The SMEmPower Monitoring, Targeting and Verification Tool

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Abstract— **This paper presents the methodology and the implementation of the monitoring and targeting (M&T) and monitoring and verification (M&V) tools that were developed in the context of the SMEmPower Efficiency Horizon 2020 project. The tools were built to allow energy managers and energy experts of Small and Medium Enterprises (SMEs) to store and organize energy consumption and production measurements, identify increased energy readings, create scenarios of reduced energy consumption, and finally verify the efficiency of energy conservation measures. The tools were used during the three training rounds that were organized in eight countries by the SMEmPower Efficiency project partners. More specifically, they have been applied for the practical action of the trainees in order to perform energy evaluations or actualization of energy audits in pilot sites under real consumption and production data.**

Keywords—Energy efficiency, energy savings, monitoring, SME, verification.

I. Introduction

Monitoring, targeting and verification (M&T&V) is a management technique in which information is recorded and analyzed in order to improve the existing operating procedure of a given mechanism. The principle is simple and based on a simple notion: that which is not measured cannot be managed. Essentially, this technique combines the principles of data recording and statistics to adduce conclusions.

The principle has been used in various different data sets. For example, it has been used in water sanitation [1], medicine research concerning cancer [2], and many cases of energy usage, in small-medium enterprises (SMEs) [3], or generally industries and energy consuming plants [4-5].

According to [6], the EU aims to be climate-neutral by 2050, an economy with net-zero greenhouse gas emissions. To achieve this, the EU has invested a lot in renewable energy sources (RES) and energy efficiency trends and policies, targeting both the industry and the households. Specifically, many EU projects have been dedicated in making industries more energy efficient [7-13], and a massive project has been supported by 32 partners from 27 countries aiming to analyze energy efficiency in the industrial sector. A brochure of this project that analyses both energy efficiency trends and the policy instruments that are currently implemented to improve energy efficiency is available in [14].

The M&T&V procedure has been standardized by the international performance measurement and verification protocol (IPMVP) [15]. This protocol provides guidance focused on energy savings, but it can be applied to any other quantities being measured and verified. It was initially adopted by energy services and companies and now is used by government agencies as well. The IPMVP has also been used as a risk reduction framework for their investments. A similar guideline published by ASHRAE in 2002 is expected to provide adequate assurance for the payment of services by allowing for well-specified measurement methods that provide reasonably accurate savings calculations, and to calculate pollution reductions from energy efficiency activities [16].

This paper presents the M&T&V tool that has been developed in the context of the SMEmPower Efficiency project, which is funded by the European Union's Horizon 2020 research programme. The tool was included in the educational and training (E&T) program that has been delivered to energy managers, professionals and experts within the context of SMEmPower Efficiency project. The main target of the E&T program was to train SME key staff to use intelligent energy management solutions; to design, propose and successfully find pathways to implement intelligent and affordable energy efficient investments; to facilitate a change in SME staff energy consumption behavior and obtain the support of decision makers. The presented M&T&V tool has played a key role towards this aforementioned target due to the fact that it constitutes an on-line, simple and straightforward tool that can be utilized by SME staff with under no special information technology (IT) qualifications. This paper is split into six sections. The first one presents introductional information regarding the M&T&V concept. Then, the information of the project that funded the tool is presented. The next three sections present each one of the three parts that comprise the tool. The fifth section presents a case study using the online tool that was carried out in one of the SME's that participated in the E&T program, and finally, in the last one, the conclusions of this paper are presented.

II. THE SMEmPOWER EFFICIENCY PROJECT AND TOOL

SMEmPower Efficiency is a project that has developed and implemented a common E&T program for energy professionals in eight (8) countries [13]. Over 700 energy professionals have been trained and received accreditation of 5 ECTS/EQF 6, and over 140 SME's have participated [17]. The selection of SMEs was made so that to include as many professional activity codes as possible, The SMEs involved came from many sectors; from service companies, such as a shop and a homeopathic clinic, to companies with production processes such as the production of cement or pastry products.

During their training, the energy professionals have accessed and used the online energy management M&T and M&V parts of the tool that were developed in the project. The tool is available both as an offline version in an excel format file, and as an online application embedded in the project's website. In this paper the online version is presented.

