

# Implementation of Monitoring & Targeting Method in Optimization of Body Shop Heating System



## **Executive Summary:**

The goal of the project was to utilize Monitoring & Targeting methodology for optimization of the heating system in a body shop through analysis and evaluation of the existing energy consumption data for heating. Through utilization of manually controlled air heating units Sahara the influence of human factor on the heat consumption was identified, separated and acted upon.

Through Monitoring & Targeting method it was possible to identify and quantify energy savings once a number of the air heating units Sahara were not utilized and heating was provided through the existing HVAC system.

The method provided the energy manager not only with a powerful tool for energy management giving daily feedback and visualization of data but also a quantification of savings which amounted to about 200,000 EUR for the entire heating season.

## Monitoring & Targeting and variables

The Monitoring & Targeting method originated in California in 1980s. It is a well-tried approach to energy management based on regular evaluation of data in individual areas of energy consumption. The energy data is analyzed against relevant variables which have an influence on its value. Such variables have a direct impact on how energy is managed in a given area under observation. The main premise of this method is **"If you don't measure it, you can't manage it"**. Monitoring & Targeting (M&T) provides an energy manager not only with a feedback on how energy consuming equipment and appliances are operated but also with impact measurement of energy saving measures and forecasting. At the same time, the targets are not set on the basis of absolute values but on **variable values**. Those can be adapted as operational regime changes or as the variables alter. Therefore, the method and the particular target setting is **objective and far**.

An example of variables can be a number of pieces produced, volume of color used, outside temperature, humidity, natural light, etc. depending on which area of energy consumption is being evaluated. Finding the right variable for analysis is a key aspect of the entire method. Thus, the appropriate variable should **be independent on energy consumption** and should demonstrate a real external influence on the consumption (filtering out human factor). E.g. Heating energy consumption should be correlated against outside temperature equivalent (heating degree days).



## Importance of submetering

Submetering is a cornerstone of energy management using M&T and it has two main functions. Firstly, it enables the energy manager to **measure specific areas of energy consumption individually** (lighting, ventilation, heating, cooling, process, etc.). Each of these areas has different variables which influence them and submetering provides a way to correlate individual areas of energy consumption with the relevant variable(s). Secondly, submetering allows for assigning responsibility for energy consumption to staff and helps to point out its direct influence on it. Submetering can contribute to a better identification and monitoring of energy consumption for instance through separate metering of production lines or parts of the production process.

#### **Frequency of submetering**

Frequency of metering is an important aspect of effective energy management using M&T. At this point, an energy manger must ask himself: *"How often am I able to assess energy consumption data*? ". In other words, is he/she able to assess the data on a daily, weekly or rather monthly basis? *"At what level of resolution do I get the data?* Most of the state-of-the-art automatized submeters allow for data resolution up to 15min interval. *"How often do management meetings on energy performance take place*? ". It is necessary to **determine the right interval** in which energy performance should be discussed at the management level. And lastly, "*How good is my memory*?". If an energy manager assesses the data in a monthly interval, it is questionable whether he will still be able to remember what influenced the consumption in positive or negative way.

The optimal data assessment frequency is therefore from daily to weekly. More detailed resolution requires significant time to assess and interpret. 1min or 15min data resolution can be useful while investigating what exactly happened in a specific timeframe. Within the context of M&T such resolution is, however, not used. On the other hand, monthly and annual consumption data are useful for invoicing purposes, however, for proactive energy management are too general.

Regression analysis is a widespread technique on how to correlate two or more variables and determine the correlation coefficient. The main value of the regression analysis for energy management is a visualization of operational variability. Operational variability is depicted as a scatter diagram of the regression analysis in which the individual dots represent the level of energy consumption on a given day (week or month). Such operational variability represents potential for improvement. At the same time, regression analysis enables baseload identification of the energy consumption area under observation.





