Monitoring the energy behavior of SMEs before and after Energy Efficiency measures: A case study

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***Abstract*—European Union's target to achieve climate neutrality until 2050, along with the increase in energy costs, boosted the interest on improving energy efficiency (EE) in companies and especially in the small and medium-sized enterprises (SMEs). The SMEmPower Efficiency project, a HORIZON 2020 funded project, aims to address this issue by proposing a holistic approach. This includes also energy checks in real cases, i.e., SMEs. In this paper, a project pilot SME is presented and analyzed based on its real consumption and production measurements. The energy monitoring, targeting and verification (M&T&V) tools are used for the company's energy data before and after the energy check. The adoption of the EE measures is evaluated using the M&V tool and the obtained results are compared to the CUSUM methodology.**

Keywords—CUSUM, energy check, energy efficiency, M&T&V, small and medium-sized enterprises

I. Introduction

The "Fit for 55" package reflects the European Union (EU) targets towards reducing the energy consumption and achieving climate neutrality until 2050 [1], [2]. A set of measures are proposed through the "Fit for 55" package to reach the target of 55% reduction in greenhouse gas (GHG) emissions by 2030, compared to 1990, aiming to make Europe climate-neutral by 2050. Part of this set is the Energy Efficiency Directive (EED). Article 8 of the EED promotes energy audits and the adoption of suggested measures by companies. Although such energy audits are not mandatory for the small and medium-sized enterprises (SMEs), requirement for Member States are included to develop programmes that encourage SMEs to undertake energy audits and implement energy efficiency (EE) measures. Besides, the increase in the energy costs, globally and independently of the type of energy carrier, boosts the need to reduce energy consumption, focusing on EE measures, in compliance with the EU policy targets related to climate neutrality.

Nevertheless, EE is not a high priority for SMEs, as concluded from a survey taken place in 213 SMEs, in 10 European countries [3]. Lack of interest, time and motivation on EE issues has been identified as the main cause, partially due to the fact that SMEs are not obliged to appointing an energy manager and to undertake energy audits. [4]. Also, high pay-back period, and lack of funding are the main barriers.

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Considering that the SMEs represent the 99% of the enterprises and the 60% of the employment worldwide [5], consuming more than the 13% of the global final energy and, in Europe, they are responsible for about the 64% of the overall environmental impact [6], it can be assumed that they constitute a significant area for employing EE measures to reduce the energy demand [5].

As analyzed by several empirical and theoretical researches, SMEs represent an enormous energy saving potential [7] – [10]. An average of 5% of energy demand reduction was achieved by implementing short payback period measures proposed by energy audits in 280 SMEs under the PINE Intelligent Energy Europe project [7], corresponding to 6,500 toe savings and 13,500 tn GHG reduction per year. Several other attempts towards EE improvement are made by performing consumption analyses [8] or by using specialized tools [9], as a pre-audit analysis. Analysing the company energy consumption is a significant step to be performed before the energy auditing. A widely used technique is the linear regression for tracing the corelation between the energy consumption and the production in the SME [8]. In [9] the measurement and targeting (M&T) tool is used, to estimate the EE targets by exploring energy consumption data. By extracting the consumption trends, EE measures can be identified. The cumulative sum of differences (CUSUM) methodology is also used for energy data analysis in order to identify the best period to be used as a baseline for the M&T or to monitor the energy consumption trend of a company [10].

Scope of this paper is to implement the above well-established methodologies for energy monitoring on a pilot SME and to evaluate the impact of EE measures adopted. The M&T and measurement and verification (M&V) methods, along with the CUSUM method have been applied to a real data case, as used within the SMEmPower Efficiency project.

The rest of the paper is organized as follows: Section II describes the SMEmPower Efficiency project, its targets and outcomes. Section III presents the proposed methodology to perform the energy analytics and the results are presented in Section IV. Section V concludes the paper.

