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Energy Management and Monitoring Systems in Buildings - Do the Technologies Meet Expectations?

Energiemanagement- und Monitoringsysteme in Gebäuden - Erfüllen die Technologien die Erwartungen?

Masterarbeit

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1. Introduction

In the lights of the recent events, for instance the increasing nature catastrophes all over the world like dramatic wildfires; for example in Australia, Turkey and California, USA; droughts, heavy rainfalls; for example in western Germany and New York, USA; or global warming (World Meteorological Organisation (WMO), 2021), it becomes apparent that sustainability and climate protection are more important than ever and must be the main priority for governments, companies and every human being. In fact, the Intergovernmental Panel on Climate Change identified that “Human-induced climate change is already increasing the frequency and intensity of many weather and climate extremes in every region across the globe” (WMO, 2021, p. 5). To give an illustration, the aftermath of this are temperatures of around 50 degree Celsius in Canada or severe flooding in Germany with more than 180 deaths, both in 2021 (WMO, 2021). Whereas those events would not have been as drastic without the human-caused climate change (WMO, 2021). To achieve climate protection, the most recent agenda for sustainable development, from the United Nations (UN), wants - among other aims - “to ensure the lasting protection of the planet and its natural resources” (United Nations (UN), 2015, p. 6). One important point is to use the global resources efficiently. In fact, the increase of energy efficiency is said to have the biggest impact on stopping climate change (Beretitsch & Wonner-Beretitsch, 2017).

Conversely, buildings consume over a third of the energy worldwide, wherefore they account for the largest share, and produce one third of the global greenhouse gases (Allouhi et al., 2015; American Council for an Energy-Efficient Economy, 2018; International Energy Agency (IEA), 2020; United Nations Environment Programme (UNEP), 2020). Furthermore, the worldwide energy demand of the building sector is predicted to constantly increase over the next years, as can be seen in Figure 1.

In general, there are two types of buildings. The first one is residential, which are buildings where people live in. The other type is non-residential, which describes “a building, that is not used for people to live in” (O'Shea, 2011, p. 571). To give an example, this type includes office buildings, hospitals, shopping centres, industrial buildings but also restaurants and retail. Due to the use of those buildings, they can be owned publicly or privately, for example by companies but also individuals.

Overall, the demand for energy increases faster from non-residential buildings than from residential buildings (U.S. Energy Information Administration (EIA), 2013; Allouhi et al., 2015).

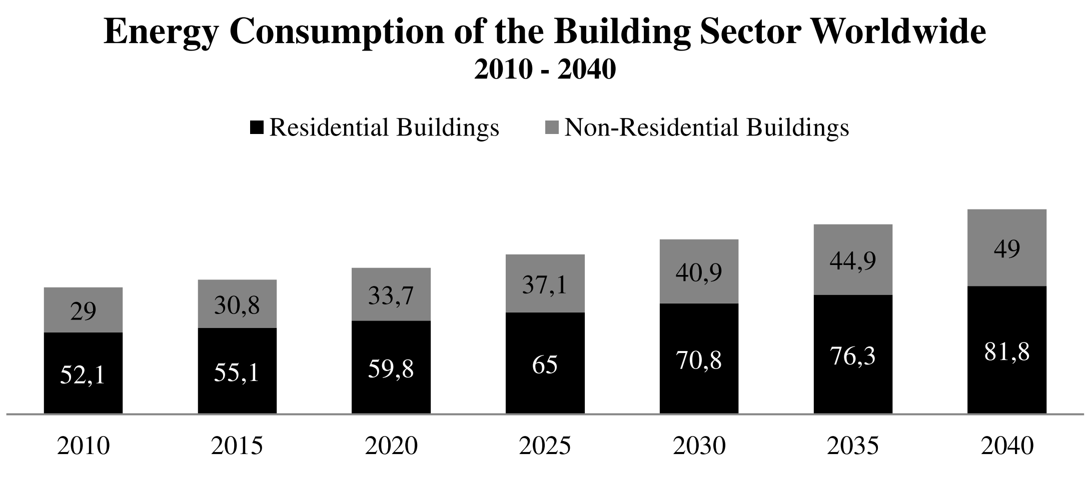

Figure 1 - Energy Consumption in Building Sector worldwide

Source: Own Creation based on EIA (2013)

Moreover, the buildings in the European Union (EU) are even responsible for about 40% of the overall energy consumption (European Commission, 2020). Coupled with that, nearly 80% of the buildings in the EU do not perform energy efficient, which means they waste a lot of energy (European Commission, 2020). For this reason, buildings need to use energy sustainably and perform more efficiently. The researcher Vlachokostas even goes as far as to say “more energy-efficient buildings is an imperative need” (2020, p. 649).

