PROCESS OPTIMIZATION ENABLES ENERGY SAVINGS FROM COKE MAKING TO CONTINUOUS CASTING [1]

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Abstract
Optimization systems for different processes in the metallurgical industry from coke making, sinter plants, iron making to steel plants have been installed in numerous applications. Typical direct and indirect energy savings and their contribution to the total energy consumption per ton of crude steel are investigated. The basic principles of the different models and their impact onto the plant operation are described and completed by an outlook onto future developments.
Key words: Process optimization; Energy savings.

Resumo
Existem instalações de varias aplicações de sistemas de otimização para processos diversos na indústria siderúrgica, do processo de coqueria, sinterização, redução e aciaria. Os potenciais típicos de conservação de energia direta ou indireta e a contribuição de cada uma no consumo especifico de energia por tonelada de aço estão sendo investigados. Os princípios básicos dos modelos diferenciados e o impacto na planta em operação estão sendo descritos e complementados com uma previsão para desenvolvimentos futuros.
Palavas-chave: Otimização de processo; Economia de energia.

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1 INTRODUCTION

The liquid phase, i.e. the area from the coking plant and sintering plant, the blast furnace and all the way up to the steel works, is responsible for roughly 85% of the energy conversion in integrated metallurgical facilities. This amount depends among other things on the raw materials used, especially the share of scrap and the assignment of energy costs in auxiliary plants (e.g. consideration of energy costs as those for the supply of oxygen).
In the last years, increasing attention has been paid to these energy flows due to rising costs caused by increased demand and limited availability of lower-priced raw materials and considerations about legislative measures in order to reduce greenhouse gases.
Among the various levers to increase the energy efficiency of integrated iron- and steelmaking plants optimization solutions are attractive due to the relatively low investment costs.

2 TYPICAL SYSTEM STRUCTURE

2.1 Process Automation System / Process Control System

In addition to basic functions such as data acquisition from the field instruments and setpoint execution, technological controls (main control loops) are implemented in the basis automation system – specially for fast reacting controls and controls requiring a very high availability. Setpoints requiring complex model calculation are usualy provided be the process optimization (level 2).

2.2 Process Information and Data-Management System

The data acquisition function preprocesses and stores the data from a broad spectrum of raw data sources including front-end signals, material weights, laboratory data, events, model results and cost data, etc. It validates and interprets process data and visualizes the results in Windows- or web-based graphical user interfaces. Data handling encompasses the chemical and physical data of the plant as well as the process history.

2.3 VAiron Expert System

For systems with a long response time and complex response behaviour (e.g. ironmaking plants) Siemens VAI developed the VAiron Closed Loop Expert System in close cooperation with the Austrian steel producer voestalpine. The core of the system is a diagnostic system, which is based on historical data, auxiliary calculations and actual measuring values, diagnoses the overall sinter-plant status and previous sintering conditions. Input data is checked for plausibility or compared to admissible limits in order to avoid erroneous diagnoses.
The major function of the VAiron expert system is to provide corrective actions by suggesting the modification of process variables. Each particular corrective action can be executed in closed-loop operation or in semi-automatic operation. In closed-loop operation the calculated set-points determined by the expert system are automatically transferred to the process-control system whenever a set-point change occurs due to changing process conditions. The system performs all

recommendations simultaneously and does not require any interaction by the operators. In semi-automatic operation the calculated set-points determined by the expert system are presented to the operator on the HMI (human-machine interface) of the process-optimization system. Within a certain time period, the operator has the possibility to acknowledge, change or refuse the recommendations.

3 COKE MAKING

Environmentally sustainable development is an important issue in coke production today. Pollutants are an inevitable by-product of the coking process. With good plant design and operation, however, emissions can be cut to low levels or eliminated altogether. Permanently increasing cost pressure in the iron and steel industry means that cost-optimized operation and highest production quality are the key factors also for competitive and profitable coke production. Therefore automation systems contributing to better energy efficiency and improved coke quality are continuously in the focus of research and development.

