# Monitoring as a secure basis for energy efficiency measures

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## Keywords

energy efficiency measures, industry, realisation of savings, visualisation of losses, measurement, multi channel load analysis, evaluation of measures, energy services

## Abstract

Today´s energy efficiency programs for industry offer opportunities to save a lot of money in the field of energy consumption. Practice, however, shows that results and realized savings in many cases are rather poor.

Successful realisations of energy saving measures in most cases are made whenever energy consumption, losses or waste of energy is visible for the decision makers. So a detailed analysis of the companies' energy situation with various measurement systems and visualisation of results is the basis for appropriate activities.

The paper shows a lot of convincing and surprising results, that can be obtained with different technologies of monitoring in various fields of energy technologies and that directly lead to savings and optimizations:

Multi-channel load monitoring in electrical systems leads to exact power and energy statistics of the company, the results permit a precise cost center and cost unit calculation. Apart from control engineering problems (e.g. compressor control), time constants of thermal consumers, which are not assessed correctly in most cases, can be recognised. Monitoring of thermal power for example shows problems with hydraulic systems or visualizes losses caused by polluted heat exchangers.

Additional measurement of temperatures and other services provided by energy in the system (light, compressed air, …) allows a detailed evaluation of energy and the efficiency of the system in different operating conditions.

Additional to this, consequent monitoring allows to evaluate the results of well aimed measures and to optimize different parameters after changes in the system.

## Introduction

More than 10 years of energy consulting in industry allows us to look back on a lot of successful and less successful projects. We also have been involved in many campaigns all over Austria and so could see how other consultants work and what are the benefits of their special approach to point out energy saving potentials. And there is no doubt – the only projects we can really call "successful" are those that lead to realized measures and savings.

Very often good ideas for energy savings stay in the stadium of a concept that you can find in some file in the office of the responsible person. Actual interviews with our clients show, that the main reason for measures not to be realized is, that the responsible persons are not sure about the facts pointed out in the paper in their hands. And in most cases there is no doubt about the calculation that leads to the result, but about the basic facts and estimations that are made in the beginning. As especially electrical energy and power is hard to estimate but in most cases responsible for major financial expenses, we decided to satisfy this special needs of our clients by a visualisation of the power-graph of their single machines and show them in relation to the total power demand: so "Multi Channel Load Monitoring" was a ideal tool for energy consulting in industry.

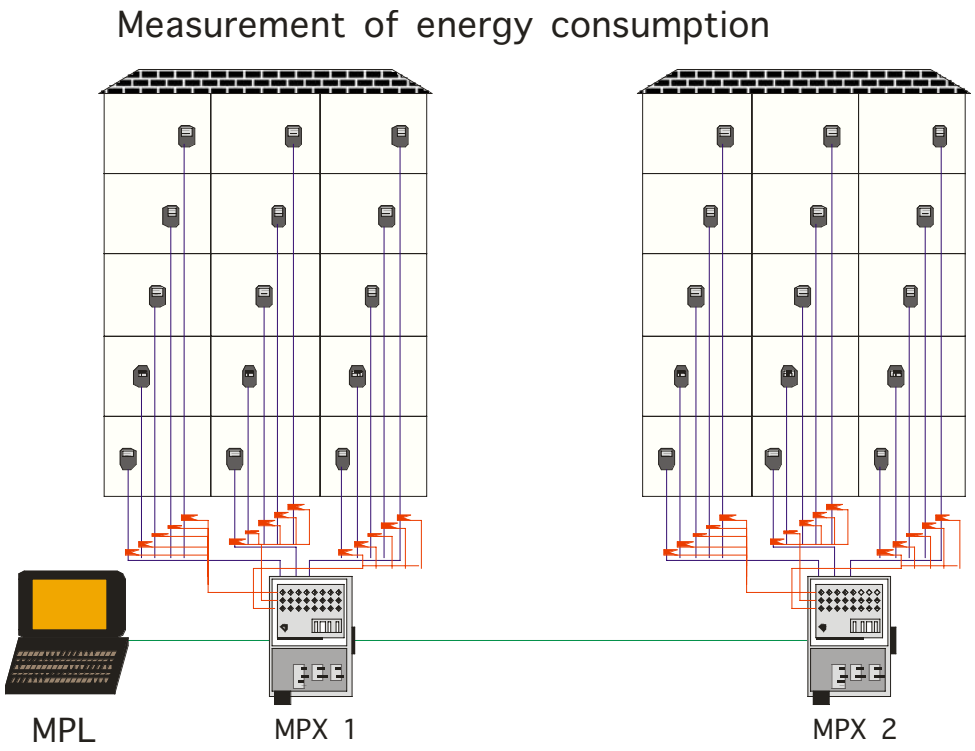


***Figure 1.*** *Measuring device MCA. Application of the measurements in 60 households.*

## Multi-Channel-Load Monitoring

### HISTORY AND FIRST STEPS

It was in 1993 when we came up with the idea of Multi Channel Load Monitoring working on a project, where we wanted to compare different aspects of energy demand of sixty households [1].First of all the differences of the habitual use of energy. Secondly it was our goal to find out about the influence of aspects like the change of seasons over the year. And then we wanted to know if information and motivation about energy saving potentials could cause changes. And we knew, that we had to measure the load curve of each of these 60 households in a high resolution to get answers to our questions.