II. THE SMEMPOWER EFFICIENCY PROJECT APPROACH

A. General perspective

The objective of the HORIZON 2020 SMEmPower Efficiency project is to empower SMEs to undergo energy audits and use the proposed measures, towards the improvement of their EE and the achievement of energy and financial savings. To do this, a holistic methodology has been chosen to address the existing barriers that currently prevent the implementation of such actions. As a first step, during the first period of the project, the existing barriers were investigated through surveys, seeking feedback by SMEs located at the 8 project participating countries, namely Cyprus, Germany, Greece, Italy, Romania, Slovenia, Spain, and the U.K., as analyzed in [4]. Results of the survey showed that there is a lack of awareness among the SMEs personnel and decision makers regarding the importance of the EE, from both energy and financial perspective. Most of the companies do not consider EE as a high priority, while also the majority of them is not well informed about the existing funding opportunities in their countries. However, another finding from the analysis was that the staff of SMEs is generally keen on attending training to improve skills and competencies. And this is a gap that the SMEmPower Efficiency project aims to bridge.

Thus, the project has been built on three dimensions, i.e., the Individual, the Organizational and the Institutional. In the framework of the Individual dimension, an integrated Education and Training (E&T) program of level 6 of the European Qualification Framework (EQF) has been designed and delivered, once every year, in the project participating countries [11]. Even though targeting mainly at energy related SME staff, the courses attracted participants with different educational and professional background, people interested in gaining specific knowledge on the procedures to improve the EE specifically in SMEs. The E&T program at each one of the project participating countries has been certified with five European Credit Transfer and Accumulation System (ECTS) credits. The training courses provided a solid background on the technical design and on the financial analysis, required to support the implementation of cost-effective EE improvement measures in enterprises. Moreover, the trainees became more familiar with the procedures for improving the EE in SMEs by working on real case with data provided by companies participating as pilots in the involved countries.

This action was strongly connected to the Organizational dimension of the project, targeting the SMEs decision makers. In this framework, after the conclusion of the so-called practical action, during which the E&T program participants implemented energy analysis for the participating companies and identified targeted efficiency improvement measures, the extracted results were presented through short trainings in-house. The key staff of the companies, top level management and decision makers, were thus informed on the EE measures for their company and the existing funding opportunities, facilitating the decision-making processes towards the implementation of such measures.

As for the Institutional dimension, it included targeted workshops for SMEs decision makers, stakeholders from financial institutions, energy experts, and people interested in the improvement of EE in SMEs. Throughout the duration of the project, three workshops were delivered at each of the participating countries, during which the existing barriers in the implementation of energy saving measures, the funding opportunities and the relevant policies were discussed. The interested parties came together and interacted on the experiences and the know-how to bridge the gap between energy audits and the actual financing of measures.

In addition, four long lasting tools were developed and provided for free to all the interested stakeholders, namely an advanced training handbook translated into the seven project participating countries languages, a web platform for energy analytics, a tool for M&T, and a tool for M&V [12]. These tools were used and tested also by the E&T program participants when conducting the energy analysis, during the practical action, as described in the following subsection.

B. Details on the practical action

The E&T program included a practical action, during which the trainees were asked to conduct an energy check for one of the collaborating pilot companies. Aim was to identify and propose targeted measures to achieve energy and costs savings through the efficiency improvement. For that purpose, SMEs from various economic areas, according to the Statistical Classification of Economic Activities in the European Community (NACE) were engaged [13]. The practical action was carried out in collaboration with more than 150 companies from the project participating countries. The SMEs that got involved in the project are active in manufacturing, professional, scientific and technical activities, accommodation and food services, administrative and support services etc., as listed in [14]. The wide spread of the pilot companies in various activity fields has been crucial, as important differences can appear in the energy check processes depending on their activities.

Another important criterion in the selection of the collaborating SMEs was the energy consumption intensity. Companies with higher energy consumption may have a wider potential choice for EE solutions. At the same time, the implementation of energy savings measures in these companies could lead to higher energy gains. Additionally, the availability of an internal or external energy manager was considered, along with the existing budget of the companies, allocated for EE improvement and implementation of renewable energy sources, and their commitment to apply for relative EU funds.