3.1 Coke Battery – Optimized Heating and Scheduling Operations

In controlling of a coke battery, the main objective is to keep the coking process stable and free from disturbances while producing coke of excellent quality. These priority studies must be achieved whilst taking particularly care of minimizing energy costs and environmental pollution, and ensure increased productivity and maximum battery service life. Applying constant and effective coking process control and optimization will attain these different objectives. In Siemens VAI, these objectives are attained by the Coking Process Management System (CPMS), which is a state-of-the-art level-2 control system to optimize the process control of the battery and facilitate the operators' work. By advanced process modelling for efficient scheduling of the coke oven machine operations and optimized coke oven heating, savings in fuel consumption by 2-5% and more uniform coke quality can be achieved.

3.2 Typical Total Energy Savings

Due to the stabilized heating and process operation significant energy savings can be achieved.

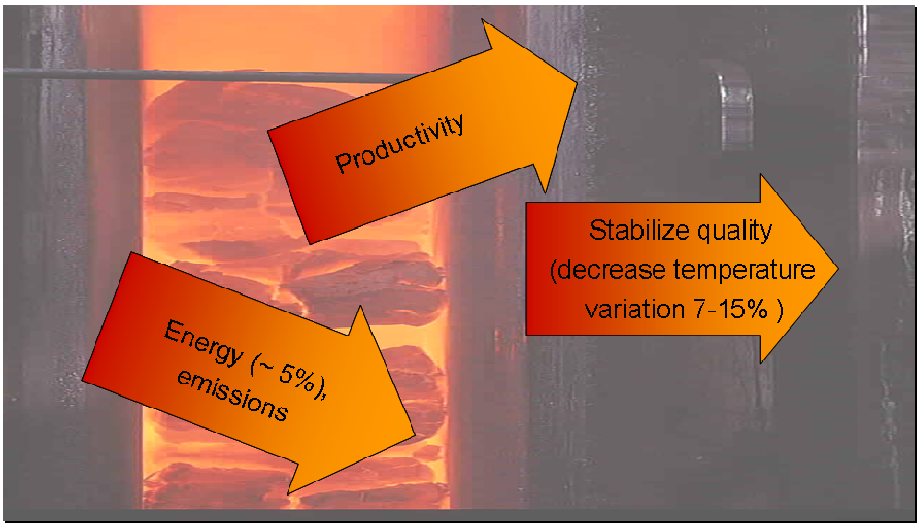

Figure 1: Typical benefits SIMETAL Coke coke making optimization.

4 SINTER PROCESS

Sinter VAiron is an advanced process-optimization system which extends from ore preparation in the blending yards, covers the production of sinter feed in the sinter plant, and takes into consideration the requirements of the blast furnace. The main overall target of the system is to achieve a high output of uniform sinter quality at low operational costs. This is accomplished by the application of a number of sophisticated tracking, diagnosis and control models and systems which are bundled within an overall expert system.

4.1 Sinter Expert System

In the sintering process, the sinter product must satisfy defined target values with respect to chemical and physical parameters. Sinter quality begins with the proper selection and mixing of the raw materials in the blending yard and sinter plant. The chemical properties are stabilized by an automatic adaptation of the raw material mix. An enhanced burn-through-point-control system which takes into account physical and chemical properties of the sinter mix is incorporated in Sinter VAiron. A key feature of the system is its capability to quickly react to process fluctuations and aberrant situations, such as an inhomogeneous mixture, poor surface ignition or incomplete burn-through of mix. This is achieved in closed-loop process control, resulting in smooth sintering operations and uniform product quality.
These include the quantity of sinter return fines, coke additions, productivity control, basicity of the sinter product, coke base in the raw sinter mix, the SO_2 content in the waste gas and the FeO content of the produced sinter.

4.2 Typical Energy Savings

There are 3 fields, where a sinter optimization can contribute to increased energy efficiency:

- The coke rate is minimized if (among other factors) the following process parameters are kept in an optimal range: raw mix moisture, strand speed, transversal burn through point and coke rate. The SIMETAL^{CIS}Sinter VAiron keeps the process close to this optimum.
- If the sintering plant represents a bottleneck in the production chain, an increase in production results in a reduction of fuel consumption in the BF due to the lower reductant consumption of the sinter in comparison with other burden materials.
- Optimized control of the ignition hood will lead to reduced gas rates

