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Energy Efficiency Monitoring and Reporting Make Improvements Visible

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Abstract

Energy efficiency monitoring and reporting is not a new issue in the energy-intensive industry; this work has been done for several years already in power plants for example. Respectively the main focus of monitoring and reporting in the process industry has been in production, and the follow-up of energy consumption has been a secondary aspect. Increasing energy prices and the importance of energy security have also made this item more and more crucial in this industry area.

Comprehensive monitoring helps manage energy efficiency, finds energy saving potential and enters sufficiently deep in the process through a system-oriented approach. It can also be used to increase and maintain knowhow, as well as for other energy efficiency work at the target location. Correspondingly, reporting can be utilized to manage and implement energy efficiency targets as well as to benchmark and plan targets and goals.

The base of monitoring and reporting is in extensive measurement instrumentation and the infrastructure of ICT but also the user of the applications and equipment generally plays a key role. Usability of systems is essential as well as the practical nature of information /Nielsen 1993/.

There are plenty of possibilities for new plants, but the building of extensive monitoring and reporting systems in a cost effective way is much more complicated for existing plants. In these cases the development project of monitoring and a reporting system should contain the following phases:

- Definition of users and needs for energy efficiency information
- Survey of available technical resources
- Development plan
- Installation and implementation
- User training

Energy efficiency is and will be an essential part of daily work in the process industry. The role of monitoring and reporting in this work is to visualize implemented improvements and achievements in order to improve cost efficiency of production.

Introduction

Energy efficiency monitoring and reporting is not a new issue in the energy-intensive industry; this work has been done for several years already in power plants for example /Voimalaitos automaatio 2007/. Respectively the main focus of monitoring and reporting in the process industry has been in production and the follow-up of energy consumption has been a secondary aspect even though it can play an important role in reducing energy use and emissions. Energy efficiency follow-up savings potential varies quite much between cases but for example in pulp and paper industry it has varied between 2 -18 % /Kramer et al 2009/ which means hundreds of thousands euros savings per year.

It has been defined in European Commission's Reference document on best available techniques that the following items are BAT of measuring and monitoring /European commission 2009/:

- analysing and benchmarking the system and its performance
- planning actions and investments to optimise energy efficiency considering the cost benefits and cross-media effects
- for new systems, optimising energy efficiency in the design of the installation, unit or system and in the selection of processes
- for existing systems, optimising the energy efficiency of the system through its operation and management, including regular monitoring and maintenance.

As we can see, the development of energy efficiency follow-up is a very wide and extensive topic. Based on the experiences and interviews in the process industry the development of energy efficiency monitoring and reporting should include the steps presented in figure 1.

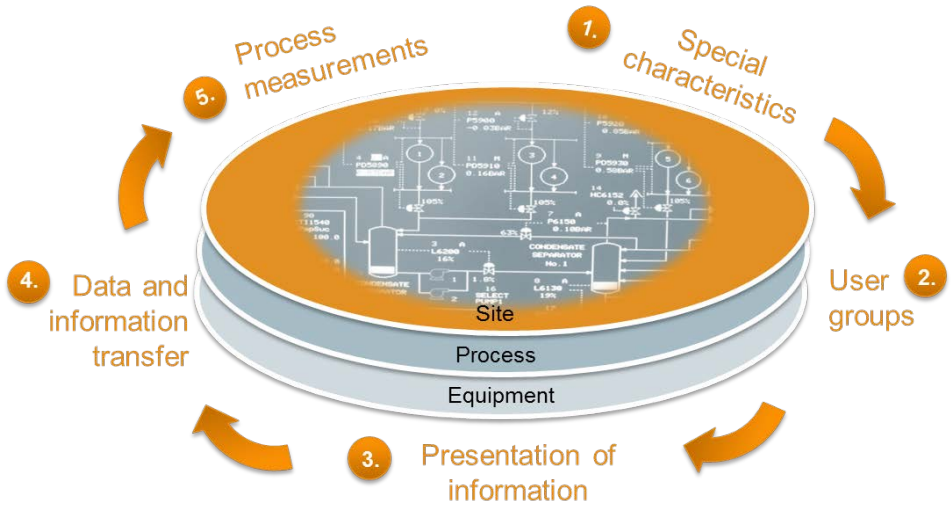

Figure 1. Steps for improving energy efficiency follow up

These steps are the same in all cases, but their content can be very different. Consider and compare for example the food industry and the process industry. That's why all the steps are presented in the following section and a more detailed check-list is given in appendix.