The online tool is divided into three parts which are: the data uploader, or energy analytics part; the M&T; and the M&V tools. The data uploader is a simple interface to let the user upload measurements either as files or manually to the database of the project,. These data can later be used by the M&T and M&V tools. The M&T tool provides the energy managers with guidance on the level of energy consumption that is expected in a certain time period by developing the baseline best-fit line for the SME and in turn it allows the user to create a reduced energy consumption scenario. The energy manager must then evaluate if this scenario is viable, and if not, create a new one by altering specific parameters of the tool. The M&V tool is used after the energy manager has created a scenario in the M&T tool. In order to work, it requires an additional year of data to be uploaded, which originates after the energy conservation measures have been implemented. This tool simply verifies that the implemented energy saving measures have indeed caused energy saving, by comparing the energy consumption of the two years, and additionally it calculates: (a) the respective CO2 reduction, (b) the amount of energy saved, and (c) the monetary savings.
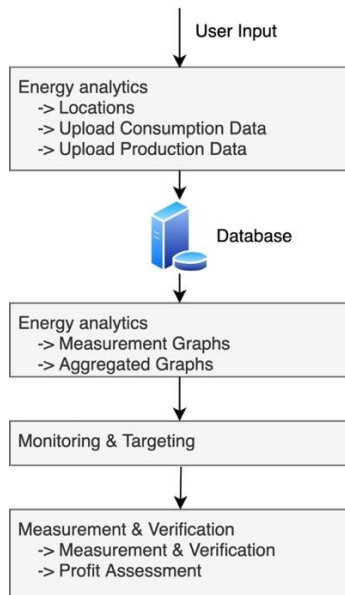

Fig. 1. Layout of the developed tool

III. THE DATA UPLOADER

The data uploader or energy analytics is split into five (5) sub-tabs as depicted in Fig. 1. The first sub-tab "Locations" is essentially a dataset selector. It lets the user to create up to five (5) different locations and select one of them as the active one. Each location can include different data, it can be a different building with different consumption or production data, or a scenario of the user which may be under development or construction. The second sub-tab "Upload Consumption Data" is a submission form for the electricity and fossil fuel consumption data and their respective cost. New data can be entered and existing data can be altered by using the manual data logger, i.e., a manual entry form, or by using the template uploader via .csv or .xlsx files. A table of the existing data is also presented at this point, for inspection purposes in case manual data change is needed. The third sub-tab is called "Upload Production Data". It serves the same purpose as the previous one, but instead of consumption data, the users upload their production data. Production data may have multiple measurement units, as the SMEs may produce many different goods or they could constitute service providers. The tool only accepts a single production number for each month, and therefore different production data within the same SME must be aggregated by the user to the same production type. For example, if an SME produces products measured in both kg and L then one of them should be expressed in the other's unit in order for their aggregation to be valid. The fourth and fifth sub-tabs are for inspection and verification of the data. In the fourth one "Measurement Graphs", the fossil and the consumption readings of the user are visualized separately for each individual month. Additionally, if the entered data cover at least a full year time period, the seasonal average is plotted in a four-bar graph. In the last sub-tab "Aggregated Graphs", the data are summed up yearly and presented in the same way as in the fourth sub-tab. This sub-tab requires a minimum of two (2) years of data to display any results.

IV. THE MONITORING AND TARGETING TOOL

The M&T tool can be used after uploading at least one year of data in the energy analytics tool. Essentially, this tool uses the data submitted by the energy professional in order to apply a linear regression model and then uses the value of a coefficient that is set by the user to selectively reduce the energy consumption of one or more months for a set amount of production. Thus, the user can produce a measured and targeted reduced energy consumption scenario. If a large quantity of data is available, the energy manager should select those that correspond to typical consumption patterns, i.e., close to the average monthly consumption values for a scaling value of production. Let $Y = (Y_1,...,Y_n)$, be the dependent variable where n is the number of elements that consist Y, i.e., the consumption energy in any units, and $X = (X_1,...,X_n)$, be the independent variable where n is the number of elements that consist X, i.e., the production of the SME in any units. Supposing that the consumption Y depends on the units of production X, the linear expression in (1) couldexpress the dependency between X and Y:

$$Y = a_{real}X + \beta_{real} \qquad (1)$$

Where α_{real} and β_{real} are the two coefficients of the linear expression, i.e. the slope and the intercept with the y axis. Using the known values of Y_n and X_n that are previously uploaded by the user, the slope and intercept can be calculated using the following expressions in (2) and (3):

$$a_{real} = \frac{\sum (x_n - \overline{x})(y_n - \overline{y})}{\sum (x_n - \overline{x})^2} \qquad (2)$$

$$\beta_{real} = \overline{y} - a_{real}\overline{x} \qquad (3)$$

Where $\overline{x}$ and $\overline{y}$ are the mean values of X and Y. Substituting (2) and (3) into (1) provides us with the line of best fit for the data. After this point, the targeting part begins by finding the best-case consumption, i.e., starting by depicting the month which had the highest amount of production with the least amount of consumption. This is done by using (4) to calculate the difference of each Y_n from the best fit line, and by selecting the minimum one using (5), as that is the best-case consumption.