For conducting the energy analysis, the participants received the necessary data by the companies. The available data included the description of the production or operational procedures, information regarding the companies' facilities and infrastructure, along with the energy consumption and production data for the last years. This data was used to set the energy savings target employing the M&T tool, developed in the framework of the SMEmPower Efficiency project. The target was set in collaboration with the engaged SMEs representatives, which were participating in the practical action to facilitate the process. After setting the target, dedicated measures for each one of the companies were designed through a feasibility study. The effectiveness of the proposed measures was then verified using the M&V tool, also developed by the project. The energy analysis results are presented in detail in [15], where also cumulative results are provided regarding the energy, costs and the CO2 reductions that can be achieved as a result of the implementation of the targeted EE improvement measures.

III. Methodology

A. Overall approach

In this paper, a study is presented for a specific SME engaged by the SMEmPower Efficiency project for the practical action in Greece, using its real data. Based on the real energy consumption data, a manually monthly energy saving target, set by the company is estimated. This target is evaluated regarding its expected impact, using the M&T tool developed in the framework of the SMEmPower Efficiency project. With this tool the expected monthly energy consumption reduction is calculated. The satisfaction level of the target is then verified by employing the project's M&V tool, using the data obtained after the implementation of EE measures. The analysis is continued for the next year, in order to assure that the energy consumption of the company is properly reduced, i.e., it reaches the desired level and it continuous to perform that way. The overall methodological approach applied in this analysis is depicted in Fig.1.

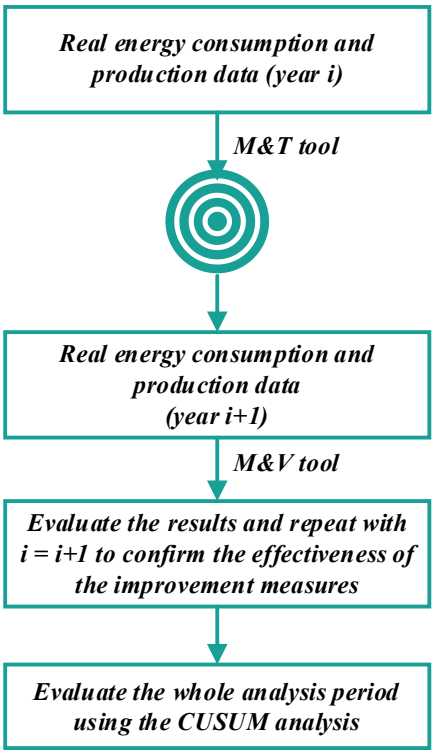

Fig. 1. Methodological approach.

Even though applied to a specific SME, this procedure can be used by companies from different economic sectors. The methodology can be used to evaluate the expected and the achieved results by the implementation of EE measures in the previous years. At the same time, the project M&T&V tools can be employed for the target setting and the verification of the impact of EE measures for future years. It is important to emphasize that when conducting such an analysis, the continuous communication with the company is necessary, as the target should be set in collaboration with its responsible personnel. Besides, all the information needed for the process should be provided by the interested stakeholders, usually the SME or company under study.

B. Input data

The data needed to conduct such an analysis can be categorized as follows: (i) the building characteristics with detailed explanation of the premises, used either for the production processes or for the offices, (ii) details on the Heating, Ventilation, Air Conditioning (HVAC), and lighting systems of all the spaces, as they consist crucial part of the company's total consumption, (iii) description of the technological process and the main consumptions in the company, (iv) the energy profile of the SME for at least two (2) consecutive years, meaning the electricity and fossil fuel consumption, (v) the production data that correspond to the time period for which consumption data is available, and (vi) information regarding any EE measures implemented by the company during the analysis period. It should be noted that although (ii) and (iii) are not necessary for the analysis in this paper, they are important inputs, together with real measurements of the energy consumption in selected critical points of the company. This data will help the energy auditorto have a clear picture of the energy consumption profile in the company to identifying the suitable EE measures. Each one of these data categories is therefore important, while conducting an energy analysis, as each one contributes to the process of setting energy saving targets, choosing the best EE measures that are better fit to the specific company, and verifying the effectiveness of their implementation.

