Steel is and will remain the most important engineering and construction material in the modern world. With an actual steel production of over 100 million tons per month, the global iron and steel industry is a very dynamic industrial sector. Further steps are ongoing towards increasing resource and energy efficiency, reducing emissions and providing safe and healthy work environments.

Process automation equipment including gas analysis instrumentation contributes essentially to that.

Siemens Sensors and Communication, a leader in process analytics, has proven worldwide its competence to plan, engineer, manufacture, implement and service analyzer systems for use in iron and steel making plants. This case study provides detailed information.

Iron and steel

Steel is an alloy of iron usually containing less than 1% carbon. Because of its versatile properties and its recycling possibilities, steel is the basic material for sustained development in modern industrial society. It provides a broad range of uses in almost all important sectors of industry such as apparatus and machinery manufacture, bridge and building construction, power and environmental engineering, and automotive and transportation industries.

The process of steelmaking has undergone many changes because of technological and economical reasons. Large, integrated steel mills were built in the 1950s and 1960s at high capital costs and limited flexibility. They produced steel in batches by refining iron ore in several steps.

Increasing energy costs made thermal efficiency in steel mills a priority. The furnaces used in integrated plants were already very efficient; however, the production processes needed to be improved. To help reduce energy consumption, continuous casting methods were developed. By keeping blast furnaces continually feed with iron ore, heat is used more efficiently. With increasing environmental concerns relevant regulations have become more stringent, again affecting the steel-making industry. Global competition is another factor that has forced steel-making facilities to optimize processes and to reduce expenses and increase quality.

Process analytical equipment, mainly continuous gas analyzers, support the steel making industry to master successfully these challenging changes. Siemens Sensors and Communication provides efficient analyzers, expertise and solutions to this analysis task.
The Iron and steel making process

Steel making basics

Steel production involves four basic steps (fig. 1):

• First, fuel and/or electricity, iron ore, reducing agents e.g. coke, additives and if so, scrap are prepared (Inputs)
• Next, iron ore is converted to pig iron through chemical reduction at high temperatures using a reducing agent. Three different routes are available
• Next, raw steel is produced from pig iron using oxygen to remove carbon and other components from pig iron. Two different routes (basic oxygen vessel and electric arc) are in use
• Finally, raw steel is further treated and refined (secondary metallurgy)

Reduction routes

Blast furnace
A blast furnace is a shaft-like unit (fig. 2) that operates according to the countercurrent principle. Iron ore, coke, heated air and limestone or other fluxes are fed into the blast furnace. All iron ore carriers contain oxygen, which has to be removed through reduction in the blast furnace by using carbon as a reducing agent. The most important carbon carrier is coke, which is produced in coking plants using a dry distillation process in a coke oven. Volatile components of the coal pyrolized and set free by heating the coal to 900 to 1 400 °C. Very often coking plants are located very close to the steel plant so that the coke oven can be heated using a mixture of blast furnace gas (low calorific value) and coke oven gas (high calorific value).

Hot air (blast) with a temperature of 1 200 °C is blown into the lower part of the blast furnace via a hot blast stove. This consists of a combustion chamber and a heat storage zone. Blast furnace gas enriched by natural gas is burnt in the stove. The off gas is directed over heat storing stones which absorb the heat. When switching to fresh air feed, the stones release the heat to warm up the fresh air.

The coke carbon gasifies with the oxygen contained in the blast to form reducing gas (carbon monoxide). The gas rises in the furnace, binds the oxygen, and thereby causes the reduction of the ores to iron. Limestone or other fluxes are added to react with and remove the acidic impurities from the molten iron. Hot metal and slag collect in the lower region of the blast furnace and leave from there at a temperature of approximately 1 500 °C via a tap hole into ladles. The limestone-impurities mixtures float to the top of the molten iron and are skimmed off after melting is complete.

Sintering products may also be added to the furnace. Sintering is a process in which solid wastes are combined into a porous mass that can then be added to the blast furnace. These wastes include iron ore fines, pollution control dust, coke breeze, water treatment plant sludge, and flux. Sintering plants help reduce solid waste by combusting waste products and capturing trace iron present in the mixture.

To optimize the process and lower the production costs, other carbon carriers such as coal, oil, gas or processed waste plastics may be injected as a coke substitute.