Market research led to the conclusion that there simply was no appliance available at the market which would have met our expectations. So?! No way to continue with the project!? Well, we thought, why not develop our own equipment. In any case much better than to give up. And then, with a slight delay of 12 months, we continued our project with the first 4 prototypes of our own system.

From the point of a professional electrician everything was quite easy: at a central point in the house, in this case the main distribution, we just measured the 3 phases working voltage directly. At the same time we took the individual currents coming from this point into the house in using current-clamps. As all households are connected with this point we could test 15 households at once without a disturbing interruption in the all day life of the families. The results were very satisfying so we could define different household categories depending on their characteristics [1].

Individual households show a difference in how many people are present. “Category 0” would mean that hardly anybody is present during the week, using the flat just on the weekend. The load curve is dominated by some kind of standby-consumption caused by refrigerator, electronics and water consumption. “Category 1” shows a rather bigger consumption for hot water and some activities in the morning and in the evening. “Category 3” means energy is used every single day for a considerable amount of time with hot water boiling as the main consumption. Figure 2b shows different refrigerators with their time constants which differ in factors like switch on and off as well as maximum power. The 4$^{th}$ picture in the series shows the addition of two cooling appliances. The need of energy caused by stand-by modus can make up 20 to 50 Watt.

The plausibility check – done by weekly meter readings of all households - also shows how the energy needs changes within a year. The little need for energy during the summer months is easy to explain by the fact that people simply go on vacation. A remarkable up and down is given in the weeks 38, 39 and 40 which can be explained by an irregular meter reading as the interval between the readings was not really 1 week. The trend line points out, that energy consumption changes over the year similar to a cosines function (see formula in Figure 3) [1].

### FIRST STEPS IN THE INDUSTRY

Beginning with energy consulting in industry, we soon figured out that basically the given factors are the same anyway, but instead of single households we now would have to deal with machines. And those responsible in companies ac-