C. M&T&V tools utilization

After providing the required input data, the SMEmPower Efficiency M&T tool is used to identify the energy consumption reduction that corresponds to a specific target that has been manually set. First, the monthly energy consumption and corresponding production data for at least one whole year is inserted into the M&T tool. Through a linear regression model, the linear energy consumption distribution is extracted, i.e., the linear expression that describes better the correlation between the production and the energy consumption data. Moreover, the desired monthly energy consumption reduction is entered manually into the tool and the targeted monthly energy consumption is calculated, along with the linear expression that describes best the dependency between the real production and the targeted consumption data.

After implementing the proposed measure/s and based on the data collection for at least one year after launching the measure/s, the M&V tool is used to identify whether the initially set target is reached. Thus, the consumption and production data for the first year after implementing the EE measure/s is introduced into the M&V tool. To estimate whether the target is achieved or not, the real consumption data for the year after the EE measures is compared to the consumption extracted using the linear expression based on the data before the energy measures implementation. This means that the real consumption measurements are compared to the expected ones for the case that the company would not have implemented any EE measure.

If the real yearly cumulative consumption exceeds the targeted one, then the procedure should be repeated using as the baseline the measurements corresponding to the year after the measure/s implementation. The M&T tool is again used to set the target. The target results to EE measure/s and their effectiveness is evaluated employing the M&V tool. Thus, the applied methodology is an iterative one and is concluded when the initial target set by the company is reached. If the desired energy reduction level is achieved, then a manual target equal to 0% is introduced into the M&T tool and the methodology is used just only to confirm that the measure/s impact on energy savings is still monitored.

D. CUSUM analysis

The EE measures implementation in the company under analysis is expected to lead to a reduced consumption pattern. Moreover, throughout the analysis period, other events may occur which may lead to overall energy consumption variations, even to EE degradation. To evaluate graphically the existence of such changes and towards the avoidance of risks for the company's efficiency, the CUSUM methodology is employed. The CUSUM analysis is used to detect any change in patterns, such as the typical electrical/thermal consumption of a company. In the CUSUM analysis the deviation of the actual measured consumption data from the one expected from a consistent company energy performance is computed. Specifically, having as reference the measurements coming from the first year of the analysis, i.e., the one initially inserted into the M&T tool, the linear equation that describes best the dependency between the consumption and production data is extracted. This equation is used to calculate the expected consumption pattern for the whole analysis period. The sum of differences between the actual consumption and the expected one is extracted. If no changes have occurred, the differences would be near zero. Otherwise, the CUSUM increases or decreases over time and the CUSUM graph is separated into sections, each one of which corresponds to the pattern changes. The CUSUM analysis will indicate whether any significant event has affected the energy performance of the company, e.g., whether the adopted measures have led to lower energy consumption or not.

IV. CASE STUDY

In this Section, an indicative case study from a SME, engaged in the SMEmPower project practical action is analyzed. An overview of the company's energy profile along with the impact of the EE measures is presented.

The company is a SME located in Greece, manufacturing cardboard, specifically monolayer smooth paper, with recycled material. The raw material, which consists of recycle paper, and auxiliary materials used in the production process is 428 kg, and the products are 363.8 kg of paper. The company's NACE code is "C – Manufacturing; 17.29 - Manufacture of other articles of paper and paperboard". The number of employees is 57. The company has eight buildings; one for offices, five for production and two for warehouses where end products are stored. The total gross area (main and auxiliary buildings) equals to 43,560 sqm, while the net area equals to 35,640 sqm. The building envelope consists mainly of industrial panels, while also there is some peripheral masonry. The company production runs for 7days/week, 24hours/day, excluding 2-3 days for season holidays. The scheduled maintenance periods are 5-10 days in October and 2-4 days every month, with a duration of 4-6 hours.