In Germany alone there are around 21.7 million buildings for residential and non-residential purposes. From them nearly 2.7 million are non-residential buildings (NRB), who account for over a third of the energy consumed by all buildings in Germany (Beretitsch & Wonner-Beretitsch, 2017; Deutsche Energie-Agentur GmbH (dena), 2019; Bundesministerium für Wirtschaft und Energie, 2021). Slightly more than ten percent of the buildings are responsible for over a third of the energy consumed by buildings in Germany. More specifically, each non-residential building has a four-times higher influence on the overall energy consumption than a residential building. In fact, office buildings and retail stores consume the most energy of the NRB (Allouhi et al., 2015). As there are fewer NRB it is possible to increase the energy efficiency of those faster and with less effort than when targeting residential buildings (Beretitsch & Wonner-Beretitsch, 2017). For all of those reasons, the focus in this thesis lies on buildings with no residential purpose.

Additionally, there are several reasons why building owners aim to reduce the energy use and increase the energy efficiency of a building. They are either based on economic reasons, like cost reductions, or increasingly environmental reasons, for example to reduce the impact of a building on the climate change. Moreover, political aims and governmental regulations can advance the involvement of an owner. The desire for a better operation of both the technologies and the building or for a comfortable atmospheric environment can also cause investments into energy efficiency increasing measures (Buckman, Mayfield & B.M. Beck, 2014; Yuan, Farnham & Emura, 2015; Beretitsch & Wonner-Beretitsch, 2017; Girbig, 2017; Vlachokostas, 2020).

Two solutions to increase the energy efficiency of a building are the “optimal management of energy resources” (Vlachokostas, 2020, p. 656) and “more sustainable energy system[s]” (Rocha, Siddiqui & Stadler, 2015, p. 203). The management and monitoring of energy consumption were identified as a possible solution to reduce the energy consumption and also the impact a building has on its environment (Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA), 2013; Mulville, Jones & Huebner, 2014; Yuan, Farnham & Emura, 2015; Bhutta, 2017). More specifically, Energy Management and Monitoring Systems (EMMonS) are expected to improve the energy efficiency.

Even though, the need for energy efficient buildings is not new there were only few studies which analysed the existing systems like EMMonS and whether they actually support the operation of a building or even could reduce the energy consumption. Moreover, most papers concentrated on presenting or inventing more technologies and systems. Besides, they focus on such technologies for residential buildings, but only a few cover non-residential buildings. Over the past years more companies talked about using EMMonS or similar technologies to monitor their NRB performances and energy consumption, but it is questionable whether they just have installed them or actually effectively use them (Buckman, Mayfield & B.M. Beck, 2014; Gagula & Lützel, 05.05.2021). In addition, the German Federal Office for Economic Affairs and Export Control (BAFA) stated, that there is no detailed market analysis so far for energy management due to the lack of a broadly valid definition for EMMonS, a huge variety of suppliers and no separate sells, as Energy Management is mostly sold together with devises or technologies (BAFA, 2013, p. 26).

In fact, the overall investments into energy efficiency of buildings accumulated to 152 billion USD in 2019 of which more than half was spent for the envelope, and the other half for heating, ventilation, air conditioning, lighting or appliances (UNEP, 2020). However, those are only a small part of the total spending on building constructions and renovations which sum up to 5.8 trillion USD worldwide in 2019 (UNEP, 2020). Building owners invest around 2.6% of the total spending into energy efficiency in a building. Then again, European building owners, especially from Germany, have decreased their investments in contrast to the previous years (IEA, 2019).

For those reasons, the question arises whether it is reasonable for building owners to decrease their investments. In other words, were the made investments effective and even more important can the implemented technologies like EMMonS meet their expectations and are a solution to fight climate change. Hence the Research Question (RQ) for this study was formulated as follows:

Do the implemented EMMonS contribute to the increase of energy efficiency and the reduction of the energy consumption in a building?

In order to answer this question, the remainder of this paper is organised the following way. To begin with, Chapter 2 defines EMMonS to have a cohesive understanding of the systems. In Chapter 3 the methodology explains how the interviews are conducted, who provide the primary data for the study. Moreover, the qualitative content analysis, which is carried out subsequently, is described. Afterwards, the results of the analysis, including the developed codes, are presented in Chapter 4. Next, Chapter 5 discusses the results and answers the RQ. Moreover it gives recommendations for what needs to change in the future. Following this, limitations of this research and potential for future studies is explained in Chapter 6. Finally, Chapter 7 concludes this study.

Additionally, a potential topic for future research is alternative energy resources for buildings, whose increase is also part of the SDGs (UN, 2015). They bring a whole new perspective to the topic of energy efficiency of a building, which could not be considered in the scope of this research.

Likewise, the differentiation of automated, intelligent and smart buildings, like Buckman, Mayfield & B.M. Beck (2014) did in their research, was not taken into the analysis as that would have brought another level to the whole topic and made it even more complex than it already is.

All things considered, the whole topic is multifaceted and has lots of potential for more research. Above all, with the given amount of time and resources, this research was able to generate a very good insight of the non-residential building market of EMMonS. More specifically, it provides a good orientation of short-comings and required changes for the further success of the systems.