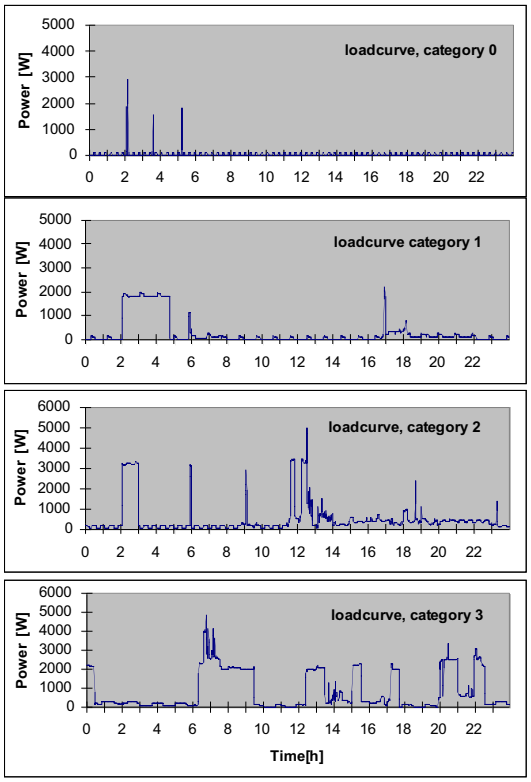


***Figure 2a.*** *Different household characteristics.*

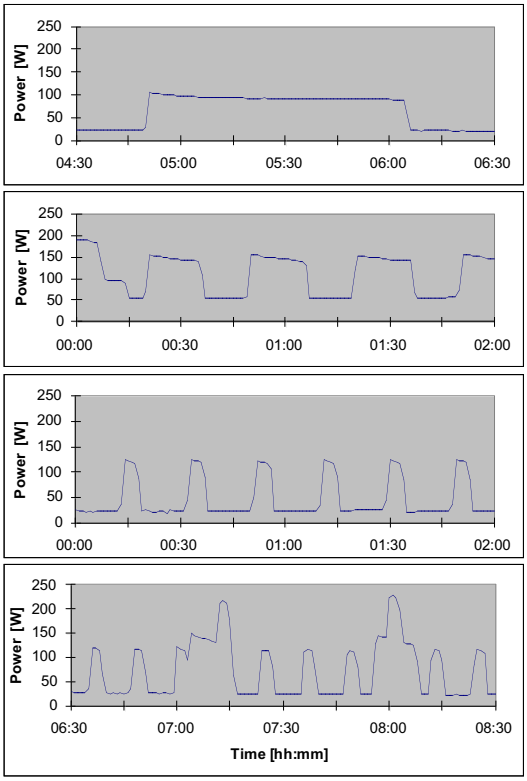


***Figure 2b.*** *Different cool storage appliances and stand-by.*

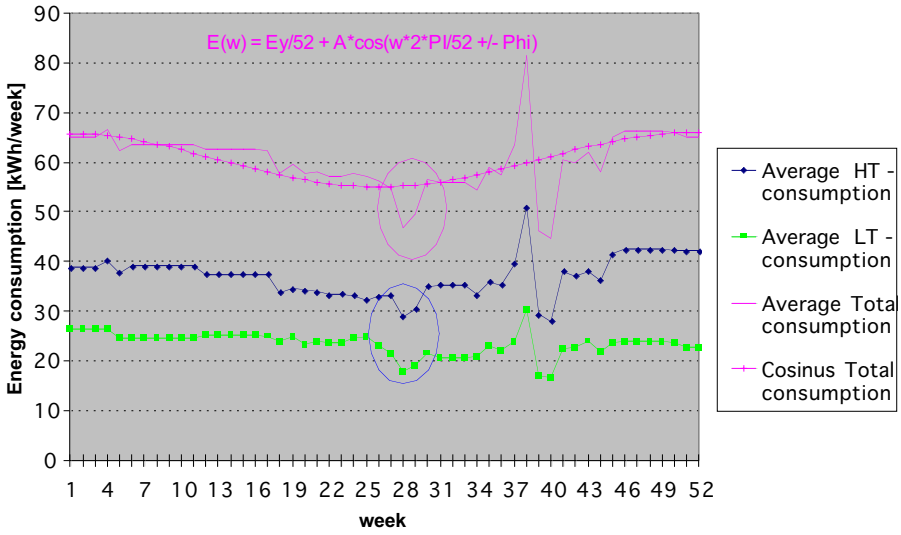


***Figure 3.*** *Weekly energy consumption and reading errors.*

tually had the same questions as Mr. and Mrs. Smith in their apartment:

- What influences energy expenditure?
- Which machine needs most energy?
- When is spent most?
- What for is energy needed constantly, what for in the peak times?
- Where is energy really wasted?
- Where do we find completely unexpected energy losses?
- Where and how much can we save on energy and money?

We found, that in some companies they had begun to collect data by installing lots of energy meters, but what we wanted to serve was a measurement of load curves for 2 weeks in a high 1-minute resolution that had to be installed and de-installed easily and without any disturbance for the production

***Figure 4.*** *Multi Channel Load Monitoring in industry. Set up of measurement devices.*

in any company. The easy to handle system allows first precise and basic perceptions and results within a few days and without a longer preliminary time.

## REAL LIFE APPLICATIONS

It is useful to use the following course of action in energy consulting to draw successful results [2,3].

### Measurements

In order to analyse a company properly we had to set up the measurement applications. The workload of course depended on the amount of instruments necessary to calculate the need of energy of all users. In most of the cases the responsible electrician was a good help and fully involved in our job. A period of 2 weeks of measurement in the company was normal to be able to show differences and ups and downs of energy needs.

### Evaluation and Interpretation

After the mentioned two weeks the data is taken and evaluated in the office so you can see the daily load curves of all the single consumers (14 data sheets). Normally as many channels are measured that several sheets are needed which are then discussed by our consultants who try to interpret the measurements with the background of their experience. Out of that first comments and remarks are given in possibilities on where and how to save energy.

### Discussion of the reports

From our point of view there should be a focus on the discussion of the reports with the responsible persons. At least half a day is needed to explain the measured results in the company. Depending on the interest of the participants also a whole day could be used. We respond to answers, suggest ways of improvement and help the company owners to see the possible savings. They are motivated to come up with their own ideas and together we pick out the most efficient ones and have a more detailed look at those.

### Suggestions for improvement

These discussions and measurements are the basis for the decisions about the following, more detailed, course of action. We try to make a list of the economically useful measurements and explain how we could help to put the theoretical knowledge into practice and therefore save energy, money and time.

## RESULTS OUT OF THE USE OF MULTI-CHANNEL LOAD MONITORING

Experience in Multi-Channel-Load Monitoring was very helpful for a better understanding of the relevant processes in the individual companies and gave us an insight into the basic procedures and how they are related to each other. The following examples and results represent a part of our vast experience [2,3,4]. In most of the following cases a daily load curve is shown, with a total consumption related to the right y-axis and one or more detailed load curves related to the left y-axis. Measurements are taken every single minute, because the consumer behaviour can be pointed out best that way - a higher resolution would be confusing, a lower resolution doesn't show enough details.

### Illumination – a heavily underestimated source of energy loss!

Most responsible persons do not realize how important the topic of illumination is. It seems to be a minor consumer in comparison to all the power intensive machines and simply nobody knows how to change anything.

Figure 6 shows the load curve of the illumination of a metal working company (blue line) in relation to the overall load curve (black line) and other load curves of main consumers of the company. During the night illumination is responsible for half the consumption, during the day for about a third. All in all illumination is the largest consumer, more energy intensive than the machines. Basically all the lights were on all the time in all the places, although -especially during the night - there are working only a few employees. With a plan how to divide the whole area in individual zones we just had to tell the employees only to switch on the lights they really need to do their job. By taking this small step of improvement the use of energy could be reduced up to 70% in the afternoon and night.

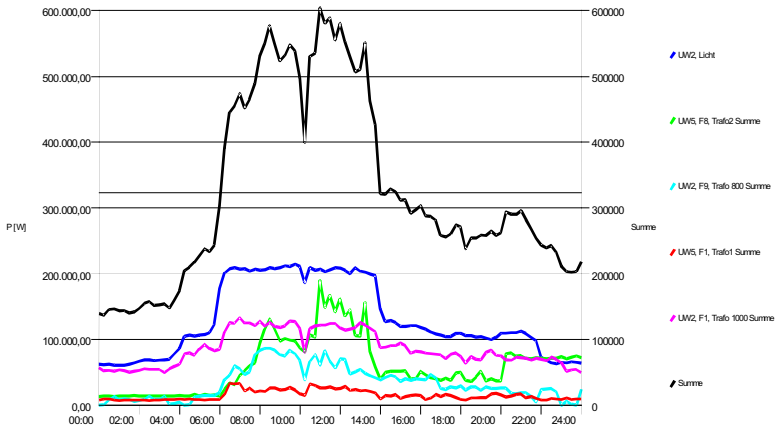


***Figure 5.*** *Illumination. Major load in the metal processing industry.*

**The air extraction system – always under control?**

In many wood working companies we noticed that although unnecessary, the air extraction system was used permanently. The following example shows the red load curve of a wood chopper, chopping the wood waste mainly between 6 a.m. and 2 p.m. including some breaks. This chopper has a proper air extraction system in order to transport the wood chips into a storage silo, being on nearly all the time between 6 a.m. and 8 p.m. A coupling of the extraction system to the chopper by a control system is only a little change causing considerable savings.