To cover the energy needs for the production process, electricity and natural gas are used. The average yearly total consumption is 45,250 MWh; from which 9,500 MWh correspond to electricity and 35,750 MWh to thermal energy. Fig. 2, depicts the company consumption over four reported years, i.e., 2017-2020. It is observed that the thermal energy consumption is significantly higher than its electricity counterpart. Moreover, the total energy consumption pattern follows the thermal energy consumption one, indicating that its impact on the total consumption is more significant compared to the electricity part. Finally, a closer look in this graph reveals a specific pattern regarding a decrease in energy consumption in October of each year. The explanation for this reduction relies on the annual programmed maintenance activities of the company.

Based on the 2017 energy consumption data, the company proceeded with energy auditing and the implementation of EE measures by January 2018. They are related mostly to the thermal energy and only few to the electricity: LED lighting, inverters, encoders (instead of tachogenerators), alternators reconstruction, vacuum pumps upgrade, steam boiler refurbish with two stages economizer and fumes condensing chimney, anaerobic treatment. Therefore, despite the later analysis performed in the project framework, the provided data by the SME constitute a solid dataset to check the M&T&V tools, developed by the project. The analysis of the energy consumption of the company has been performed as follows: First, a decision on the corresponding EE measures has been taken, considering the energy profile of 2017 and setting a flat consumption reduction target of 5%. The percentage has been decided by the company, based on techno-economic criteria. The targeted consumption of 2017 has been estimated, using the M&T tool. After the implementation of the measures, their evaluation followed by comparing the measured and the estimated consumption (based on the target of 5%) of 2018, using the M&V tool.

Fig. 3 depicts two lines, as resulted by the linear regression model application: the one refers to the real consumption data (red line with points) and the other to the targeted consumption of 2017, based on the 5% target. Fig. 4 presents the respective monthly energy consumption before and after setting the target. In Fig.4 the y-axis difference between the bar and the light green line point indicates the reduced energy consumption between the initial case with no target set and the state after setting the target. The proposed and finally adopted EE measures have been based on this analysis. Their impact on the consumption of the company was measured by monitoring the consumption during the next years. For 2018, the total measured and estimated (based on the target set in 2017) consumption is 44,140.6 MWh and 45,250.5 MWh, respectively. The target has been reached given that the measured energy consumption is lower than the estimated one. For the monthly consumption, as presented in Fig. 5, the real energy consumption was lower than the estimated energy consumption for most of the examined months. Only for months January, February and March the target was not reached. It should be reminded though that the aggregated consumption values regarding the whole year verify lower energy consumption after the measures implementation.

From 2018 onwards, no other measures have been adopted. Nevertheless, consumption monitoring continues to assess the EE measures' performance. Furthermore, consumption monitoring leads to tracking any anomalies and thus, to anticipate a potential over-consumption.

To this point, a comparison between the estimated, based on the target set in 2017, and the measured consumption has been performed by using the M&V tool. Thus, two additional analyses have been performed; one for the year 2019 and one for 2020 based on the total consumption of 2018 and 2019, respectively and for target 0%. The measured and the estimated consumption for both years are presented in Figs. 6 and 7 for 2019 and 2020, respectively. The total measured consumed energy, i.e., 44,087.9 MWh and 45,437.1 MWh, for 2019 and 2020 respectively, is higher than the corresponding

estimation, i.e., 43943.7 MWh and 43706 MWh, respectively, for both years.

This can be also observed by applying the CUSUM methodology on the 4-years data, as depicted in Fig. 8. In Fig. 9, the curves with a negative slope indicate energy saving. When the slope is positive the opposite occurs [10]. After adopting the EE measures, the company energy consumption decreases. This is more obvious in the thermal energy given that most of the measures concern the thermal part of the total consumption.

