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ICT SYSTEMS IN REDUCING ENVIRONMENTAL IMPACT – A WAY TOWARDS SUSTAINABILITY?

SYSTEMY INFORMATYCZNE JAKO INSTRUMENT REDUKCJI ŚLADU ŚRODOWISKOWEGO – DROGA KU ROZWOJOWI ZRÓWNOWAŻONEMU?

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Summary: The article discusses the issue of the evaluation of IT solutions in terms of sustainable development. Information systems manufacturers are increasingly showing interest in the market of pro-environmental services. The products they offer are to fit into the sector related to the reduction of energy intensity, renewable energy sources as well as waste management and recycling. However, there are many doubts about the benefits as well as the legitimacy of using such solutions. The article attempts a preliminary analysis of the potential benefits and problems that may occur using the example of a household energy consumption management system. The analysis takes into account the negative environmental and social effects that co-occur in the dissemination of IT solutions. These effects, often overlooked or not considered at all, constitute an important component of growth barriers for the entire ICT sector.

Keywords: sustainable development, ICT systems, environmental impact, energy consumption.

Streszczenie: W artykule omówiono kwestię oceny rozwiązań IT pod kątem zrównoważonego rozwoju. Producenci systemów informatycznych wykazują coraz większe zainteresowanie rynkiem usług proekologicznych. Oferowane przez nich produkty powinny pasować do sektora związanego ze zmniejszeniem energochłonności, odnawialnych źródeł energii, a także gospodarki odpadami i recyklingu. Istnieje jednak wiele wątpliwości co do korzyści, a także wiarygodności korzystania z takich rozwiązań. W artykule podjęto próbę wstępnej analizy korzyści i problemów, które mogą wystąpić, na przykładzie systemu zarządzania zużyciem energii w gospodarstwie domowym. Analiza uwzględnia negatywne skutki środowiskowe i społeczne, które współwystępują przy rozpowszechnianiu rozwiązań informatycznych. Efekty te, często pomijane i w ogóle niebrane pod uwagę, stanowią ważny element barier wzrostu dla całego sektora ICT.

Słowa kluczowe: zrównoważony rozwój, systemy informatyczne, efekt środowiskowy, zużycie energii.

1. Introduction

The negative impact on the environment is inextricably associated with civilization activities. However, the feature of a sustainable economy is to develop a way to manage the environment in such a way that it does not lead to the permanent deterioration of its condition. It is trying to achieve this through the implementation of specific concepts of economic development. These concepts include models of sustainable production and consumption, and very important elements of these models are the reduction of energy and resources consumption. The effective management of energy and resources consumption is seen as a success factor for the successful implementation of both concepts. However, it is necessary to use the appropriate supporting instruments to obtain the right level of efficiency. The obvious direction in this case is the development of the appropriate IT tools. These tools can perform monitoring and control functions as well as act as decision support systems. The most frequently used applications include: management of energy consumption in buildings, support for distributed generation in the smart grid structure, evaluation of the carbon footprint, management of complex transport systems and support for recycling systems (Catulli and Fryer, 2012).

Despite the above-mentioned applications, the widespread use and dissemination of information systems is also associated with the necessity of using raw materials for the production of the IT infrastructure and the consumption of the energy necessary for its operation. In some cases these costs can probably be offset by the potential benefits. Moreover, environmental costs related to IT development are also becoming more and more important, which leads to attempts to estimate the environmental barriers of growth for the IT sector. It is a significant fact that the concept of environmental barriers is being applied to the sector generally considered as having no major impact on the environment. In this context, an interesting issue is whether the more intensive use of information systems is one of the means of implementing the transformation towards a sustainable economy, or is it one of the blind development paths leading to a deepening of the environmental crisis? An initial assessment of the factors related to the problem is the main goal of the article.

The first part of the article is focused on a description of the research methodology and smart-home system concept. The second part contains an analysis of the possible limitations and problems related to the production and use of ICT systems in households, with particular emphasis on environmental issues. The article ends with a summary and outline of future research directions.