**Compressed air – much room to improve the efficient use**

Compressed air is a very inefficient form of energy. Measurements in a small carpentry shows the important factors like running-time, the actual need of air, the pressure level and leakages. As the enterprise is only producing for 10 hours a day, while the compressor is running day and night, a major amount of energy can be saved by simply switching off the application from 8 p.m. until 6 a.m. The individual peaks in the load curve show how often the compressor reloads the air system to provide constant high pressure. The running time during the night is also a measure for the leakages. As pointed out in the picture below, the need of air for leakages during the night is nearly the same as during the day which means, that the „productive consumption" of compressed air is minimal.

As no user needed a higher pressure, the level of pressure was reduced by 2 bar at 6 p.m. A sudden reduction of the loss by leakages could be noticed as well as the running time of the compressor which led to less costs for depreciation and service.

**Control engineering – the right adjustment is important**

Generally it can be said that not the installation of an unit is of importance to realize savings but using and adjusting it correctly. The below pictured lines show the load curves of a hotel equipped with a load management system adjusted to 200 kW. As the maximum load never reached this level the load management system did not have an effect at all. A considerable saving was done in simply reducing the actual

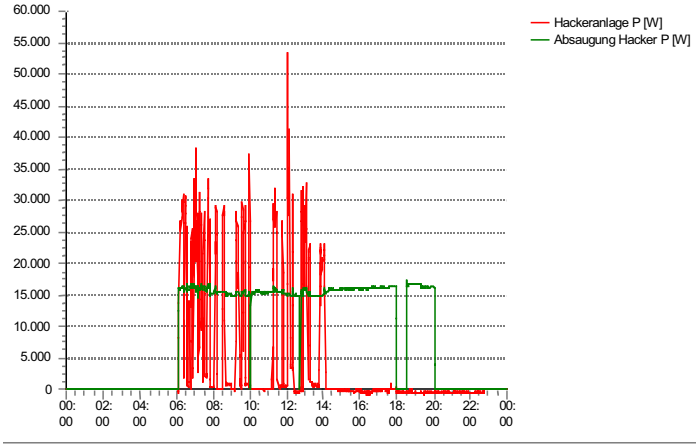


***Figure 6.*** *Wood working industry. The extraction system passes through.*

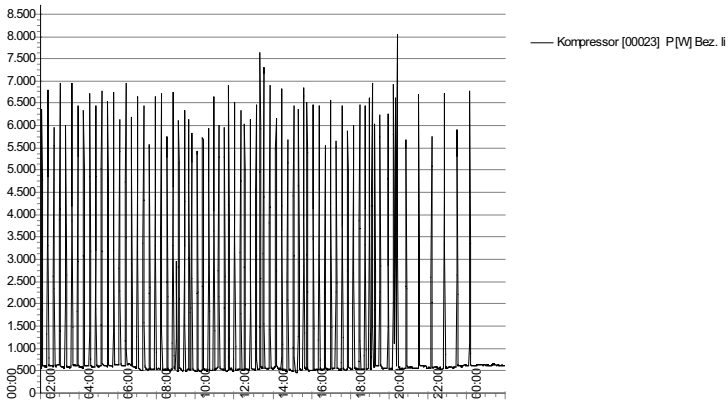


***Figure 7.*** *Compressed air system. losses cause the main consumption.*

value to 125 kW by reducing the power level of the control system.

**Combined Heat and Power – Solely Power is not enough!**

In the tourism industry we could find a Combined Heat and Power System (CHP) which ironically reduced the power

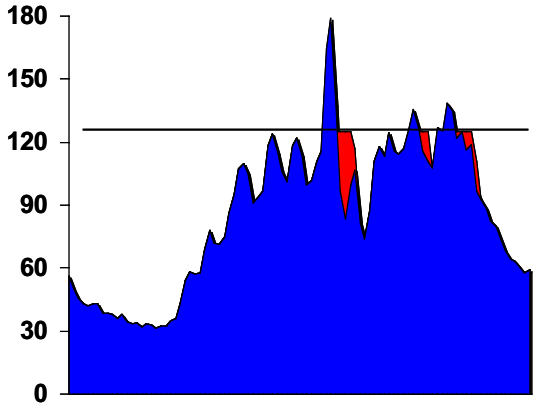


***Figure 8.*** *Load management system. After installation a correct parameterizing is of importance.*

when the maximum electric load was needed (light brown line). The green and red lines show the behaviour of the 2 generators of the CHP-system. An exact verification showed that mainly the adjustment of the control unit of the CHP system and the boiler is of importance.

The additional boiler kept the temperature-level of the buffer that high, that during peak times the CHP-system could not deliver more heat to the buffer and had to shut down as no emergency cooling system was installed. By giving priority to the CHP-system it now can deliver all its heat-energy to the buffer and stays turned on. The boiler is only switched on when the buffer temperature really drops to a rate, where a heating is absolutely necessary.