$$E_{1\_n} = y_n - (a_{real}x_n - b_{real}) \qquad (4)$$

$$m = \min(E_{1\_n}) \qquad (5)$$

With the minimum value m known, a data set can be generated by fitting the best-case consumption to the rest of the data using (6). Additionally, a target trend transposition coefficient T_c is subtracted. This serves two purposes: (a) it behaves as an additional flat reduction to the consumption of each value of the data, and (b) as a threshold that is used to control whether a reduction will be applied to a value or it will remain the same. Without this coefficient, the best-case value of the data could not be further reduced by a value set by the user. Thus, this formulation allows the user to have control on the target to be set.

$$E_{opt\_n} = \begin{cases} y_n - (|m| - T_c) & y_n - (|m| - T_c) > 0 \\ y_n & y_n - (|m| - T_c) \le 0 \end{cases} \qquad (6)$$

Since the value of Tc is substracted from the consumption values, it cannot exceed certain limits. The maximum and minimum value are given in (7).

$$|m| - \min(Y) \le T_c \le |m| + \max(E_1) \qquad (7)$$

The expression in (6) creates a new set of consumption data values from which a new best-fit line can be derived. Let $E_{opt} = (E_{opt\_1}, ..., E_{opt\_n})$, be the dependent variable where n is the number of elements that consist E_{opt}, i.e., the consumption energy in any units that is calculated from (6), and $X = (X_1, ..., X_n)$, the same production as before. Using the known values of $E_{opt\text{-}n}$ and E_n, the slope and intercept can be calculated using (8) and (9):

$$a_{opt} = \frac{\sum (x_n - \overline{x})(E_{opt\_n} - \overline{E}_{opt})}{\sum (x_n - \overline{x})^2} \qquad (8)$$

$$\beta_{opt} = \overline{E}_{opt} - a_{opt}\overline{x} \qquad (9)$$

With the new values derived from (8) and (9), the optimized best-fit line can be calculated using (10):

$$Y_{opt} = a_{opt} * x_n + \beta_{opt} \qquad (10)$$

$$y_{opt\_n} = \begin{cases} Y_{opt} & \text{if } Y_{opt} < y_n \\ y_n & Y_{opt} \ge y_n \end{cases} \qquad (11)$$

The above line in (10) is essentially the best-fit optimized line that occurs after (6) has been applied to all of the consumption values; it is a line shifted vertically towards the horizontal axis, and with a different slope. The vertical shift between two vertical points, i.e., the optimized line and the original line from (1), shows the difference in energy consumption if this targeted consumption line is reached by implementing energy saving measures. It is simply calculated using (12):

$$y_{savings\_n} = \begin{cases} y_n - y_{opt\_n} & \text{if } y_{opt\_n} > 0 \\ 0 & y_{opt\_n} \le 0 \end{cases} \qquad (12)$$

At this point, the core of the M&T tool, which is the targeting, is completed. The tool additionally calculates four more values. These are: the specific consumption for both the original or real input data, and the optimized data, as shown in (13) and (14) respectively:

$$SC_{real\_n} = \frac{Y_n}{X_n} \qquad (13)$$

$$SC_{opt\_n} = \frac{Y_{opt\_n}}{X_n} \qquad (14)$$

Finally, the difference between the real and optimized specific consumption is calculated as presented in (15) and the same savings expressed in percentage are shown in (16).

$$SC_{savings\_n} = \begin{cases} SC_n - SC_{opt\_n} & SC_{opt\_n} > 0 \\ 0 & SC_{opt\_n} \le 0 \end{cases} \qquad (15)$$

$$SC_{optimized\_n} = \begin{cases} y_{opt\_n} / x_n & \text{if } y_{opt\_n} / x_n < SC \\ SC & y_{opt\_n} / x_n \ge SC \end{cases} \qquad (16)$$

The above procedure described in (1)-(12) is the automatic targeting mode of the M&T tool. The tool can also be operated manually. This case is simpler and more straightforward; the user must input a percentage reduction in consumption energy for each month. The percentage reduces the values $Y = (Y_1, ..., Y_n)$, by that amount, basically directly creating the $Y_{opt} = (Y_{opt\_1}, ..., Y_{opt\_n})$, of (11). The rest of the equations after (11) are calculated in the same way. All of the above best-fit lines, values and coefficients are depicted in a table and in graphs for better visualization.