Special characteristics

In order to execute energy efficiency actions, special characteristics of each process and location have to be understood. For example, the geographical location defines which kind of legislation, climate and physical resources (raw materials and energy fractions etc.) are available. In addition, manufacturing processes and the end product's quality specifications create boundary conditions for energy efficiency. For example, in the process industry heat balance may be very complicated and because of this it is crucial to focus on improving the monitoring of heat consumption. On the other hand reporting is preferred to on-line information in a non-energy intensive process industry where the main processes are not continuous.

The technical age of a mill or production line is often forgotten /RISI/. When planning a new production line it is possible to improve its energy efficiency monitoring cost effectively because no concrete actions have yet been done. Also there are far more extensive controlling systems and methods used in new lines than in older ones. On the other hand personnel's experience and knowledge may be weaker in new lines than personnel who have optimized process for years in an existing production line.

There are also some items which need to be checked before starting the development of energy efficiency monitoring and reporting. For example, information about documentation practices in company and knowledge and motivation of personnel is needed. If documentation of measurement instruments is poor, it is recommended to update these documents before proceeding in development work. Also personnel's knowledge of energy efficiency should be wide enough in order for them to adopt new methods and solutions.

User groups and need for energy efficiency information

In the process industry there are several user groups for energy efficiency information whose needs for information quality and amount can vary a lot /Kuorelahti 2011, Pentti 2009/. Information presentation tools and equipment too can be different. It is essential that available information is in a useful format and that it supports each user's daily work. Figure 2 presents typical user groups for energy efficiency information /Reese D. 2009/.

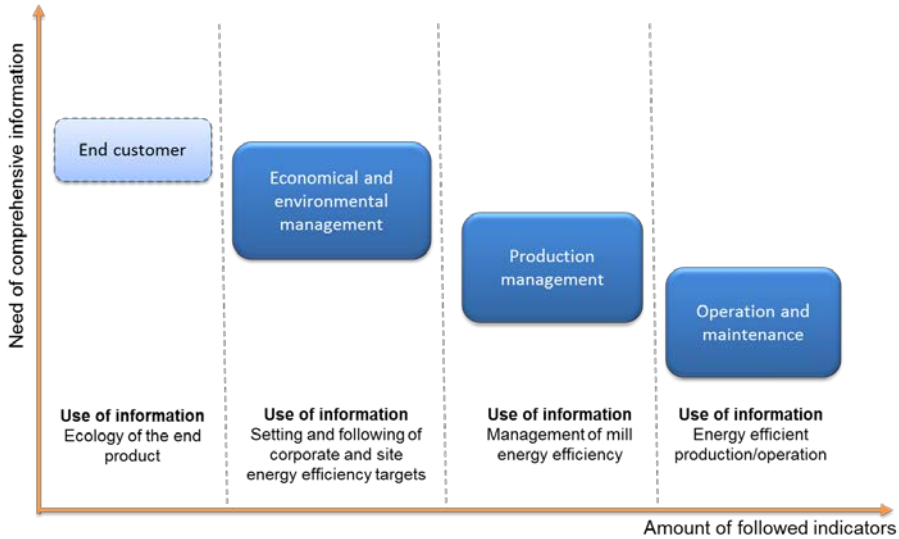

Figure 2. The most typical user groups of energy efficiency information

At economy and environmental management level it is essential to get a comprehensive picture of an existing situation. Typically information is used in an energy efficiency target setting and follows improvements made when the amount of followed indicators is less than ten. Followed indicators are mill-wide consumptions, emissions or energy cost when the need of data resolution is for example one month.