Direct and Smelt Reduction
Direct and Smelt reduction are alternative technologies to the conventional blast furnace process avoiding the use of expensive coke. Direct reduction technology was developed first as a possible replacement for the dominant blast furnace to allow economic production even on a smaller scale. Later, it was followed by the smelting reduction technology.

Direct reduction is a gas-based iron-making technology, using natural gas instead of coke. The natural gas reacts with CO₂ to CO and H₂. The CO then acts as reducing agent.

Smelt reduction technology is a coal-based iron making process. Smelting reduction technology, as the name clearly suggests, involves both solid-state reduction and melting. Smelting is melting involving chemical reduction reactions. Smelting reduction technology exploits the principle that coal can be gasified in a bath of molten iron.
The coal is fed into the smelting reduction vessel where it is gasified. This delivers heat and hot gas containing carbon monoxide as a reducing agent. The heat is used for melting the iron.

The output of both processes is Sponge Iron.

**Steel creation routes**

**Basic Oxygen Furnace (BOF)**
The hot iron still contains impurities such as carbon, silicon, sulphur and phosphorus at concentrations higher than desired. These unwanted constituents are removed in Basic Oxygen Furnaces also known as steel converters (fig. 3). The impurities are oxidized in the converter by top-blowing oxygen through a water-cooled lance. Certain quantities of scrap are added as cooling agents, since the oxidation process generates a strong amount of heat. A converter holds up to 400 t crude steel. Lime is also added for slag forming purposes, and alloying agents. The blowing process takes approximately 20 minutes. Also practiced nowadays besides pure top-blowing with oxygen is combined blowing, in which inert stirring gases or oxygen is additionally injected through the converter bottom.

**Electric arc furnace**
Great importance is being attached to scrap recycling for reasons of optimum raw materials utilization and environmental protection. If using scrap metals as main feed material, the electric arc furnace (EAF) is used as the melting unit, whose arc makes it possible to transform electrical energy into melting heat with very good efficiency.

Steelmaking from scrap metals involves melting scrap metal, removing impurities and casting it into the desired shapes. Production of steel from scrap can also be economical on a much smaller scale. Frequently mills producing steel with EAF technology are called mini-mills.

To charge the furnace, the roof of the EAF is lifted and the scrap charged into the furnace. The roof is moved back and the electrodes lowered, igniting an arc on the cold scrap. During the melt-down process, temperatures in the arc reach as high as 3 500 °C, and in the steel bath as high as 1 800 °C. The high temperatures also enable the dissolution of difficult-to-melt scrap alloy constituents. Additional injection of oxygen or of other fuel-gas mixtures accelerates the melt-down process.

**Secondary Metallurgy**
The high quality demands which the steel - produced by either the blast furnace/ converter or electric arc furnace route - has to make post-treatment necessary. This is done in the secondary metallurgy process (ladle or vacuum treatment) of the liquid crude steel (fig. 4).

This production step primarily follows the objective of reducing the carbon, nitrogen, hydrogen, phosphorus and several other elements in the steel, in addition to homogenizing the liquid steel and keeping the temperature within tight and precise limits.

After the molten metal is released from the secondary metallurgy treatment it is formed into its final shape and finished to prevent corrosion.

Read more on page 5.
Process analysis in an iron and steel plant

Tasks and objectives

In an iron and steel mill, the use of process analytics is required at several locations of the plant with different objectives. The measured data obtained from the analyzers are used to monitor and control the following issues:

- Function and economic efficiency of the entire steel mill operation through continuous monitoring of all process steps and optimization measures
- Safety for personnel and equipment through monitoring some of the plant units for risks of explosion or fire
- Environmental protection through the control of the systems used for flue gas purification and through monitoring the residual concentrations of pollutants in the flue gas to maintain the permissible concentration limit

Use of process analytics

Gas analyzer

Fig. 5 shows, for example, how a steel plant based on the blast furnace and basic oxygen furnace route including a coke gas plant, is typically equipped with process analytical instrumentation. Table 1 shows sampling points together with the corresponding measuring components, measuring tasks and suitable analyzers. Other steel plants, of course, will differ from this example depending on process routes, local conditions and technological issues.