V. MEASUREMENT AND VERIFICATION

The M&V tool is used to verify the energy and cost savings. For this to be possible, the energy saving measures must be implemented and at least a year of data after the implementation must be uploaded to the tool. The procedure

of uploading is the same as in the M&T tool using the data uploader. The M&V analysis requires that the M&T tool has been used and a target has been set. This is because the concept of this M&V tool is to compare the values of a set of data with another set of data which originates before applying energy saving measures.

The M&V tool is split into two sub-tabs as depicted in Fig. 1. Let $Y_s = (Y_{s-1},...,Y_{s-n})$, be the consumption energy in any units for the second year after the measures have been implemented, and $X_s = (X_{s-1},...,X_{s-n})$, the production of the SME for the second year after the measures have been implemented in any units.

The first sub-tab "Measurement & Verification" is used to verify the savings of each month independently and as a total sum. To do this, it calculates the best-fit line for the data sets Y_s and X_s using (1)-(3), and compares this line with the targeted one from (10). By subtracting the difference between the points of the lines, the verified savings are calculated as values and as percentages. If these values are negative, the energy consumed for that point is less than it would have been without the energy saving measures, and therefore energy saving has been achieved and the target has been reached. Finally, this part requires the price of energy (euro/kWh) to calculate the savings in terms of profit for each month.

The second sub-tab "Profit Assessment", is an episcopal table for the measured and verified achieved energy savings. It includes the Specific energy use in kWh and the Total energy use in MWh, before and after the energy efficiency measures have been implemented.

VI. EXAMPLE CASE-STUDY

In this section, a case-study for an SME that participated in the E&T program is presented. Only the first year of data is actually taken from the SME, the second year of data requires that the energy saving measures are implemented, which is not possible at the time of writing, so these data have been artificially produced. The focus is to present the user-interface (UI) of the tools and the targeting procedure rather than the viability of the targeted scenario. Therefore, this case-study uses two consecutive recent years of data that will be shifted back in time for this example for General Data Protection Regulation (GDPR) reasons.

Initially, the data must be uploaded in the energy analytics tool. A new location is created and the production units are set as pieces (PCS). Then, using the excel templates for the consumption and the production the data is uploaded to the tool. In this examined case the SME only uses electrical energy. The consumption and production of the SME can be plotted monthly or yearly in the graphing sub-tabs of the tool, as depicted in Figs 2 and 3.

The next step is the application of the M&T tool. Initially the time period and energy type for the data that will be targeted must be selected, in this case, electrical energy and time period of one year from January 2000 to December 2000. The tool automatically draws the data and based on the set value for the transposition coefficient, it plots graphs. In this case, we manually select $T_c=5$. Figs 4-7 depict the entirety of the M&T tool. From the top to the bottom of the figures, the first part with the rectangular cells in Fig.4 is the input part of the tool; this is where the user's preference

about the time period is set also and where the min and max values of the Tc coefficient are shown.
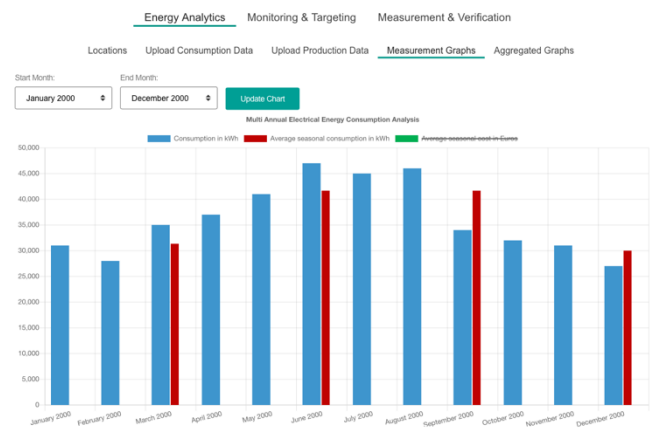