### Energy users –Machines alone don't use energy

One mustn't forget that mainly the user, not only the machine itself, has the major influence on the real energy consumption. As production is the most important thing for the enterprises employees are told to look after the most efficient way of producing. The air extraction of the manual varnishing system (blue line; red line is total consumption, green and brown show other extraction systems) was running all day long , because the employees did not use the energy saving technique, which would have switched off the extraction system by simply hanging the varnishing pistol on a hook connected to a switch. Instead they just put it somewhere nearer on a nail in the wall which was more comfortable. The simple step was to install the hook with the switch-off function in the position where the nail was before.

## Load Monitoring in Thermal Processes

The same procedure used in the field of electrical power is applicable for usage in thermal systems. It would also be

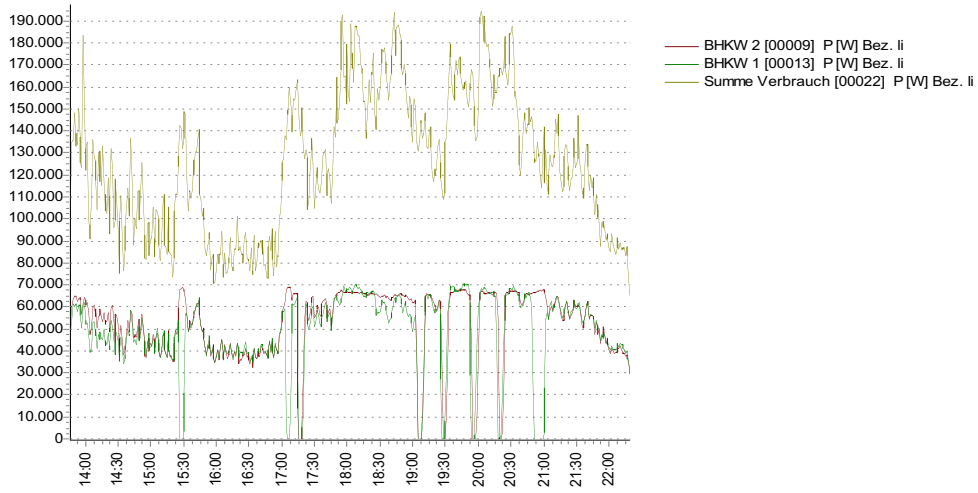


***Figure 9.*** *CHP-Combined Heat and Power. Problems at peak energy demand.*

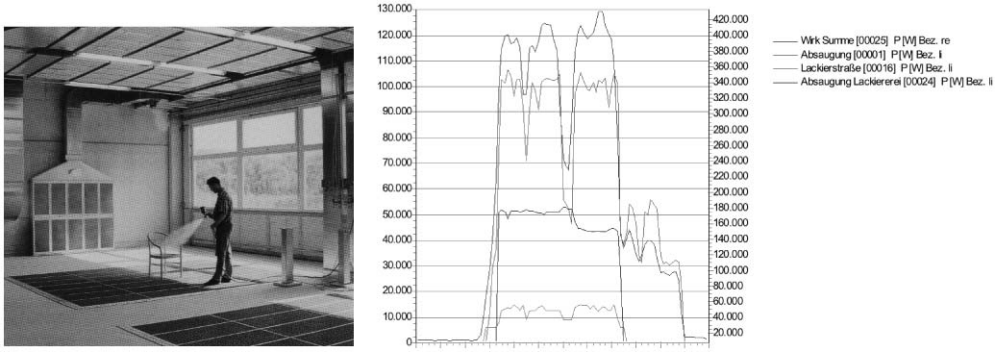


***Figure 10.*** *Production comes to the fore – the need of energy is hardly considered.*

possible to work with an analog system of the Multi Channel Load Monitoring but a lot more work would have to be involved. Instead of simple and rather cheap clip-on ammeters is an ultrasonic sensor used to measure the power, which rises the costs by the factor 10 in comparison to electrical energy (5 000 Euro / consumer).

#### HYDRAULIC PROBLEMS – COLD AND WARM FOR A WOOD DRYING CHAMBER

Doing measurements on a wood drying chamber we noticed a major variation of power (green line) and heat (red and blue lines show system temperatures) in a rhythm of 15 minutes. The thermal power varies between 300 kW and more than 1 000 kW. We found, that by opening one damper that much power was lost at certain points that there was nearly no power left for the rest of the chambers. In the meantime we found a solution in setting up a new, better adjusted distribution device.