Detailed production-based data is also needed in production management /NRMCA 2007/ when the amount of followed indicators increases. In this level on-line information is typically used, though history-based data is also

regularly utilized. It is essential that information is always somehow linked to the production amount and end product quality.

Operational level users can be roughly divided in two main groups: process operators and maintenance personnel. For a common factor for both these user groups is the need for practical information. On-line monitoring is a useful tool for both of these groups.

The most important user group for energy efficiency information is the users of an end product. Their needs have to be constantly noticed. Customers need comprehensive product-based information.

Presentation of energy efficiency information

Presentation of information is an important issue because it is always an interface between a machine and a user. It is very difficult to improve or change the operating method of process if the interface is poorly designed, the content is not clear or used presentation objects are not suitable for users. That is why it is essential to notice the following three issues when presenting this kind of information:

1. Energy efficiency indicators
2. Presentation tools and applications
3. Presentation objects

Energy efficiency indicators

Energy efficiency indicator tells a user what the level of energy efficiency is in analysed process and if energy efficiency is higher or lower than in a comparison situation. There are a number of ways to allocate energy efficiency indicators but in the process industry these can be divided in three classes (Table 1):

1. Mill level indicators (Red)
2. Production line level indicators (Yellow)
3. Process specific indicators (Green)

Mill level indicators are normally specific or annual consumptions, but they can also be economical key factors that sum together different energy fractions. Because these kinds of indicators show “the big picture”, their typical user is the mill manager, environmental manager or even a company’s CEO. A good mill level indicator is unambiguously defined and it is comparable between different years and mills.

In this allocation the second level indicators are production line indicators. Production line or unit indicators could also be the same as followed in mill level, but typically these are more detailed and process-specified. For example a condensate returning rate can differ a lot between production lines because of different process equipment and connections. Production line indicators are useful for production engineers and managers but in some cases also production line operators and maintenance could follow these values.

Although according to this allocation process specific indicators are located on the lowest level, these are in many cases the most essential figures when improving energy efficiency in practical level. In this point it has to be noticed that practical level energy efficiency indicators do not have to be consumption measurement, it could also be a temperature or pressure decrease. It is essential that the user understands the link between the indicator and the process, how sensitive the indicator is and which kind of boundary conditions it has.

Table 1. Example of energy efficiency indicators in process industry. Colour indicator indicates allocation level presented before

Indicator	Unit	
Energy cost	€/d, Rub/t,..	
Purchaced energy	MWh/a, %	
Specific energy consumption	kWh/t, t/t GJ/m^3,..	
Water consumption	m^3/t	
Return of condensate	%	
Current / load	A / %	
Efficiency of heat recovery	%	
Power of condencer	kW	
Opening of reduction valve	%	
Process/building temperature	C°	
Running time	h/d	
Condensate and waste water temperature	C°	
Pressure loss over heat recovery or screen	Pa	
Decrease of steam pressure	kPa	

Applications and systems for presentation

Following of energy efficiency can be divided in two main parts: energy efficiency monitoring and reporting. Monitoring utilizes on-line information (update interval < 1 min) and there are typically hundreds or thousands of positions that are followed. Normally, it is used to produce data for the following purposes /Bureau of energy efficiency/:

- Controlling of process
- Following of consumption
- Comparison of consumption to different situations
- Producing alarms
- Finding reasons for exceptional situations

In the process industry typical users for monitoring are production line operators and maintenance personnel. Depending of needs there are different kinds of presentation objects available for monitoring. Because of the nature of operator work different kinds of traffic lights, colour codes and alarms are very effective and informative presentation objects. Otherwise trend figures could help to find out and analyse slow changes in a process. Also energy and mass balances could be very useful in monitoring displays. The best results can be achieved by combining different kinds of objects when there are suitable solutions and information for each user /Reese 2006, Woods 1995, O´Hara 2003, Koskinen H. et al 2009/.

When monitoring utilizes on-line information, uses reporting normally data from historic database or some kind of memory solutions. Normally reporting is done related to time but also event-based reporting could be very informative. For example if the mill produces wide range of different products, the event based reporting can help focus improvements on the most potential product or grade. A typical user for reporting is production management, but it is as useful for higher management levels. The same presentation objects can be used in reporting than in monitoring but in this presentation format, clear tables and figures are also very informative and easy to understand /FAO/.