The adopted methodology is theoretical studies combined with an analysis of the literature on the subject. The analysis took into account scientific publications from the Springer, Wiley and Elsevier databases as well as industry publications and reports. The search publications focus on the keywords: "ICT systems", "sustainability", "smart home systems", "environmental limitations". The aim of the analyses was to obtain a consistent picture of the possible limitations for the scenario of universal digitization, with particular emphasis on households.

2. ICT systems for home energy management

The reduction of energy intensity use is one of the most important environmental goals. It is often emphasized that the reduction of electricity demand must concern both the industrial sector and households. The great importance attached to this issue is demonstrated by the fact that the development of energy consumption management systems is one of the most important development areas of EU research projects (Gram-Hansenn and Darby, 2018). In both cases it is assumed that there are unjustified energy losses which can be eliminated by better monitoring and supervision. In the case of households, the concept of a smart home is proposed to fulfill this requirement. Such a system consists in sensors, measuring devices, communication infrastructure and home appliances which are supervised by control software (Yassine, Singh, Shamim Hossain, and Muhammad, 2019). This allows for the remote management of devices and monitoring of energy consumption in real time (Mbarek, Meddeb, Jaballah, and Mosbah, 2017). The data collected in this way, on the amount of energy consumed by individual devices, frequency and time of use, and daily use cycles should constitute a repository for the analytical part of the system (Lago, Roncuncio, and Jiménez-Guarin, 2019). One of the main tasks of the analytical part is to discover patterns of use of individual devices (Monekosso and Remagnino, 2007). Determining the patterns of using electricity will allow to discover potential ways to reduce the energy consumption (Ford, 2017). The schematic concept of the smart home system is presented in Figure 1.

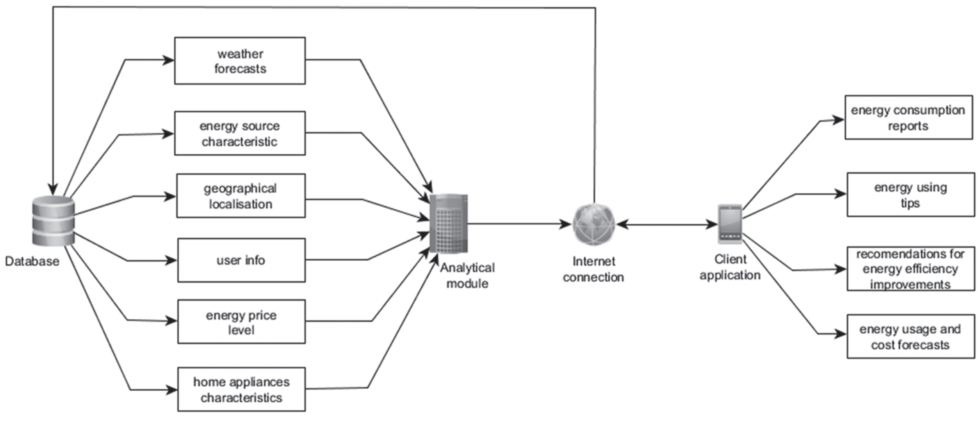

Fig. 1. Data sources and outputs for smart home energy management systems

Source: own elaboration.

A smart home system should include in its architecture some basic modules: data acquisition and storage, analysis as well as visualization and presentation (Rodriguez Fernandez, Cortes Garcia, Gonzalez Alonso, and Zalama Casanova, 2016). The acquisition module requires the ability to obtain data from various sources, with different formats. Examples of data sources include: weather forecasts (Beaudin and Zareipour, 2015), controllers of renewable energy sources infrastructure (Shakeri et al., 2018; Hemmati, 2017), information about the inhabitants of the house (Jin, Baker, Christensen, and Isley, 2017), current pricing tariffs and load on energy networks (Beaudin and Zareipour, 2015) and technical and operational characteristics from household appliances (Zhou, Wing Chan, Cao, Lin, and Wang, 2016). This list is of course not closed. The collected data constitute a repository for the analytical part of the system. The analytical part uses currently read values as well as archival data (Al-Faris, Juaidi, Manzano-Agugliaro, 2017). The tasks of the analytical part are mainly solving multi-criteria optimization problems (in order to minimize energy consumption) and performing forecasts regarding energy consumption and the efficiency of renewable energy sources (Barbato et al., 2014). An optional functionality is the ability to generate summaries and reports combined with recommendations. These recommendations are intended to indicate critical areas of energy waste and to induce users to change their behavior (Iwafune, Mori, Kawai, and Yagita, 2017). The degree to which users adapt to the recommendations is closely related to the effectiveness of the system.