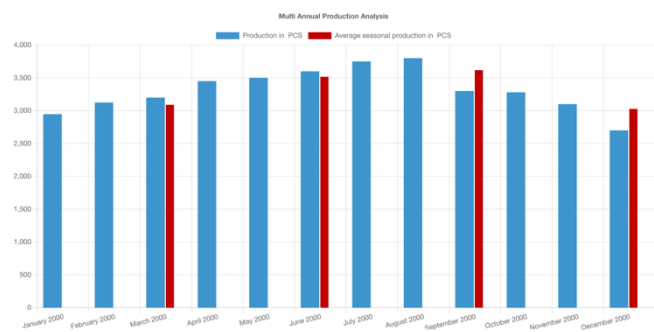Fig. 2. Monthly consumption data for the year 2000

Fig. 3. Monthly production data for the year 2000

The table in Fig.4 and all the graphs (Figs. 5-7) are generated automatically, and can be exported using the buttons at the top. The table is split into three (3) parts; the first one is the core table that includes the results in numerical form. From left to right, it includes (a) the real input data, i.e., the data drawn from the energy analytics tool and the specific consumption calculated using (13), (b) the optimized data, i.e., the data calculated using (1)-(11) and (14), and (c) the potential estimated energy savings, calculated using (15)-(16). Below this table the coefficients of both the best-fit lines from (1) and (10) are presented. The rest of the calculated part concerns the illustration of three (3) graphs. The first graph, i.e. upper part of Fig.6, depicts the real consumption values as dark green vertical bars, and the target consumption, i.e., the values from (11), using the light green dotted line. The second graph, i.e., lower part of Fig.6, depicts the annual savings in kWh which are calculated using (12), and finally, the third graph (Fig.7) depicts the total energy savings in kWh and euro, calculated using (15). By changing the value of the T_c coefficient, the optimized best-fit line from (10) depicted in the first graph, the targeted consumption depicted in the second graph and therefore the annual savings on the third graph will be changed.

In this scenario, by selecting $T_c=-5$, 113 kWh of energy savings annually are set as the target for the SME. The scenario is evaluated as viable by the energy manager and/or energy expert in the SME, and the energy saving measures are selected accordingly to be implemented.

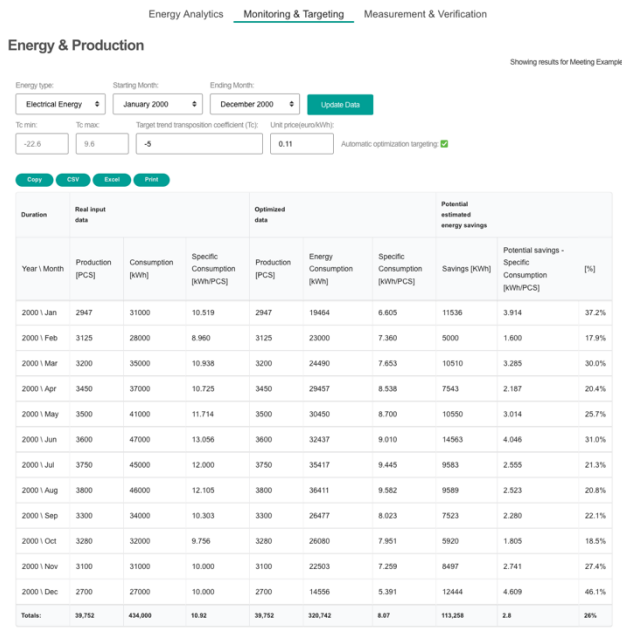**Energy & Production**

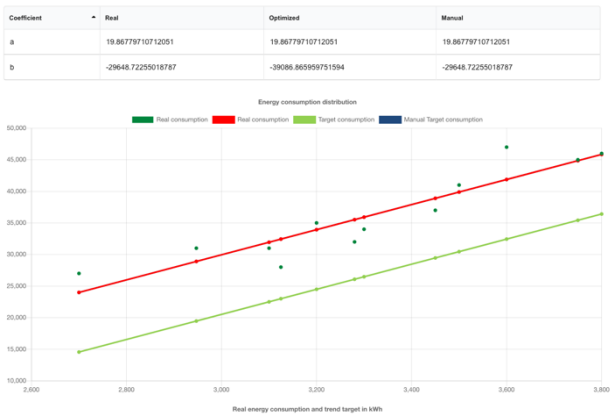Fig. 4.   Input and Inspection M&T tool top part