Scatter of data points in the diagram can vary from wide to almost one continuous line. The extent to which individual energy consumption value points and relevant variable points relate to each other and form a trend line is called correlation (R<sup>2</sup>). It is necessary to identify those periods in which the correlation between the consumption and the variable was highest (max. 1 or 100%). Such correlation points to a provable trend which can be taken and set as a target for future consumption. Since the trend line is an average of all values in the scatter diagram, one half of the points is located above the line and another half under the line. Thus, the **trend line represents a fair** (based on historical data), **realistic and achievable** (half of the times the target was met) **target**. The target is not based on a theoretical model but rather **on real operational conditions** which have been in 50% of times achieved.

#### Variance from target



Variable Data

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A trend line determines optimal energy "demand" (and thus consumption) given a specific value of the relevant variable. Given the data set it is possible to calculate the variance from target on any given day (data point) which **actually represents the saving potential**. For such calculation the equation y = mx + c is used. In order to clearly depict the savings potential, the data can be plotted in a column chart on a timeline. This way positive variance means savings whereas negative variance represents energy waste. The benefit of such chart will be even higher once the variance from target (positive and negative) is expressed in currency (EUR, USD, etc.), depending on the specific needs of the plant management.



#### CUSUM

Cumulative sum of savings diagram (CUSUM) is the most important of the M&T method and comes as a result of the preceding diagrams. The purpose of the CUSUM is to depict the sum of all variances from target cumulativelly added up on each other on a timeline. Therefore, it represents the **progress of energy management in time based on the intially set target**. This diagram is powerful as it shows the overal trend of saving or wasting energy. The CUSUM, thus, enables us to translate the energy data into three straight forward statuses: savings, waste, no change.



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CUSUM allows the energy manager to assess energy data in units of currency and on various levels of equipment. Partial energy savings in individual areas of consumption (heating, cooling, ventilation, lighting, compressed air, etc.) can be aggregated into one summary CUSUM chart for an entire production unit (business unit, hall). The same way, parts or departments of a production plant can be added up into a CUSUM of the whole plant. Such synthesis of complex analyses provides **an efficient tool in evaluation of energy management** not only for the energy manager but **also for the top management** of the plant.

It is important to note that CUSUM chart using kWh as units shows the real evolution of the consumption. CUSUM of energy costs (using currency) may be influenced by fluctuating commodities prices. When prices increase, the CUSUM slope is steeper and vice versa.



# Case study: Body shop of automotive producer

In Summer 2014, the management of the body shop together with the team of HE Consulting identified a **number of savings opportunities** in the areas of heating, ventilation, compressed air, lighting, etc. with various lengths of return on investment (ROI). The savings opportunities were identified upon thorough assessment of the current production regime against the original building design and its actual operation regime. A number of saving measures were identified as **low cost**, whereas some as no cost. One of the no-cost saving measures was a reduced utilization of manually controlled air heating units SAHARA.

#### Heating system of the body shop

The body shop hall is heated by 17 air handling units stationed on the roof in three penthouses (12 HVAC units with air volume at 75000 m3 / h and 5 units of HVAC at 45,000 m3 / h). Further, over the gates inside the hall are deployed 28 Sahara units providing thermal barrier when operating the door. Along the north wall of the paint shop are located 22 Sahara units, which were installed when the operation in the workshop was carried out mainly by manual workers. Especially those who worked in the winter near windows and doors complained about the cold coming in through open gates. In recent years the manufacturing process has been to automated and the welding is currently carried out only by robotic units. The number of workers in welding has been significantly reduced and staff is mainly working in logistics and the workplaces where they add sub-components. The Sahara units are from this perspective, a relic from the days when the number of workers body shop was several times higher than at present. According to information received from the staff the current HVAC system is designed to ensure heating for the entire body shop hall.

The Sahara units are not connected to thermostats, nor are they controlled by outside temperature. They can be manually switched on and off by staff. If a gate is open for supply of parts for the production process by the logistics staff, anyone from the workers at the shift can switch the Sahara unit/s on to provide additional flow of warm air. The units however, remain turned on until the workers themselves or the maintenance staff turns them off which usually happened at the end of the last Friday shift (22:00). On Monday 6:00 at the shift start they would be turned on again by staff. From the talks with the staff it became evident that sometimes the units stayed turned on over the weekends as well.