3. Limitations and drawbacks of the ICT-based approach to home energy management

Despite the optimistic vision of ICT systems in managing energy consumption, there are also a number of doubts and probable limitations for their universal application. Such limitations and problems can be considered in technical, economic, legal, environmental as well as project categories.

One of the most important technical issues is the security problem. According to the latest design trends, the smart home concept is to be largely based on the Internet of Things (IoT) technology. The use of this concept is also one of the most important safety risk factors (Sha, Wei, Yang, Wang, and Shi, 2018). IoT technology should definitely be assessed as relatively immature and vulnerable to various threats posed by malicious software (Symantec, 2019). In this case, access by unauthorized persons would have far stronger consequences than with traditional computer systems. These effects would include the possibility of interference in the functioning of household appliances, providing physical access to the building (Sha et al., 2018) or the disorganization of the functioning of the power grid in the smart grid system (Otuoze, Mustafa, and Larik, 2018). Along with the expansion of the scope of the tasks and growing expectations regarding effectiveness, the need for more intensive data acquisition and more advanced analytics also increases. It is expected that the data stream present in the system will become more and more intense. This involves the need to provide a network infrastructure with the right bandwidth as well as disk space necessary for archiving and storing data for analysis. The problem here seems to be the need to develop data exchange standards for smart devices. The lack of such a standard will mean that the entire burden of the integration of devices within the system will be transferred to the software manufacturers.

Environmental controversy is focused around the net environmental effect. Despite optimistic technical assumptions, the situation is encumbered with the strong risk of stimulating negative consumptive standards in recipients. Such behavior can be related to the desire of obtaining the most effective system operation by regular upgrading its executive elements. Replacing household devices with newer models which offer more and more sophisticated possibilities of configuration and operation automation will involve the generation of large quantities of hazardous waste (besides the fact that the replaced devices can be fully operational and capable of still being used). Another issue raised by users is also the lesser energy consumption of new devices. If such a scenario came true, the environmental benefit resulting from reduced energy consumption in households would not be able to compensate the environmental cost related to the disposal of the replaced devices and the production of new ones.

Furthermore, a controversial issue that would require more in-depth studies is the actual achieved degree of energy savings. A more frequently encountered appeal to users is for them to not leave electronic and electrical equipment in stand-by mode, but to completely cut off the power. There were also assumptions of the legal regulations which would require producers to design products devoid of the possibility of using this mode. Smart household appliances must however be powered the whole time, among others, due to the necessity of maintaining the functioning of the network interface. The degree of using this approach must therefore be evaluated in detail in the future. It is impossible to exclude that, with the mass utilization of this technology, the environmental benefits resulting from the ability of the more accurate control of household appliance operation would be illusory. This trend could become strengthened along with the forecasted increasing degree of household equipment automation.

An important problem is also the need to obtain the raw materials necessary to create the hardware part of the system. The most critical part of the problem is to ensure the availability of non-renewable resources, especially rare earth elements (Iddri, 2019). The extraction and processing of these raw materials is associated with high economic and environmental costs. Interestingly, these costs are rarely included in the final assessment of the impact of the high technology sector on the environment (Lean ICT, 2019). The situation is exacerbated by the very low level of recycling (below 1%), of key raw materials for the electronics and renewable energy sectors (Binnemans et al., 2013).

The positive environmental effects include the strengthening of some positive market trends. These trends include the strengthening of demand for energy-saving household appliances and renewable energy source systems. Obviously, the demand for such devices would show a growing trend regardless of the existence of such a product as the energy consumption management system. Nevertheless, any stimuli that strengthen this trend must be deemed positive. Another issue is the scale of this impact. At this point it is necessary to state that (as yet) the demand for energy-saving household appliances and renewable energy source systems substantially outperforms the demand for energy consumption management systems which are still perceived as a technological novelty. A greater scale of impact could occur in the case of the dissemination of such solutions. The dissemination would, however, depend on the development of other sectors including, among others, energy-saving construction engineering. The development of such sectors would create a market environment which could favorably affect the ability of promoting and disseminating such systems.