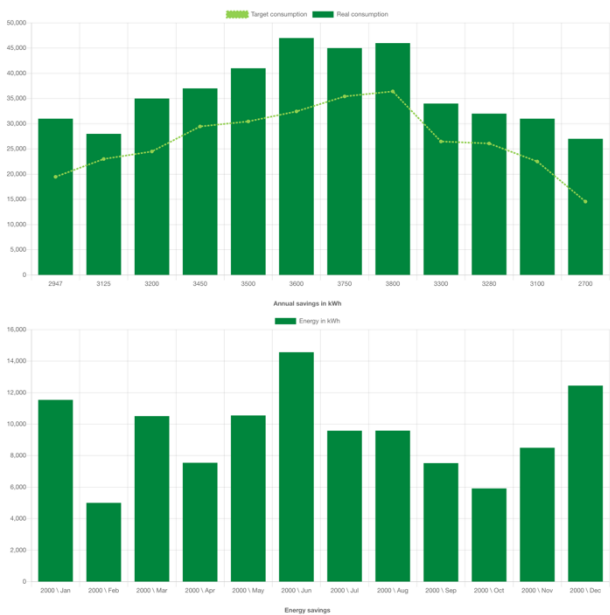Fig. 5.   M&T tool best fit lines coefficients and graphical representations

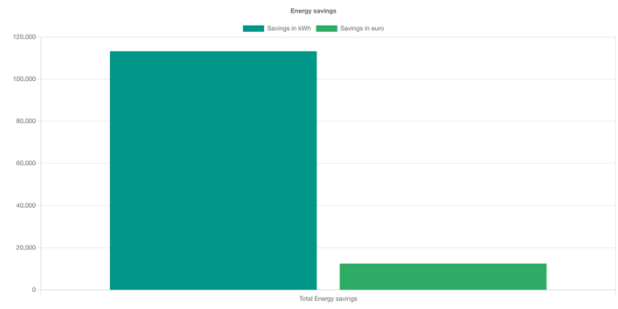Fig. 6.   M&T tool illustration bar graphs – 1.

Fig. 7.   M&T tool illustration bar graphs – 2.

After the measures have been implemented, data are recorded for the second year and uploaded to the tool. In the energy analytics tool the database is updated to include the values for the new time period. In this example the second year is considered to be year 2001, thus the monthly values for the updated time period in the database starts from January 2000 to December 2001 and is presented in terms of monthly consumption and production values in Figs. 8 and 9.
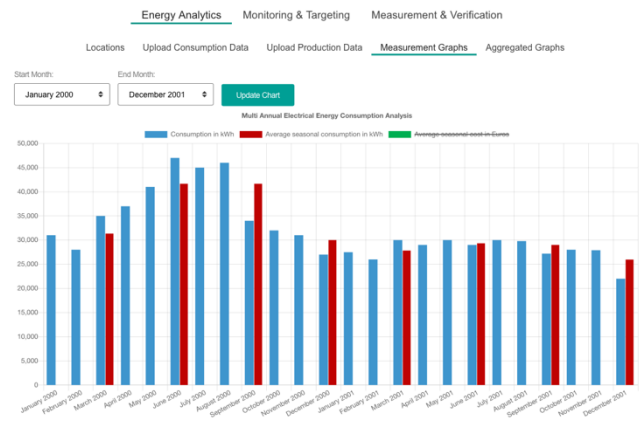

Fig. 8.   Monthly consumption data for January 2000 to December 2001
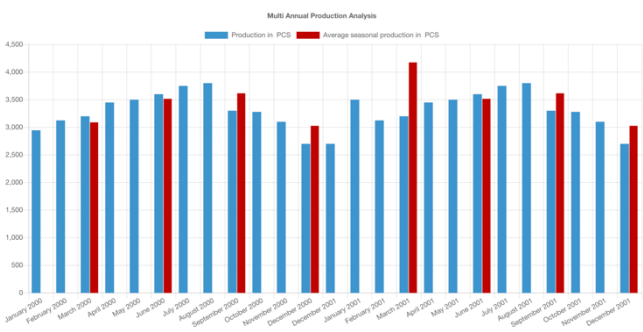

Fig. 9.   Monthly production data for January 2000 to December 2001

It can be quickly observed that the peaks in consumption power during the summer months have been flattened during the second year, for approximately the same amount of production meaning that some kind of energy efficiency improvement has been achieved in the SME.