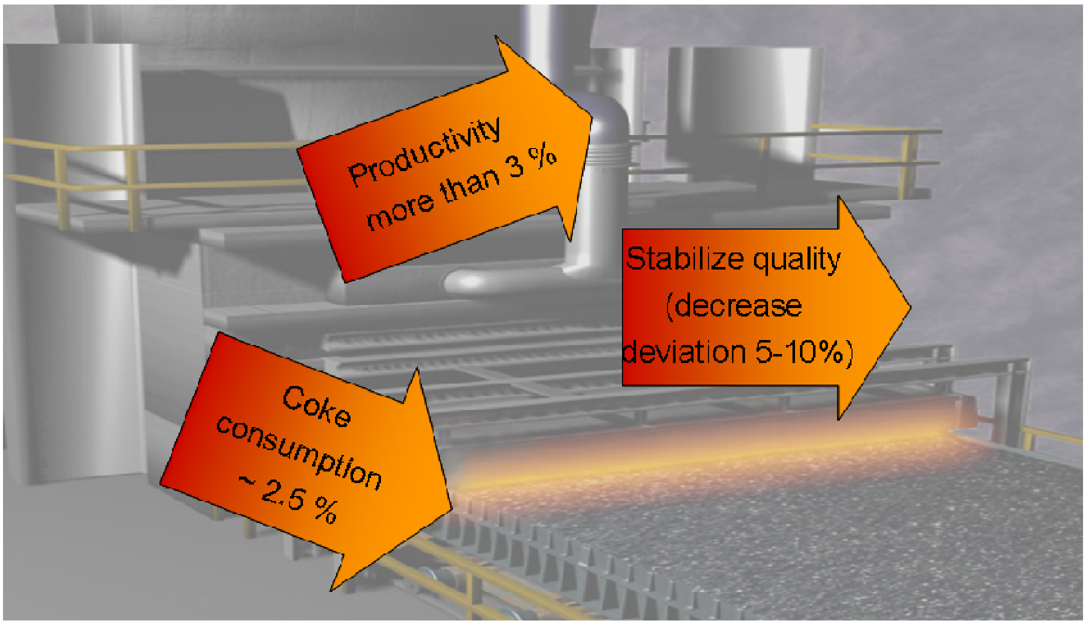

Figure 2: Typical benefits SIMETAL Sinter VAiron - sinter plant optimization.

5 BLAST FURNACE OPERATION

To enable standardized and optimal plant operation for various operating conditions a reliable process automation system was developed:
The VAiron expert system allows the blast furnace to be operated without the need for operator interaction. For example, control of the coke rate, basicity and the steam-injection rate are simultaneously and automatically executed in a closed-loop mode to ensure stable and consistent process operations at low production costs.

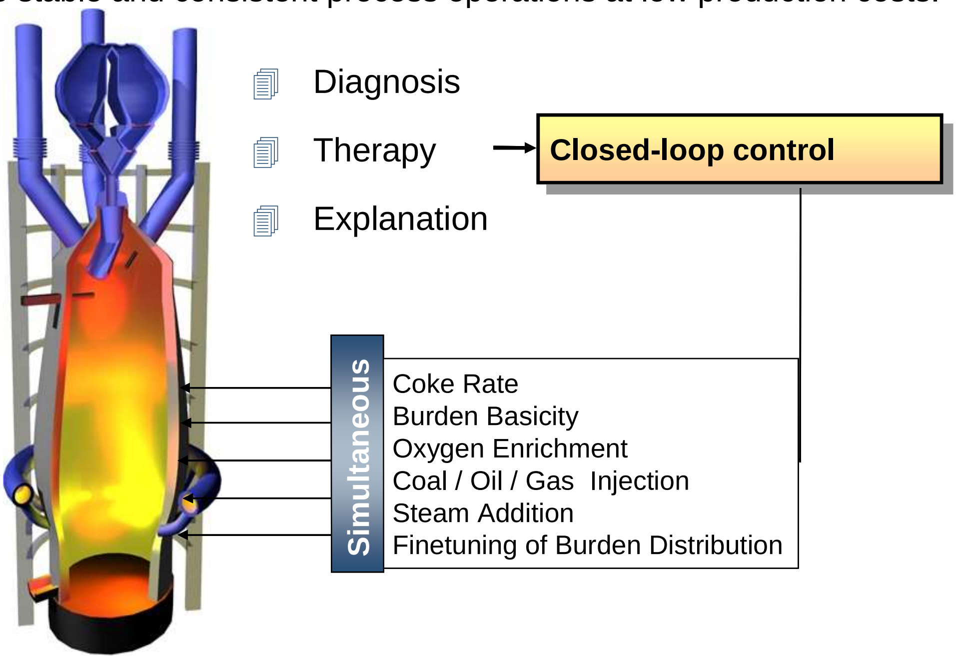

Figure 3. Closed loop control of blast furnace operational parameters.