## Saving opportunity

Therefore, the Sahara units **heat up the hall space regardless of the heat demand**. In fact, the units could be included in the heating baseload of the heat energy consumption (warm water). Assuming the 22 main Sahara units are in operation 24 hours a day, 5 days a week and 26 weeks a year, then the annual heat consumption amounts to about 2 GWh (assuming the specific heat output of heat exchanger is 30kW).

Based on the assessment of the Sahara heating units' operational regime and its context, HE Consulting together with the body shop staff came to a conclusion that **some of the units could be either switched off completely** or the maintenance staff would be asked to turned **them off when not needed**. The switching off routine and its impact on the overall heat consumption in the body shop will be discussed next.

#### **Consumption data analysis during working days**

For the evaluation of heating consumption data in the body shop, HE Consulting conducted a regression analysis using the M&T method described above. The data range for the analysis was 1. 1. 2014 - 1.5. 2014. The regression analysis (based on daily data) showed a **clear correlation between the heat consumption and outside temperature**. A trend line was set as the average of all data points in the data set which represents the average consumption of heat given the specific outside temperature. The correlation coefficient between the two variables was 0,9044 (90%), thus a very good correlation. From the scatter chart it is apparent that on some days the heat consumption at a given outside temperature was higher than on other days and vice versa. Variances from the trend line (target) are caused by human factor which has a direct impact on the consumption in the body shop. Such variance represents the savings potential.





Before the heating season 2014/2015 started, the Sahara units were put out of operation and the heating was to be provided by the existing hall HVAC system designed to provide sufficient heating for the entire hall. Therefore, HE Consulting assessed the **impact of this measure on the energy consumption** using the M&T method.

Based on the regression analysis, HE Consulting set up a target for heat consumption in the form of the trend line. In the following heating season 2014/2015 starting 22. 9. 2014 the daily consumption data had been **continuously assessed compared to this target**.

Since 22. 9. 2014 the daily data had been continuously assessed and evaluated together with the energy management team **in a weekly interval**. Each week a new chart with the variance from target was discussed and evaluated. The new data points clearly pointed out at a decrease in heat consumption as the points moved below the trend line. At the same time, it is apparent that the heating baseload was reduced significantly.

Individual variances from target are visualized in daily cost variance in chart below. Such variance can be expressed not only in EUR but in kWh or in percentage.



Using such chart is practical also in a form of table with numerical values and traffic lights. This enables a better visualisation of the results and gives an immediate feedback to **shift attention to the points which show high variance**.

It was expected that putting the Sahara units ouf of order would result in some reduction of energy consumption. The added value of using the M&T was to identify, analyze and quantify the saving measure in real numbers and in direct expenses (costs) in a regular weekly interval. Such approach to energy management enables energy manager to get the **information that there has been a positive or negative change** in the consumption



trend. In case there is negative change of trend the energy manager can proactively react on it and **prevent further energy loss**.

Since the overal consumption trend changed, HE Consulting together with the body shop staff set a **new target**. New target was set in the period of 22.9.2014 - 30.10.2014. In the chart, the original target is marked in purple (to which the savings are calculated) and the new target in green.



Since 1. 11. 2014 the consumption has been monitored compared to the new trend. However, the overall savings since the beginning of the heating season are traced against the original target via the CUSUM chart. The daily values (savings or losses) are cumulatively added on each other. From the CUSUM it is apparent that on 13. 10. 2014 the trend **dramatically changed downwards (savings)**. The flat parts of the CUSUM line represent consumption in non-production days.

The evolution of heat consumption is clearly visible in the CUSUM graph. On 22. 9. 2014 the heat consumption started (heating season start). During the three weeks in the period 22. 9. 2014 - 8. 10. 2014 partial savings had been achieved since staff had been turning off the Sahara units. However, between 8. 10. 2014 - 14.10. 2014 a trend change appeared which corresponded to the fact that the Sahara units remained switched on at several places when not needed. In this timeframe the savings achieved in the previous weeks returned back to zero. 14. 10. 2014 marks a **dramatic trend change** when the Sahara units were put out of operation and the CUSUM line changed the direction steeply downwards. By 23. 11. 2014 the **savings achieved about 15,000 EUR and continue**.