There are different kinds of applications and systems available for presenting energy efficiency information. Some of these systems are designed only for reporting but typically on-line monitoring is also used very extensively in the process industry. Because there are different kinds of users, it is valuable if hierarchy of used solution supports each user's daily work (Figure 3).

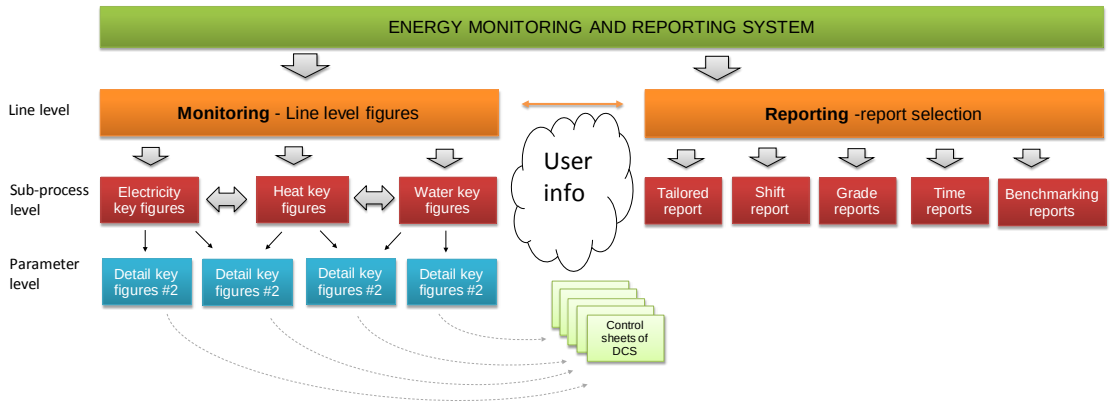

Figure 3. An example hierarchy of monitoring and reporting system /Modified Ahtila et. all 2010/

Data and information transfer

Data and information transfer is a very wide and also in some cases, complicated item. Data transfer is defined in this article as technical issue and it contains all the possibilities to transfer measurement data to machine-human interface. If this transferred and presented data leads to action, it can also be said that information transfer has been happened.

Data transfer between systems and applications

Data transfer can be defined to start when the measurement signal is available and when transfer to a user is required. If the measurement instrument is local the measurement result can be directly useful for the user. Usually on-line information is needed and each measurement instrument has to be connected to a transmitter. The transmitter sends data to different kinds of solutions, which refine data to a useful format for the users. Physically, data from the transmitter can be transferred by utilizing physical fields or wireless methods (Industrial Ethernet, radio frequency, SMS, etc). Correspondingly, field connection or OPC-boundary can be utilized as a connection between different kinds of systems /OPC Foundation/. A simplified data transfer hierarchy in the process industry is presented in figure 4.