As the blast furnace expert system has frequently been described in publications we will not go into detail in this paper.
However we will describe one important components of the BF optimization in more detail: the Fines Charging Concept.

5.1 Fines Charging

Burden fines with their small average grain size can heavily influence the gas distribution, pressure loss and the overall furnace performance.
On the other hand, all the fines being sent back and used in the sinter plant as sinter feed have been previously purchased or produced with the original intention of being used as coarse BF charging material. Thus the direct usage of fines in the blast furnace leads to an increase of the effective sinter plant production, and the existing price difference between coarse material and sinter feed material appears as an additional economic incentive. Voestalpine in Linz adopted an operation philosophy that allows making full usage of undersize material within the blast furnace without being confronted with the negative side effects.
At Voestalpine Linz BF A, all burden materials are transported via a conveyor belt to the furnace top. To make full usage of burden fines within the furnace, it must be guaranteed that the fines are positioned well apart from the screened material both on the conveyor and also within the furnace. The screened burden components can be transported to the furnace top also as burden mix to equalize the metallurgical properties of the different burden materials, but as well, a separation on purpose is also possible to make use of different properties if required. To position the materials properly within the furnace the process control system determines the precise schedule of discharging. To establish high fine volumes, the burden is discharged according to the "spiral charging method".

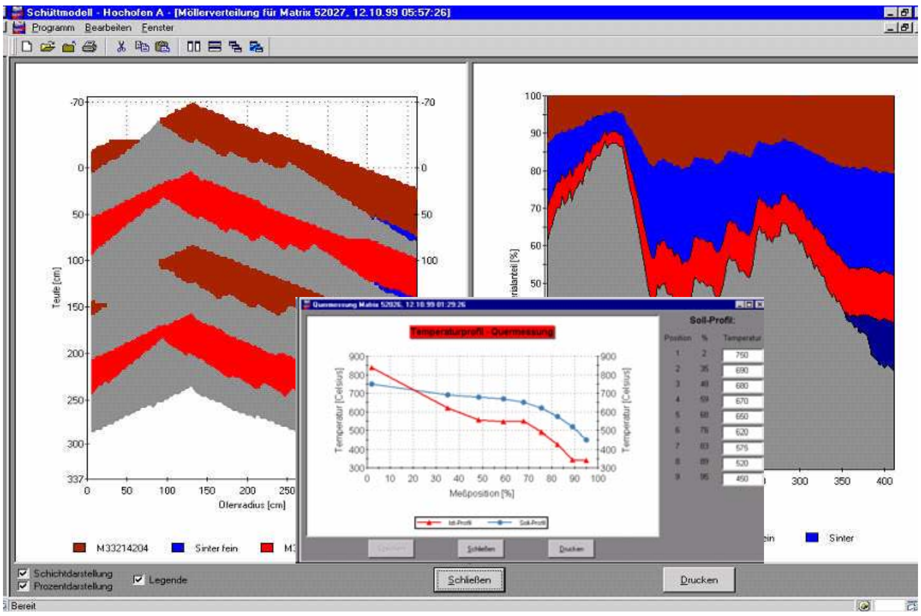

Figure 4: Burden Distribution Model.

The control of the exact distribution is done via the on line burden distribution model in combination with the expert system based on the actual descending behaviour of the furnace in order to control the permeability of the furnace.

5.2 Typical Energy Savings

The smooth and standardized operation leads to a significant reduction of the fuel rate.

Due to the charging of fines the re- sintering can be avoided, which directly saves coke in the sinter process.

6 HOT STOVE

The Hot Stove Optimization Model calculates the optimal heating strategy to ensure blast supply at target temperature at reduced energy costs. It is designed to optimize stove control in all common operational modes.
A predictive calculation of the changeover time leads to regular stove cycles. The self-learning model automatically indicates and compensates for measurement inaccuracies. The corresponding compensation factors can be used as a basis for specific maintenance. The standardized operation and additional security checks have a positive impact on the lifetime of the hot stoves.