In order to use the M&V tool, the second year of data must be selected, which in this case refers to the time period from January 2001 to December 2001. The tool then automatically draws the data and no other input from the

user is needed in this case. The tool automatically creates the table depicted in Fig. 10. From left to right, this table initially presents the consumption and production values for this new year during which the energy efficiency measures are running, then, the next six columns, present the estimated consumption of this second year based on the best-fit line for the data of the first year and then the optimized consumption data for his second year based on the target(s) set by the user. The basic concept here is to provide an estimation about the consumption of the SME based on the baseline time period that concerns no efficiency measures along with the respective estimation based on the target(s) set. Finally, the last three columns show whether the energy efficiency measures have succeded in yielding energy savings and moreover whether the target(s) has been reached or not.

For this example, it can be initially observed that the energy conservation measures have been proved to be efficiennt, since for every month during 2001 energy savings have been reported in repsect to the case where the SME would kept running as in 2000, i.e., with no energy conservations measures applied. Secondly, the target set via the M&T tool under the targeting routine including the T_c coefficienct has been quite optimistic for some months, since for them based on the performance in 2001 the target has not been reached. Finally, the last column shows that the target that has been set manually by explicitly setting the targeted energy savings per month is reached for every month. This is due to the fact that in this case the target is fully defined by the user while in the other targeting routine a portion of the target is defined by the developed algorithm and is based in the utilized set of data.

VII. Conclusions

This paper presents the methodology and a case study of the M&T&V tool that has been developed in the context of the SMEmPower Efficiency project, which is funded by the European Union's Horizon 2020 research programme.

The point of the online tool is to allow energy managers and energy experts to organize energy consumption and production measurements, identify increased energy readings, create scenarios of reduced energy consumption, and finally verify the results by uploading measurements after the energy saving measures have been implemented. The above procedure is done in three steps: 1) by uploading data in the energy analytics tool and inspecting them, 2) by using the M&T tool to create an energy saving scenario that is realistic and can be employed, 3) by uploading the measurements after the energy saving scenario has been implemented and verifying the results in order to depict to what extend these measures have been successful and moreover to verify whether the target(s) that have been set have indeed been reached.

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No.	Duration Year\Month	Real - after the energy efficiency implementation Production	Measured consumption	Verification Estimated consumption based on baseline trend	Estimated consumption based on target optimized trend	Estimated consumption based on target manual trend	Baseline trend SAV %	Optimized target trend SAV %	Manual target trend SAV %	Baseline trend conclusion	Optimal trend conclusion	Manual trend conclusion
1	2001\Jan	3500	27500	39.889	30.450	39.889	-31.059	-9.688	-31.059	energy saving	target reached	target reached
2	2001\Feb	3125	26000	32.438	23.000	32.438	-19.847	13.043	-19.847	energy saving	target not reached	target reached
3	2001\Mar	3200	30000	33.928	24.490	33.928	-11.577	22.499	-11.577	energy saving	target not reached	target reached
4	2001\Apr	3450	29000	38.895	29.457	38.895	-25.440	-1.551	-25.440	energy saving	target reached	target reached
5	2001\May	3500	30000	39.889	30.450	39.889	-24.791	-1.478	-24.791	energy saving	target reached	target reached
6	2001\Jun	3600	29000	41.875	32.437	41.875	-30.746	-10.596	-30.746	energy saving	target reached	target reached
7	2001\Jul	3750	30000	44.856	35.417	44.856	-33.119	-15.295	-33.119	energy saving	target reached	target reached
8	2001\Aug	3800	29800	45.849	36.411	45.849	-35.004	-18.157	-35.004	energy saving	target reached	target reached
9	2001\Sep	3300	27200	35.915	26.477	35.915	-24.266	2.731	-24.266	energy saving	target not reached	target reached
10	2001\Oct	3280	28000	35.518	26.080	35.518	-21.167	7.362	-21.167	energy saving	target not reached	target reached
11	2001\Nov	3100	27900	31.941	22.503	31.941	-12.651	23.983	-12.651	energy saving	target not reached	target reached
12	2001\Dec	2700	22000	23.994	14.556	23.994	-8.310	51.140	-8.310	energy saving	target not reached	target reached

Fig. 10. M&V Tool with detailed verification results