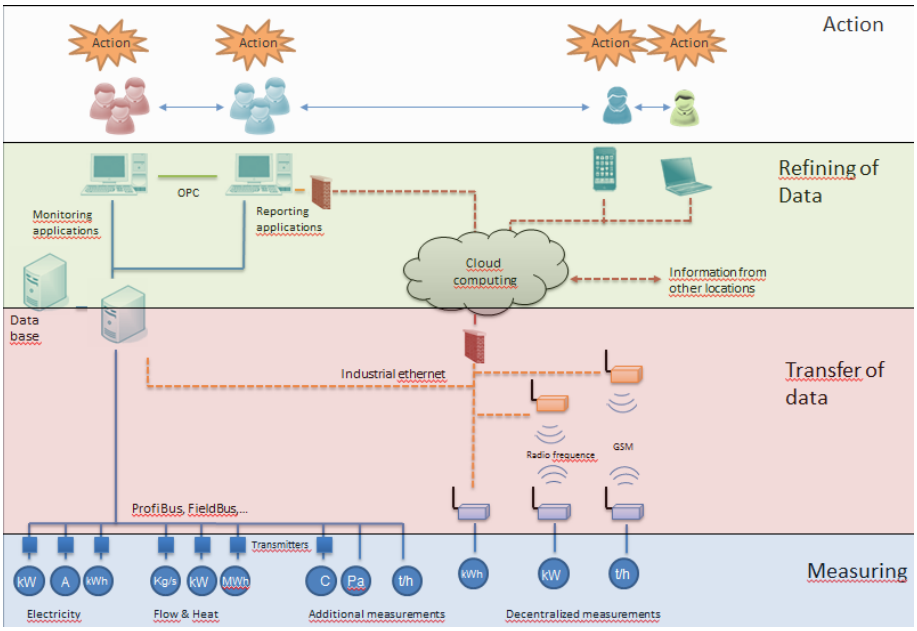

Figure 4. Simplified hierarchy of data transfer in process industry

Unfortunately in many industrial plants data transfer between systems and solutions is not as clear as in the previous figure. A process may have been modified in several phases and no one has managed improvements as a whole. There also may be lack of resources when process functionality has been the most important item.

There may for example be several controlling and automation systems that haven't been connected to each other. Different data transfer protocols may also have been used and some measurement instruments do not have any data transfer boundary. Luckily, nowadays there are lots of technical solutions for data transfer available and in many cases it is somehow possible to transfer data from one system to another with moderate costs.

Information transfer from the interface to a user and between users

Information transfer can be divided into two parts; interaction between presentation solution and a user and interaction between users. As previously mentioned it is essential that presented energy efficiency information supports each user's daily work and in that way helps the implementation of good practices. A clear and user friendly interface has the following features /Automaatioseura 2007/:

- Clarity of interface
- Readability of use
- Language of interface
- Effective and safe interaction
- Appropriateness of objects and solutions
- Target oriented solutions interface
- Consistency to other automation infrastructure

When information is translated from automation solutions to the user the essential question is how this information is refined to actions. The motivation of the user is important because often more efficient operating methods are found through trial. Training of the user is an important issue as well as different kinds of energy efficiency competitions, and campaigns, which are an effective way to motivate personnel and also share information. Some companies have connected energy efficiency factors to salary and in that way motivated personnel to think how they could affect energy efficiency in their daily work. In some companies there is also a mentor system where an older employee could transfer his knowledge to a younger one /FAO/.

Energy efficiency measurement in process level

In the main energy efficiency measurements are consumption measurements, but some other measurements can also be very useful in following energy efficiency level. These measurements could be divided into three main classes:

1. Direct energy efficiency measurements
2. Indirect energy efficiency measurements
3. Refining measurements

An example of direct measurements is electrical power or heat flow to a system. These measurements give direction and level of energy efficiency. Otherwise indirect measurement indicates direction of energy efficiency level, but does not give an exact level of energy efficiency. A good example of this kind of indicator is the supply air temperature of hood ventilation in a paper machine dryer section. It is known that the temperature has to be between 95 and 100 degrees Celsius and that there is no need to increase the temperature any higher. Lower temperatures meanwhile could create risk of condensation to the hood structure. Refining measurements are used to create more complicated or process-specific key factors. These measurements are also utilized for clarifying changes in consumption measurements. For example fresh water or outside the air temperature are good examples of refining measurements /Motiva 2012/.

In order to use measurement data effectively, it is important that there are enough measurements in process, and that these are located in the right positions and measurements are continuously compensated and calibrated. In heat consumption a rule of thumb for the number of measurement positions is that rough heat balance can be made. Otherwise for electricity measurements a good practice is to define the lowest power level at which measurement is required. Figure 5 shows an example from the process industry where motors below 30 kW use only 9 % of mill total energy, even though their total amount was over 70%.