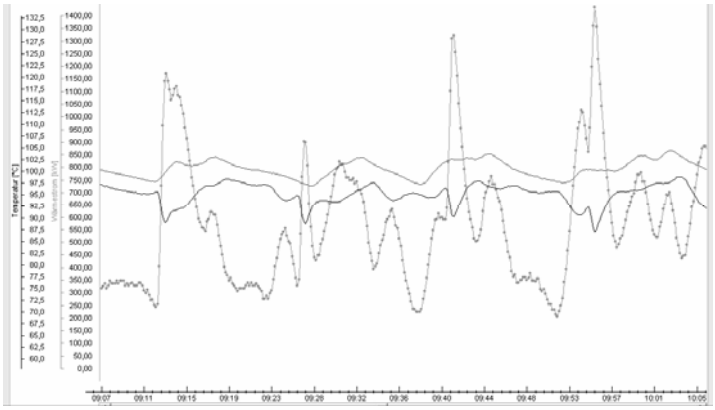

***Figure 11.*** *Temperature and thermal activity. Considerable fluctuations caused by hydraulic problems.*

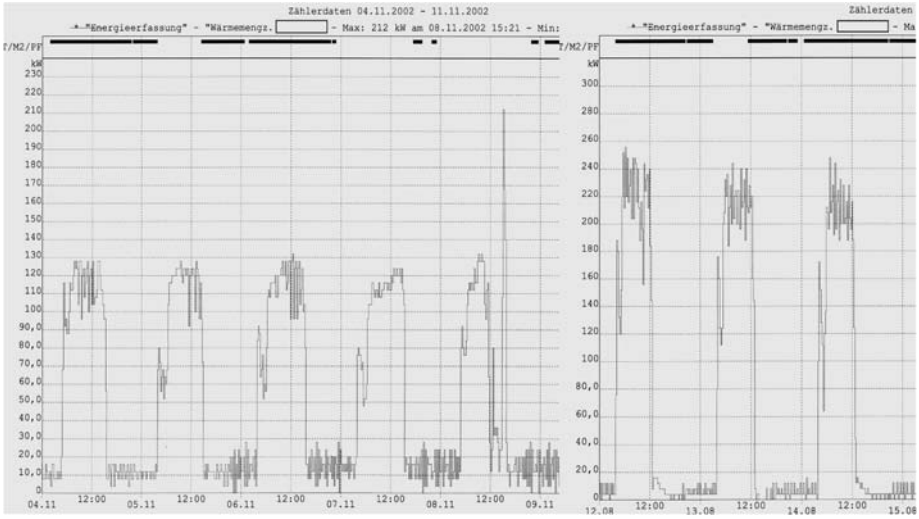


***Figure 12.*** *Power of a heat exchanging device. Different transmission capacities before and after cleaning the surface.*

#### CONTAMINATION OF HEAT EXCHANGING DEVICES – THE BOILER IS ON, SO WHY DOESN'T IT GET WARM?

Irregular service and cleaning of devices is another major point in saving energy. Especially it can be the reason why machines do not work properly any more. The following picture shows that the power of heating was 130 kW or even less when the problem was noticed first. The temperature in the bath became deeper and deeper so that a cleaning was done with the result that the power shot up to 200 kW. Even 250 kW are possible but with every single day of usage, the machine becomes less and less ineffective again. The solution was simply the introduction of a regular interval of cleaning.

#### A TOO EARLY START OF SYSTEMS – THE FEAR OF BEING UNABLE TO PRODUCE

We could notice that thermal systems are always started very early to ensure they have reached operating- temperature when the production process begins. Figure 13 shows that the machine is switched on at 3 o'clock in the morning with a high need for power in the beginning -to warm up the cold parts – and a reduction later on. At 7 o'clock, when production really starts, much more power is needed. The machine itself actually needs only half an hour to be warm which means that energy is wasted for more than 3 hours. A later start of the machine could save up to 10 % of the energy consumption.

## Further benefits of Multi-Channel Load Monitoring

Besides the fact that Multi Channel Load Monitoring uncovers the inefficient use of energy the system is also the basis of an energy concept and energy planning including the evaluation of the realised measures.

#### BASIS FOR PLANNING

The Multi Channel Load Monitoring offers as well the basis for planning. Measurements at a certain point of time of the year allow evaluating the characteristics of a consumer. With software for simulation a yearly calculation is possible and that way, like in this case for a thermal user, it is possible to figure out the need of power during the summer and the

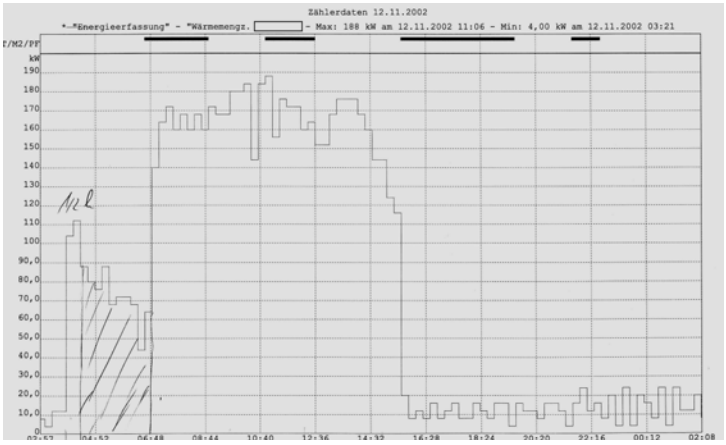


***Figure 13.*** *Requirement of energy of a process. An early start, stand by and actual use of heat.*

winter months. Additionally the example points out how consumption depends on the number of units that are installed (blue, orange and red line), which lays the basis for the profitability calculation.

### Controlling of measures

Many clients already confront the energy consulter with their suggestions about how to save energy and just want a confirmation for their ideas. A concrete example was a wood working business which had a very power intensive edge mounting device and therefore was responsible for the major consumption of energy (figure 15, blue line). The companies' owner had heard about an alternative technology and it was now our responsibility to find out if a change to the new advice would be advisable or not. The results are shown in figure 15: The load curve of an edge mounting machine with melting glue (green line) is about 20 % of the consumption of the old white lime aggregate. We found out that the investment would pay off within only four years. So the move was done not only because of the saving of energy but also because of a couple of other positive side effects.