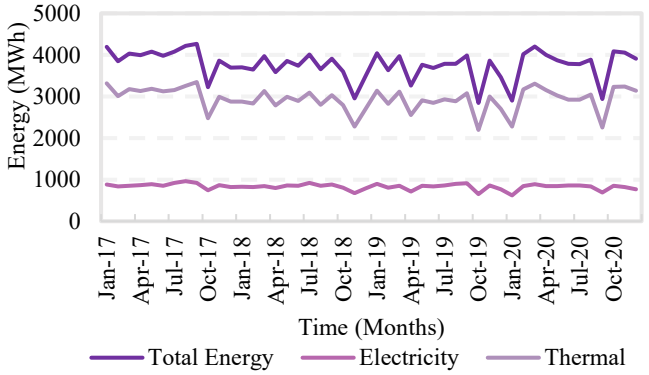

Fig. 2. Energy consumption throughout 2017-2020.

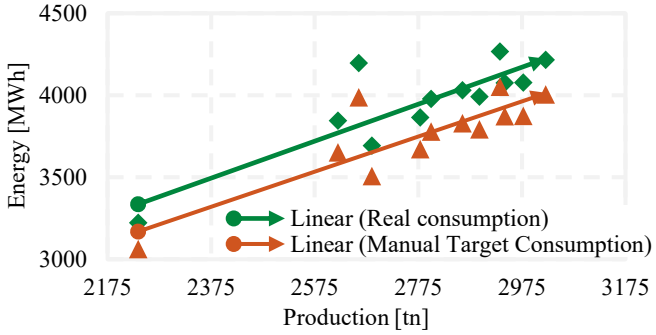

Fig. 3. M&T tool. Linear regression of real and targeted consumption 2017.

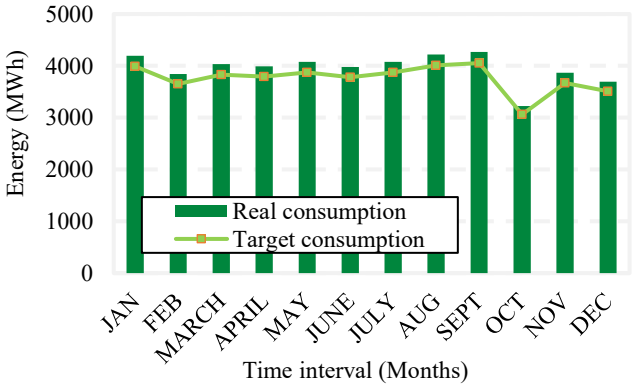

Fig. 4. M&T tool. Monthly real and targeted consumption of 2017.

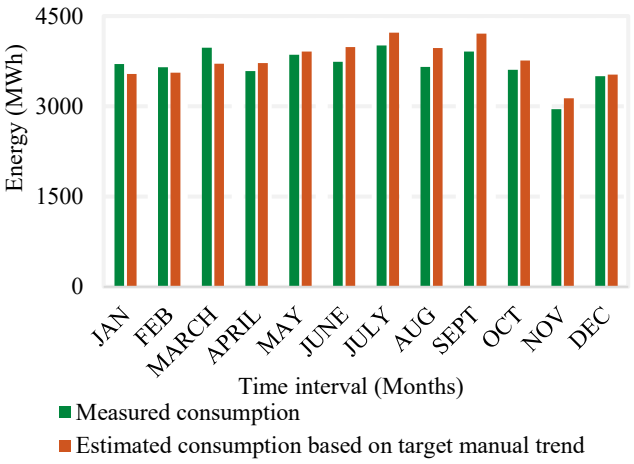

Fig. 5. M&V tool. Monthly measured and estimated consumption of 2018.