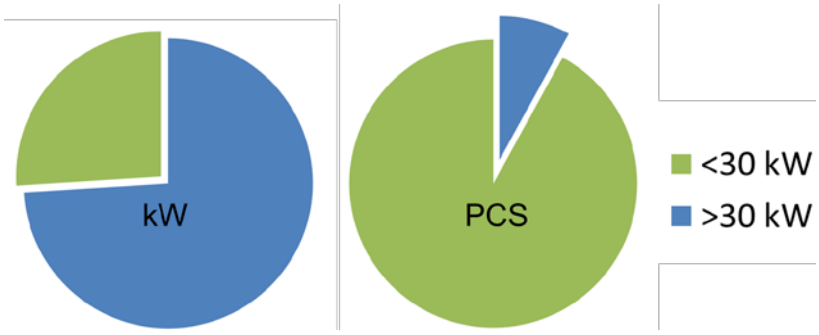

Figure 5. Example of electricity motors in process industry /Turunen 2011/

A location of measurements and flow temperature and pressure compensation are essential items when heat consumption is measured. Typically heat consumption is measured by utilizing fluid flow measurement and two temperature measurements. The most used measurement methods of fluid flow are Vortex and orification plate measurement. Both of these measurement methods need stabilization distance before and after the measurement position. A recommend distance for Vortex-measurement is 30 x d before and 10 x d after the measurement position. When measuring temperature, the fluid flow has to be as mixed as possible when turbulence does not affect problems. It is essential to understand how each measurement works and notice what kind of boundary conditions exist. Compensation is needed especially in steam and condensate flow measurements. For steam, pressure and temperature are needed whereas for condensate temperature is enough for compensation. Each measurement position should be included in a regular calibration and maintenance cycle. In particular, measurements that are used for invoicing purposes should be calibrated every second year /Motiva 2012/.

Development project of plant energy efficiency monitoring and reporting

We have so far discussed which kind of topics have to be noticed and executed in development on energy efficiency follow-up. A check-list is presented in an appendix, which can be used as a pre-study format for a development project. There are five categories, each of which includes ten questions. By filling-in the check-list the most critical development areas can be found. For each question there are three possible answers: *Yes, No* and *No information available*. The sum of *Yes*-answers measures performance quality where a higher value is better. The other analyzed item is uncertainty of survey, which is indicated as a difference between *Yes*- answers and *Yes + No information available* –answers. Results of study can be presented as in figure 6.

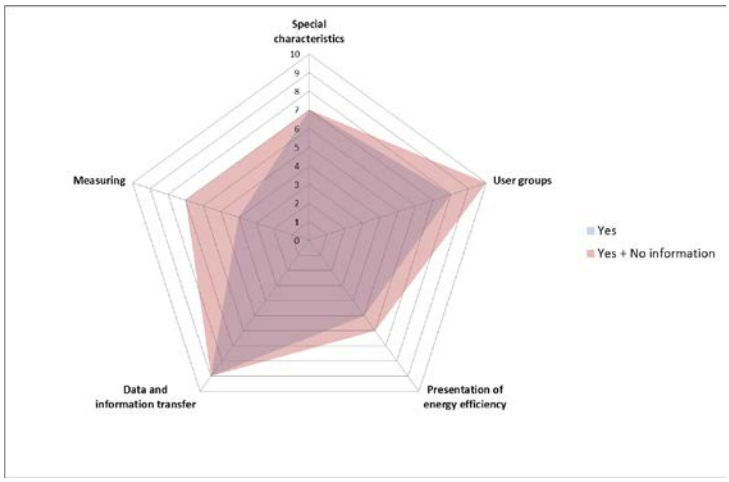

Figure 6. Presentation format of pre-study results

This pre-study phase is only the first part of the work and this is normally followed by the project, implementation and use phases. Development project steps are presented in figure 7