### Measures and estimation of their consequences

Another main benefit of this kind of monitoring is, that it is rather easy to show to the client, what the single measure can change in his system and what he will save by realising the measure. In a cement-plant we found 2 singular compressed air systems each working at about 50% of the capacity of the compressor (a 27 kW and a 55-kW machine), which

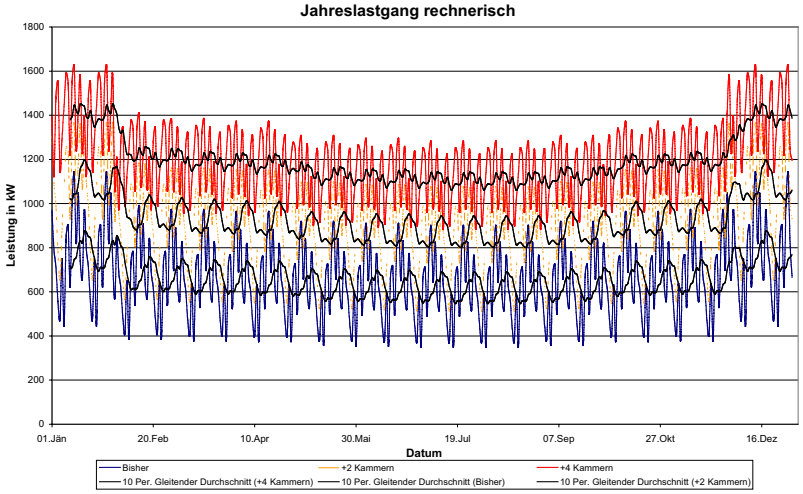


***Figure. 14.*** *Load Monitoring as basis for simulation: annual load curves for different thermal loads.*

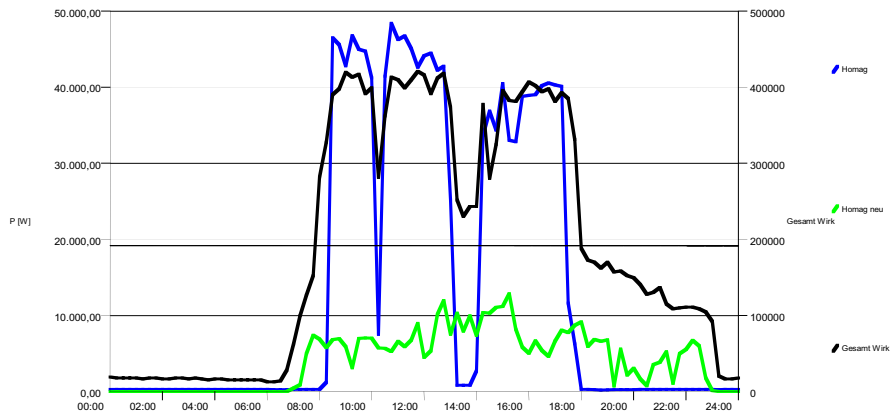


***Figure 15.*** *Edge mounting machines: comparison of different technologies.*

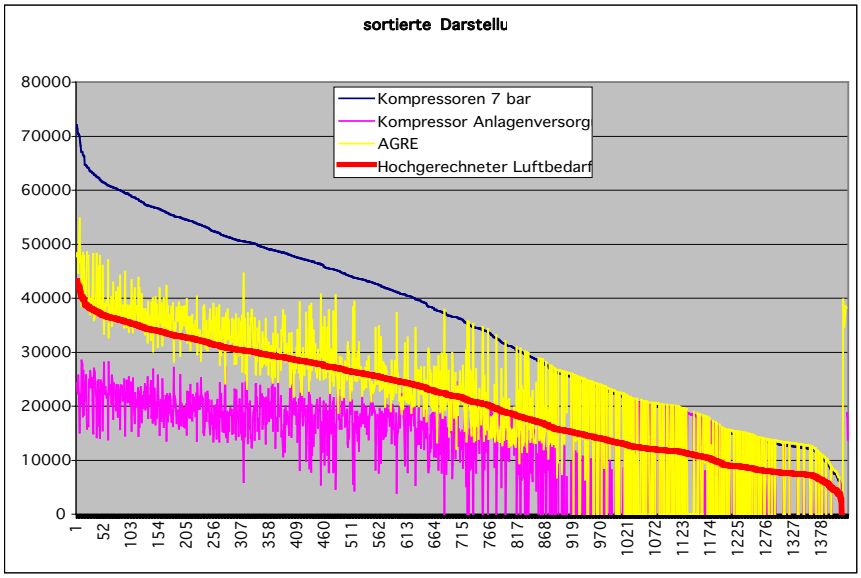


***Figure 16.*** *Effect of a measure: changes in a compressed air system.*

means big losses due to unloaded running times (25-30% of power consumption without producing compressed air). Additional those 2 compressors were installed in a rather rough surrounding, leading to high expenses for services. The idea was, to realise one bigger net-system by hanging these nets together and placing those compressors in a central point with better surroundings. A third - 15 kW compressor yet existing in the plant – should lead to a higher redundancy. Analysis of the data led us to the following figure showing the benefits of the planned system:

Based on the measured load curves of the two compressors we get the total consumption for each measurement period and sort it from the biggest to the smallest value (blue line). Yellow and pink lines show the power consumption of the single compressor in each moment of these total values. As the power of the single compressor that appears in the graph is always a result of loaded and unloaded operation it includes the losses of unloaded operation, the blue line including those losses of both compressors. The red line is an estimation of what a compressor without those losses would consume and allows to point out the best way of operation for the compressors in the new system. Up to 15k W the additional compressor delivers air, beginning with 15 kW the job is done by the 27 kW-machine assisted by the small one between 27 and 42 kW. Only when one of those machines is out of operation because of some reason and if higher peaks occur, the 55 kW machine has to be operated. This way not only energy is saved but as well cost for running time (service and life-time) are reduced by about 35%!