6.1 Benefits of the Hot Stove Optimization

Economical and environmentally-friendly operation is supported.
Reduced amount of rich gas (e.g. natural gas, coke oven gas) due to increased efficiency and precise combustion is achieved
Early detection of burner or brick deterioration.
Extended lifetime of stoves due to:

- smoother operation with smaller band width for process parameters and strict preservation of limits
- additional security measures (e.g. cross-checking of dome temperatures using flame temperature calculation).

6.2 Typical Energy Savings

The optimal energy load level depends on the reliability of all parts which facilitate the operation of the hot stove system, as well as on the bottleneck considerations and the stability and uniformity of the blast furnace operation. This level always represents a compromise between security of supply and energy efficiency
An optimal selection of the thermal condition will have the two following impacts: A direct one through the reduction of the combustion gas volume and an indirect impact through an increased wind temperature, which in turn results in a lower coke rate.

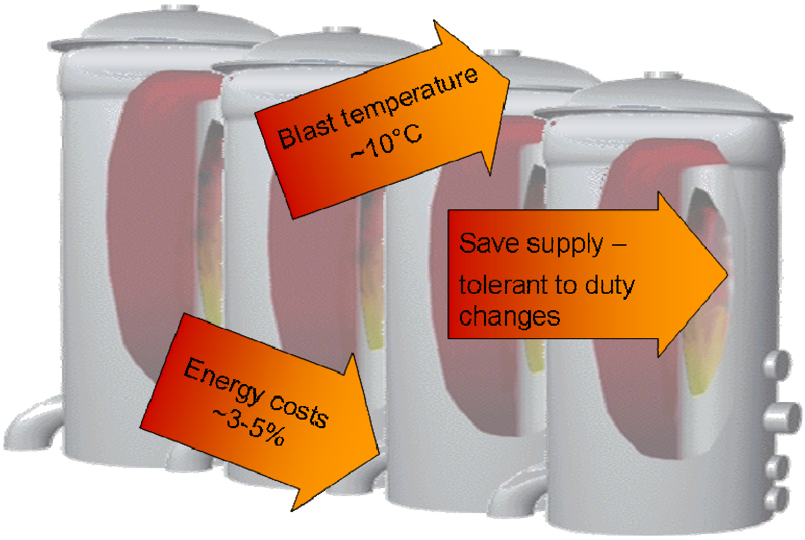

Figure 5: Typical benefits SIMETAL BF Vairon Hot Stove - hot stove optimization.

7 BOF Steel Plant Automation

The BOF process optimization solution perfectly images and optimizes the steelmaking process. The operator is guided via graphical visualization system as shown in the figure below.

Figure 6: Graphical SIMETAL BOF Optimization visualization system.

The potential energy savings of about 10% are a direct result of the increase of productivity and yield as well as the consistent high and reproducible steel quality. The determination of the required addition materials as well as the dynamic control of the oxygen blowing process enable a thermal control of the production process. Overheating of the steel bath is eliminated.
Further effects are the reduction of oxygen reblows and less production costs.

8 EAF STEEL PLANT AUTOMATION

The Electric Arc Furnace (EAF) process optimization has to handle variable charging rations of scrap, DRI and hot metal. The optimization system leads to fewer steel treatment correction steps, a minimum number of downgraded heats and exact adherence to tight production schedules.

The reduction of energy consumption by up to 5 % is a result of the determination of the required amount of electrical energy for melting the prepared and charged materials and for heating the steel bath up to the tapping temperature, considering the energy input from blown oxygen.

In case of continuous DRI (direct Reduced Iron) feeding, the DRI feed rate control dynamically controls the feed rate targeting a constant steel temperature and ensures an efficient usage of the electrical power.

9 SECONDARY METALLURGY AUTOMATION

Meeting narrow tolerances and a fully automatic production sequence from steelmaking to casting is only possible with the support of sophisticated automation systems. An overview about the main results of the process optimization system is shown in the next figure.