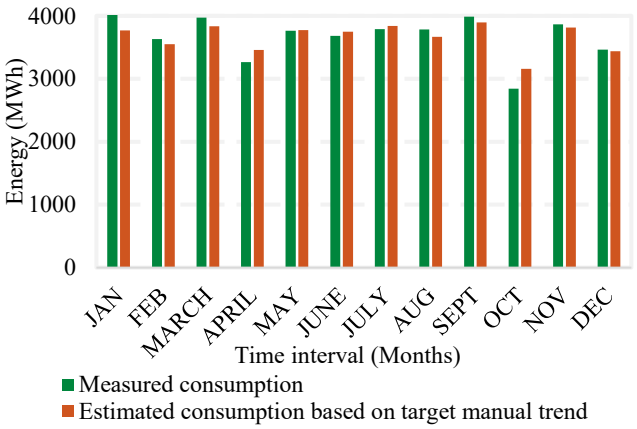

Fig. 6. M&V tool. Monthly measured and estimated consumption of 2019.

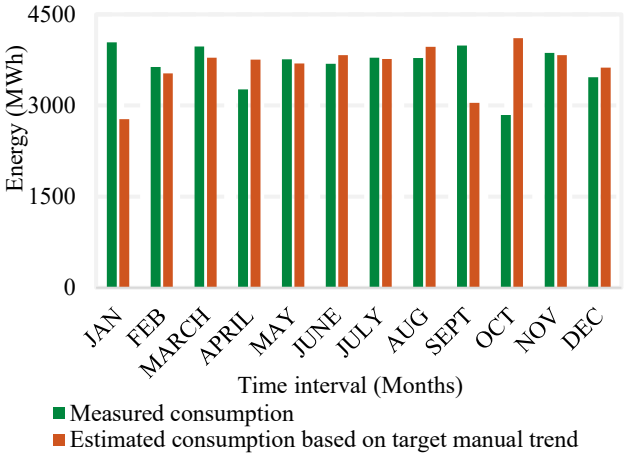

Fig. 7. M&V tool. Monthly measured and estimated consumption of 2020.

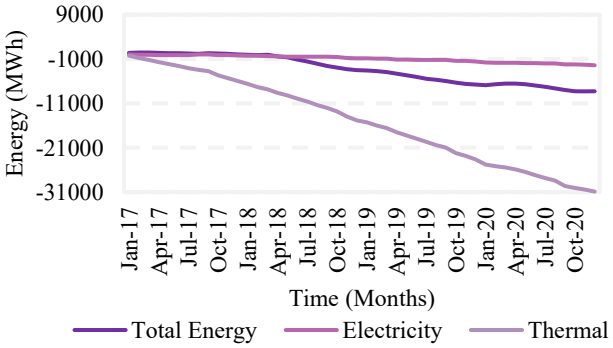

Fig. 8. CUSUM for years 2017-2020.

V. CONCLUSIONS

Setting the climate neutrality as a significant milestone, EU has adopted plenty of policies towards this direction. Big companies are obliged to perform energy audits, in contrast to SMEs which are not obliged to take any relevant action. Nevertheless, SMEs have come to the forefront of EE after the 'Fit for 55' and the REPower EU initiatives.

SMEs are not incentivized to perform energy audits, neither to adopt any EE measures, therefore rendering them as not a high priority. To tackle this issue, the SMEmPower Efficiency project has proposed a holistic approach targeting both the SME staff and the policy makers. In this paper, the results of the work with a pilot case of the project is presented.

The pilot company has already performed an energy audit and adopted the proposed EE measures. The company energy consumption profile before and after the auditing has been analyzed, using the project's M&T and M&V tools. It is clear that the energy consumption is reduced after the implementation of the proposed EE measures. The effectiveness of the measures is confirmed, as the desired consumption reduction level is achieved, while the improved consumption performance is maintained also during the following years. The CUSUM methodology confirms the results of the M&V tool, indicating that both can be used in such an analysis.

The methodology adopted can be employed for the implementation of energy checks in companies in different economic sectors, while the SMEmPower Efficiency M&T&V platforms seem to be an effective tool for this procedure.

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