7. Conclusion

In the context of climate change and the increasing awareness of the dangerous human influence on it, it is essential to find solutions that reduce the extents of climate change. Moreover, as buildings account for the largest share of the energy consumption and produce a large amount of the emissions, but are a necessary element of human lives, it is crucial to make them more sustainable. In order to do so the increase of the energy efficiency in combination with a reduction of the energy consumption of a building, were identified as a potential solution. A way to achieve this would be through EMMonS.

However, only a few studies actually analysed, whether such systems fulfil their expectations or if companies use them for their building operation. For this reason, the research at hand aimed to identify the current implementation of such systems and their impact on the energy consumption of buildings. To be specific, the research question asked whether the implemented EMMonS contribute to the increase of energy efficiency and the reduction of the energy consumptions in buildings. To answer the question, a couple of expert interviews were conducted with employees from companies which either offer or could implement such systems. In fact, a qualitative analysis of the content from the interviews was executed. During the analysis multiple codes were created, that structure and summarise the interviews in order to deduct whether the systems meet their expectations.

In the first step, it was deemed necessary to comprehend how participants in practice understand EMMonS. Accordingly, the EMMonS had to be defined prior to analysing the interviews in order to have a solid independent knowledge of the systems. Conversely, there was no uniform definition of the systems in the literature, which is why a model, that explains the systems, was created in the beginning of this paper. Afterwards, the understanding in practice was identified and then compared to the model. To summarise, it was difficult to differentiate and define the systems based on the interviews. In particular, every interviewee and company had a different understanding of the terms. Then again, some companies seemed to lack knowledge more than other companies concerning the topic. It became clear, most companies, that should install the systems in their buildings, are no experts in the field. The model developed seems to display the topic and included most aspects the interviewees brought up. In fact, the model combined the understanding of all the interviewees and only needed little adaptations after the interview analysis, to cover all aspects.

Based on this understanding of the systems, it was analysed how and which systems are used in practice. Overall, the providers offer a great variety of solutions on the market. Yet, the costs and functions are not fully transparent and tend to confuse the building operators. Moreover, the demands and requirements from the adopters and in accordance the implementation status of the systems is very diverse. In addition, the interviewees from adopting companies gave a good inside look of how the companies feel about the technologies and how familiar they are with them. Even though EMMonS are not fully understood by most interviewees, some have good systems implemented already. All in all, most of the questioned companies use EMMonS to some part, in fact most of them use Energy Monitoring. Yet, the involvement and awareness needs to increase a lot to achieve more and really create an impact that can help to mitigate the climate change. By contrast, this finding is contrary to the opening paragraph, which identified that companies refrain from investing what little they deemed necessary so far in the topic. Hence, the investments need to increase, but should most definitely not decrease.

In brief, the companies make use of various measures to operate their buildings, which have various outcomes. More specifically, an efficient building operation requires a mix of measures consisting of maintenance and reparations or if those are not possible anymore modernisations and replacements, but also employee trainings, audits and other things. In addition, every company has slightly different incentives and demands to implement the systems. However, the easier handling of buildings and technologies, coupled with the requirement to save money are essential incentives to implement EMMonS so far. Furthermore, it was noted that some companies felt the implementation and use of EMMonS could be completed at some point like a construction process, although the operation of such systems, in order to increase the energy efficiency of a building, is a continuous process. In addition, the demand and supply of the support and services for the implementation and operation has to develop and be revised in the future, because it is crucial for the systems success. In brief, the findings highlight the complexity of the topic, as there is no one way to succeed but multiple factors influence the efficient operation of a building.

Overall, it was identified that Monitoring is a tool that enables a building owner to be aware of the building performance and its energy consumption. In addition, EMMonS are useful for the whole process of increasing the energy efficiency, as they can help to discover improvement potentials, to implement measures and also to check them afterwards. As a result, the research question can be answered as the technologies proved that they are a tool to support building owners and through which energy consumption can be reduced and energy efficiency improved. In other words, yes, EMMonS live up to their expectations. However, the companies and the government are the hampering factor to the success and the potential impact those systems could have, if they would be implemented and operated correctly and as effectively as possible. Only if the companies and governments become fully involved and invest in EMMonS, those systems can reduce the overall impact of buildings on the climate. Yet, this is not what happens in practice so far.

In conclusion this paper identified the impact of EMMonS in practice and gave an inside look on the market. Moreover, it identified some required changes to improve the success of the systems and their impact on decreasing the impact of climate change. In fact, the supplying companies need to be more transparent and explain the systems better. In addition, this needs to be supported by coherent legal guidelines, regulations and specifications from the government. Correspondingly, the adopting companies need to inform themselves and become more invested in the topic. To that end, the investments in such systems should not decrease yet as the topic is not - and will not ever - be finished. For this reason, companies and governments need to take responsibility immediately and need to stop holding back or treating the topic like it is not a deal anymore.

"*The future of humanity and of our planet lies in our hands. (...) We have mapped the road to sustainable development; it will be for all of us to ensure that the journey is successful and its gains irreversible*." (UN, 2015, p. 16)