such as (Bowonder, 1984), (Newborough *et al.*, 1991), (AlFaris, Juaidi and Manzano-Agugliaro, 2016), (Sučić, Anđelković and Tomšić, 2015), (Ahir and Chakraborty, 2021), (Xu *et al.*, 2021), (Xie *et al.*, 2021), etc.

VII. CONCLUSIONS

Increasing the energy efficiency of human activities can no longer be reduced only to voluntary compliance of organizations with environmental and energy management standards. It is necessary that all processes throughout the entire life cycle of an energy unit become compliant with a multisectoral integrative (but at the same time as personalized as possible) set of norms, rules, standards, and technologies that leads to a general reduction of energy consumption and the amount of waste generated by human activities. The crisis situations that humankind is currently going through, as well as the level of technological development, make a new integrative approach to the concept of energy management system as necessary as possible. As the energy efficiency of infrastructures manifests itself at all stages of the life of a building, a vehicle or another type of built infrastructure, the processes that must be considered are not only very diverse, but also of different difficulties and complexities, requiring distinct approaches on the at least 3 major pillars of action: a behavioral/procedural pillar, a technological pillar and an educational one.

Considering the duration of use of a physical infrastructure controlled by an energy management system, the usefulness of measures to increase energy efficiency takes on new dimensions that change with the purposes of using the infrastructure, as well as with the general technological evolution that brings continuous changes of raw materials, materials, technologies, and technological processes applied throughout the entire life of the former. Energy management has, through all its valences, a major potential to increase the efficiency of the use of limited natural resources, to increase energy efficiency and to reduce the energy impact of controlled infrastructures, on the environment, while maintaining an acceptable level of utility and comfort for their users.

Many of the aspects we raised in the paper were reviewed over time by many researchers, mostly in a limited, sectorial approach. As technology evolves and continuously provides new opportunities, considering the current stage of the climate crisis and other present or predictable crisis (e.g., energy crisis, financial crisis, wars at EU border and other places in the world, etc.), our society needs to follow a new, improved, comprehensive, path to energy efficiency.

The synergic approach to energy efficiency through 3 main pillars – the procedural, technological and educational pillars – will lead to a better perception of energy efficiency in population and will have the effect of accelerating the implementation of the necessary procedural and technological measures for the entire lifetime of an energy unit. Therefore, efficient usage of energy in human activities requires a day-to-day management of energy consumption on both, professional and personal levels, the use of dedicated technological systems and social responsibility, in order to identify an equilibrium, point between costs and benefits at individual, societal and environmental level. The educational perspective operates on both, procedural and technological layers, in the most direct way, as common understanding and acceptance of rules and technologies represents the key to successfully implement energy management in professional and personal environments.

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