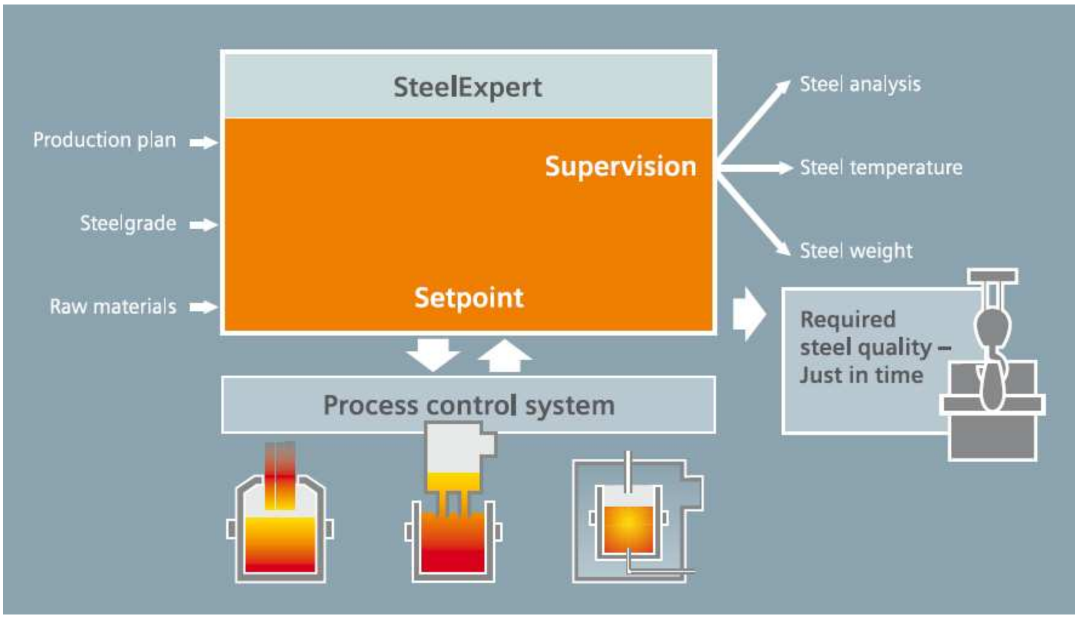

Figure 7: Secondary Metallurgy automation overview.

The overall energy reduction due to the process optimization system is approximately 3%.

The thermal supervision and control enables an exact determination of the required energy to reach the target steel bath temperature and thereby defines the appropriate duration of electrical or chemical heating. The pre-calculation model optimizes the scheduled treatment steps and eliminates return heats.

10 STAINLESS STEELMAKING AUTOMATION

The process optimization system for stainless steel converters, as AOD or K-OBM-S focus on ensuring an optimum metallurgical and process technological performance with respect to steel quality and operational costs.

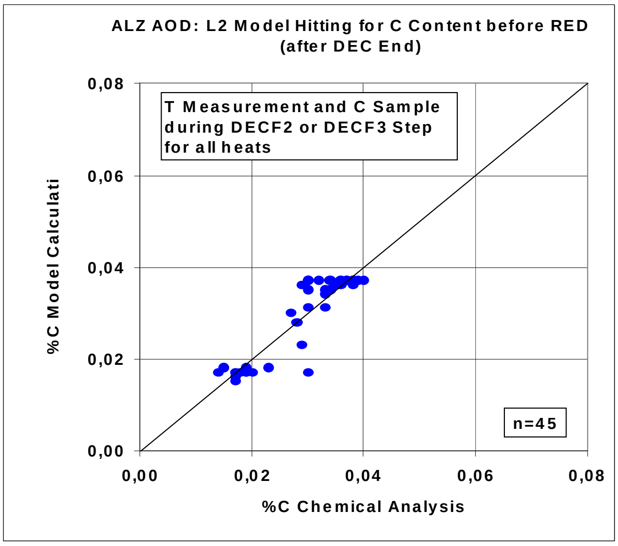

Figure 8: SIMETAL AOD Optimization (Level 2) hitting rate for C content.

The achieved energy reduction of app. 5 % is due to the increase of productivity and reduction of process gases.
The reduction of process gases is mainly because of the simulation feature, predicting the complete AOD process before the heat is actually started. This pre-calculation allows an adaptation of the standard melting practice. Improvements in usage and amount of process gases are possible.

11 SUMMARY

The shown optimization systems have a significant impact on the energy efficiency and reduced emissions. The efficiency enhancements can either assigned

- direcly to the plant or may materialize
- in subsequnt plants caused by a higher product quality or an increased productivity.

Not only the direct savings are noteworthy, the indirect savings in subsequent plants are considerable, too.
Proven by plenty successful references, Siemens VAI offers a number of advanced automation systems which successfully support energy efficient plant operation.