In the period from about mid November 2014 the outside temperature dropped under +5 Degrees Centigrade. The fact manifested itself in increased heat consumption. The reason was higher energy demand and the HVAC units started to heat up incoming air whereas previously the units recuperated heat from the air from inside the hall. This trend clearly manifests itself in the following chart as the apparent trend line steepens at the outside temperature of +5 Degrees Centigrade (10 Heating Degree Days). This phenomenon will be shown later.



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In the scheme below explains the regression charts with real numbers shown above. Heat gains from within the hall mainly from the production process (welding) and lighting provide heat which is consequently recuperated and supplied back into the hall. Those gains create negative baseload. The red field marks the Sahara units' regime in which these are permanently turned on and waste energy. Real heat demand is represented by the blue dashed line and later on by the blue line. Up until the outside temperature of 10 degreedays (+5 Degrees Centigrade) it is sufficient for the HVAC units to recuperate the indoor air to be able to supply enough warmth and to maintain the indoor temperature at 20 Degrees Centigrade. Once the outside temperature drops under 10 degreedays (red point), the HVAC units start to heat up the incoming air to supply additional heat into the hall to reach the required 20 Degrees Centigrade. At this point the trend line (red line) become steeper. Only in this situation could the Sahara units be theoretically effective (green field).





## Conclusion

Using the M&T methodology is powerful tool in proactive energy management. In this case it helped the body shop management to analyze, quantify and visualize the energy consumption trend. Also, it provided them with a tool to **proactively manage energy** (heat consumption) in the hall and to react on the trend changes as well as monitor the consumption in the long term.

It is necessary to note that the purpose of using M&T is **not to create unrealistic demands** on an energy manager or the facility or maintenance manager. It is obviously not in men's power to maintain energy consumption so that it would copy exactly the trend line. The energy manager can set a variance tolerance of e.g. 20 % which he or she considers as natural operational variability. The main meaning of M&T method is to manage energy proactively, not reactively.

M&T is an appropriate tool to **achieve savings through optimization of existing equipment** without massive investments into new appliances or technologies. At the same time, it complements theoretical calculations of energy savings by **providing the real numbers**. For most of (not only) industrial companies it will be necessary to achieve further energy savings in the upcoming years. M&T represents one of the most effective ways how to achieve those savings, because it has a **very short return on investment up to one year**. I this case, the cumulative savings for the heating season 2014/2015 achieved about 200,000 EUR.



# **HE Consulting**

At HE Consulting our main expertise is to help industrial clients achieve **significant energy savings** at their manufacturing facilities. Our approach is different from that of our competitors and from what most people believe **energy management** is about. The methodology we developed has proven to deliver for our clients large energy savings within only a short time period.

#### How can we support you?

- Preparation for ISO 50001 certification
- Energy Audits according to legislative requirements (406/2000, respectively, 27/2012/EU)
- Energy Assessments of individual projects (according to 406/2000)

However, we are not satisfied with merely identifying a savings potential for our clients and put it in a paper report. ISO 50001 certification or an energy audit with HE Consulting means that in addition to certification preparation or reaching compliance **we will not stop supporting you until the initially defined savings potential is delivered** and until you see this in a reduction of your energy bills. We call our unique methodology <u>QUEST</u>, standing for quick energy savings technique.

## What makes us different?

- We **make energy visible** in a way that you will understand. Different from conventional monitoring of consumptions we teach you to work with energy data in a new way.
- We **focus on the human factor** in energy management and help you with introducing the concept of "energy culture" to your company, meaning a paradigm shift where the responsibility for energy consumption does not lie any longer exclusively with the energy manager.
- We use and deploy rapid and effective data tools and methods but will stay with you as long as it takes until you have acquired these and can **use them independenly** without our support.
- We will ask you to pay for our services only after it is apparent that they will deliver the results and objectives that we have defined together at the beginning. This makes the program **self-financing**.





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