## Evaluation of Multi-Channel-Load-Monitoring by external authorities

### Kommunalkredit Austria

Within the scope of an energy saving programme for carpenters and grocery stores in 1995 the Multi Channel Load Monitoring was used as well. The results and detailed presentation of the individual steps and their consequences were that convincing that the responsible authorities wanted this system to become obligatory for any consulting in this program. Unfortunately the resistance movement of other consulting agencies lead to the failure of those plans.

### Ecological Company Consulting of the Upper Austrian Chamber of Economy

We also had many commissions to develop branch energy concepts for the Ecological Company Consulting of the Upper Austrian Chamber of Economy. With the support of Multi Channel Load Monitoring especially precise conclusions could be drawn and very efficient actions were taken for the single companies as well as for the whole branch. Evaluation showed that the clients who set their actions based on Multi Channel Load Monitoring knew in detail about their energy consumption and were able to realise a lot of simple and inexpensive measures that lead to remarkable savings.

### Upper Austrian Energy saving Agency (ESV)

Detailed measurements were done for individual consulting as a basis for sectoral energy saving concepts in charge of the Upper Austrian Energy Saving Agency (ESV). So the consumer can see considerable results and illustrative measures which finally lead to great success in saving energy.

### Styrian Chamber of Economy

As consultants of the Styrian Chamber of Economy we are often confronted with quite challenging tasks, that are specially brought up to us. They found that Multi Channel Load Monitoring is an adequate help to find solutions for delicate energy problems and that the special experience one gets out of this work is helpful for these special problems to be solved.

### Austrian Chamber of Economy

Since the last year even the Austrian Chamber of Economy has involved us in different energy efficiency action. As well

for the new branch energy folders for the "Energie-Effizienz-Offensive" as for the European Energy Manager (EUREM)-Training results, examples and pictures from Multi Channel Load Monitoring are a basis and get the best evaluation by the participants and the responsible persons.

## Conclusion – The benefits of Multi Channel Load Monitoring

Due to the forced use of measurement technology with the focus on visualization of possible energy-savings new and better quality concepts of energy efficiency can be developed. And this is helpful as well for the consultant as for the clients as for the whole economy.

### Benefits for the consulter

Multi Channel Load Monitoring allows the consulter to visualize energy that could not be seen without it. The system is easy to install, depending on the number of channels - that can be machines or parts of the company – and depending on the structure of the electrical distribution system in the company – it takes between 3 and up to 8 hours to set up the measurements. It can be installed without any influence on the workflow because it does not need any interruption in the energy-flow and is situated in the central distribution of the company – not near the machines. So it allows to obtain really detailed basic facts about energy consumption whenever you need them for some kind of energy saving action. To be able to show facts and figures makes it much easier to convince the clients of the importance of taking action to save energy.

### Benefits for the clients

In many cases the owners or responsible persons of the companies do not realize how much energy is wasted in their business and they would not believe, if some consultant came there and told, without showing it black on white. Those measurements show exactly where, at which time and what amount of energy is used or even wasted, so the clients can be sure to get the best advice as they can prove even the basic facts by themselves. This system makes even clear how employees and machines use energy and lay the basis for energy savings. The employer can come up with his own ideas as he knows best what he is doing and what he could do better and even may calculate how efficient a change would be as well as find arguments for taking action. Especially in decisions for investments there is given a higher security to do the right things and this way the method forces realisation of energy saving measures.

### Benefits for energy saving programmes and the economy at all

Like a medical treatment for humans a regular monitoring for companies could help to create "energy healthy businesses". The advantages of a healthy population are nearly the same as those of a energy – healthy economy. When the companies can make correct decisions about their measures, energy saving will be much more profitable and more and more companies will go that way of energy efficiency. That would bring more participants and better results and reputation for energy efficiency programs [4].Even subsidies could be distributed more effective and precise based on the results of Multi Channel Load Monitoring.

## References

[1] SATTLER, P., SAKULIN, M., SCHMAUTZER, E., GROSS, A., SCHÖFFER, W., 1995 „People as the main influence on real energy consumption", ECEEE Summer Studies, Mandelieu

[2] DITTRICH, R., SCHÖFFER , W., SATTLER, P., 1998, *"Gezielte Maßnahmensetzung durch "Vielkanalige Lastganganalyse"*, "European Conference on Industrial Energy Efficiency, Success Stories", Vienna

[3] SCHÖFFER , W., SATTLER, P., 2000 *"Multichannel Load Analysis - from visualisation to automation"*, UIE-Conference "Electricity for a sustainable urban development" Lisboa

[4] SATTLER P., SCHÖFFER, W., 1999 *"Forcing realisation of energy saving measures in business"*. ECEEE Summer Studies, Mandelieu