It is also necessary to mention the accompanying social effects. The use of a home energy management system implies, to some degree, interference with residents' habits (Smale, van Vliet, and Spaargaren, 2017). It is important that this interference should not be significant and does not cause a radical change in the behavior and manner of using the home. Otherwise, any potential for energy efficiency improvement will remain unused (Balta-Ozkan, Davidson, Bicket, and Whitmarsh, 2013). As with other products, also in this case the interest will not occur with the same intensity among all social groups. It is expected that there will be consumers with more interest, as well as groups not interested in this kind of solutions (Shin, Park, and Lee, 2018). Unquestionably, similarly to other technological novelties, the described solutions will be substantially more of interest to households with a relatively good financial situation. This means that the described solution will have little chance to contribute to the improvement of the situation of households affected by energy poverty. This may lead to a paradox. The tool that allows reducing energy consumption and energy charges is mainly intended for people for whom the reduction of energy use costs is not a fundamental necessity. On the other hand, people interested in obtaining such benefits are excluded from using them. Naturally, savings in energy expenses even for some households bring a positive social effect, but it must be viewed as moderate.

The design problems have the most general nature. One of them is the imprecisely specified purpose of using IT systems in households (Kirsten and Derby, 2018). One of the primary applications of these systems was the rationalization of energy consumption, then other potential applications were proposed. According to these proposals the possible applications are: integration with the infrastructure of renewable energy sources (Avancini et al., 2019), remote supervision over sick and disabled persons (Garcia-Rodriguez, Martinez-Tomas, Cuadra-Tronsco, Fernandez -Caballero, 2015) and finally – a general tool for raising the level of life's comfort. The variety of possible applications allows us to assume that some of the tasks to be carried out by the system will be antagonistic (e.g. the function of optimizing the use of home appliances versus the desire to use entertainment facilities at certain times of the day). It is also possible to create conflicts arising from the priorities assigned to particular system functions. A probable scenario may be the assignment, by one of the users, of the highest priority to achieve the maximum level of energy savings, even at the expense of decreasing the comfort of life. This attitude will probably be in conflict with the expectations of other users. In this situation the effective fulfillment of its functions by the system becomes doubtful.

5. Conclusion

The European Union's environmental policy puts more and more emphasis on the refusal to consider energy and raw materials. According to the new approach, these are to be elements that are managed, not just consumed. IT systems are supposed to help in this management. Their mass application, along with the proliferation of renewable energy sources, might enable energy consumers to participate more actively in increasing energy efficiency. This activity aims, in a global perspective, at enabling the transformation towards a zero-emissions economy. It is hard to resist the impression that these assumptions are formulated in an overly optimistic way. Energy consumption by the ICT sector is growing at a rate of 4% per year (Lean ICT). The common use of smart home systems must be related to the even faster rate of consumption growth. So there is a real risk that instead of the expected improvement, the situation will actually get worse. This situation is, by analogy, similar to the announcements to eliminate paper documentation thanks to the dissemination of IT systems in the administration. Nothing similar to this has happened so far. This leads to the assumption that mass digitization may turn out to be a blind development path. A retreat from this path will probably be very expensive and will involve the absorption of a large amount of resources, however this idea should not be seen as a total fiasco. Most likely it can be very helpful in connection with the progressing social changes related to the ageing of society. The potential for distributed generation in the smart grid system is also very important, and this application seems to be one of the most promising. However, the successful application depends on many factors, one of the most important is the willingness of consumers to change the paradigm of their behavior. Without this, even the most sophisticated technical means will not be able to bring about a significant effect. The ultimate recommendation must therefore be far-reaching caution and adopting a sceptical attitude towards enthusiastic visions of universal digitization.

The analysis of economic growth barriers, especially environmental ones, is becoming an increasingly important research area. The research direction is to estimate the level of such barriers for various types of industries, including the sector of high technologies. Therefore, the future research direction will be related to detailed analyses of environmental barriers for digital products and services.

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