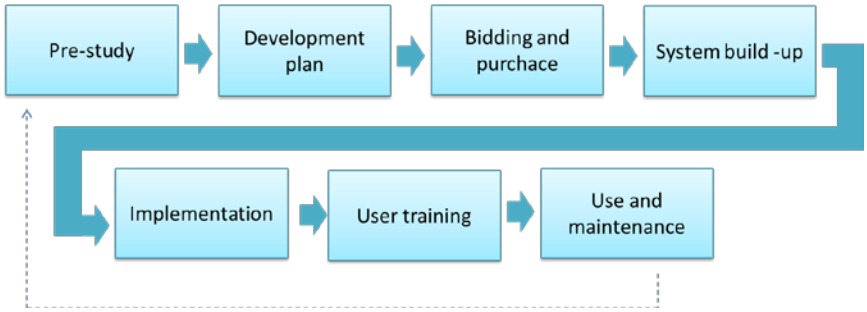

Figure 7. Development project of energy efficiency monitoring and reporting /Modified from Turunen & Kuorelahti 2011/

After implementation phase user training has to be arranged so that the importance of new systems and applications is understood. Also detailed training of system use is needed especially if new applications are not included in existing automation systems or applications. After that the new applications should also be documented and included in existing maintenance procedures to ensure reliability of produced data. Typically this kind of project takes about one year from starting point to a use phase.

Summary

As with energy efficiency, it can also be said that in general monitoring and reporting are not only technical issues but contain also many psychological items. The user is always in focus and only very few processes can be controlled and optimized so that the user does not affect it. That is why users and their needs have to be considered in development work. The best results can be achieved when energy efficiency follow-up is an essential part of each employer's daily work even though he/she does not think about it.

There are a lot of items that should be remembered in development work but the following five are the most important:

1. Understand process special features
2. Notice users of energy efficiency information and their needs
3. Choose practical and informative key factors
4. Remember transfer of information between users
5. Take care of reliability of measurements

A development project of energy efficiency follow-up normally takes about one year and the best results can be achieved by open co-operation between a customer, a consultant and a technology supplier when good practices are tailored to needs.

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Appendix

	Yes	No	No information available
Special characteristics			
Has the effect of geographical location on energy efficiency been analyzed?			
Available resources and energy fractions			
Effect of climate			
Legislation boundary conditions			
Available connections to surrounding infrastructure			
Has the effect of nature of activities on energy efficiency been analyzed?			
Production amount and its changes			
Production grades and quality			
Energy consumption distribution between processes			
Energy consumption distribution between heat and electricity			
Is there an energy management system?			
Is energy efficiency an important item for your customers?			
User groups			
Have user groups and their needs been analyzed?			
Is energy efficiency information used or does it need the following actions?			
Economical calculations			
Purchasing of energy			
Environmental reporting			
Production management			
Comparison of production sites			
Training of personnel			
Process on-line controlling			
Marketing			
Maintenance			
Presentation of energy efficiency			
Are energy efficiency key figures defined for each user group?			
Do existing key figures correspond to need?			
Are used key figures practical enough for each user group?			
Is there an on-line monitoring system available?			
Is energy efficiency on-line monitoring used regularly			
Is there a reporting system available?			
Is energy efficiency reporting used regularly			
Is energy efficiency an essential part of on-line monitoring and reporting?			
Are used presentation objects suitable for each user group?			
Are effects of main processes on energy efficiency noticed in presentation?			
Data and information transfer			
Is there a need for benchmarking between production sites?			
Are there different production units at the same site?			
Are there different kinds of data transfer formats and protocols in use?			
Are some essential energy consumers located separately from the main process without energy consumption signal available from it?			
Is there wireless and wired data transfer in use?			
Do used presentation objects support information transfer from machine to user?			
Are there tools to improve information transfer between users?			
Personnel training			
Energy efficiency campaigns			

Performance related bonus			
Mentor system			
Measuring			
Are there electricity and heat consumption measurements from the most energy intensive processes?			
Are there any electricity and heat consumption measurements from mill service and auxiliary systems?			
Are additional measurements (for example temperature, production rate etc.) used to refine energy consumption data?			
Are there on-line production rates available and are these utilized in energy efficiency reporting and monitoring?			
Are there operational performance indicators available and are these utilized in energy efficiency reporting?			
Have consumption measurements been calibrated regularly?			
Is flow compensation (temperature and/or pressure) utilized in heat consumption measurements?			
Are used invoicing measurements high accuracy measurements?			
Are flow measurement instruments located properly?			
Is mass balance used to check accuracy of consumption measurements?			