Gas chromatography

At sampling points 6, 13 and 14 the use of process gas chromatographs is very reasonable in order to analyze the fuel gases (blast furnace gas, converter gas, coke oven gas) by measuring the concentration of e.g. CO, CO₂, O₂, N₂, CH₄, H₂. Therefrom the calorific value and the Wobbe index can be calculated.

In modern steel plants, also natural gas (not shown in fig. 5) is increasingly used due to its high calorific value.

- In particular, the energy content of the gases, as described by their calorific value, provides the user with important information about efficient firing of different plants in the steel mill (coking plant, sinter plant, rolling mill, etc.) or a nearby power plant.
- High-calorific coke or natural gas is mixed with low-calorific converter or blast furnace gas in mixing stations. This is to adjust the calorific value of the mixture to the requirements of the subsequent consumer and to avoid discharging of valuable gases into the off gas.
- The knowledge of the calorific value together with information about pressure and flow rate of the fuel gas enables the user to adjust a constant energy content of the mixed gas using an intelligent control system.
- Furthermore, analysis data of the gas chromatographs (MicroSAM or SITRANS CV) are also used to determine the equivalent amount of oxygen that is required to run the combustion process. This results in a stoichiometric and uniform combustion and prevents soot production.

Small dimensions and rugged design (IP65, NEMA4X, pressure-resistant enclosure) enable MicroSAM and SITRANS CV to be installed right at the sampling point even under difficult ambient conditions. Special and air conditioned analyzer houses or rooms are not required anymore. The concept “change components rather than repair the device” together with extremely low consumption rates of auxiliary media reduces operating costs and increases availability of the chromatographs.

MicroSAM and SITRANS CV are characterized by a remarkable high accuracy in determining the quality parameters of blast furnace, coke and natural gas.
Real time analysis of converter gas using In-situ CGA

**Oxygen converter process**
The oxygen based converter process is a common method to make steel from pig iron. The converter vessel is first charged with molten pig iron from the blast furnace. Then a water cooled lance is lowered into the vessel through which pure oxygen is blown into the melt at high pressure (Fig. 7). The oxygen, through oxidation, combines with the carbon contained in the molten iron to form gaseous CO and CO\(_2\), which are separated from the molten metal and released from the melt as part of the off-gas.

**Lime based fluxes and other substances** may be charged as well to combine with impurities to form slags and/or to give the steel the desired properties. Finally the converter is emptied into ladles. The whole process is completed in 15 to 20 min.

**Gas analysis and “melting curve”**
The converter off-gas mainly consists of carbon monoxide and carbon dioxide from the oxidation process. Their concentration levels and concentration variations over the process runtime directly provide important information about progress and endpoint of decarbonization, the temperature of the liquid metal and details about the slagging process. That way the CO and CO\(_2\) operation curves act just like a “fingerprint” of the melting cycle details.

<table>
<thead>
<tr>
<th>Sampling point location</th>
<th>Measuring task</th>
<th>Measuring components</th>
<th>Suitable Siemens analyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 At the stack of the sinter plant</td>
<td>Monitoring compliance of pollutant emission with existing regulations</td>
<td>CO, SO(_2), NO(_x), O(_2), NH(_3)</td>
<td>ULTRAMAT 23</td>
</tr>
<tr>
<td>2 At the raw material storage hall</td>
<td>Monitoring ambient air for toxic gases</td>
<td>CO</td>
<td>ULTRAMAT 23</td>
</tr>
<tr>
<td>3 At the raw material silo</td>
<td>Early detection of dangers arising from • Acetylene from calcium carbide • Fire hazard originating from magnesium</td>
<td>C(_2)H(_2), O(_2)</td>
<td>In-situ CGA (special appl.) OXYMAT 6</td>
</tr>
<tr>
<td>4 After blast furnace uptake duct</td>
<td>Optimizing the blast furnace process from blast furnace gas composition</td>
<td>CO, CO(_2), CH(_4), H(_2)</td>
<td>ULTRAMAT 23 CALOMAT 6</td>
</tr>
<tr>
<td>5 After dust bags</td>
<td>Early detection of explosion risk for the dust bags from CO contents of the blast furnace gas</td>
<td>CO, CO(_2), CH(_4), H(_2)</td>
<td>ULTRAMAT 23 CALOMAT 6</td>
</tr>
<tr>
<td>6 At the blast furnace gas outlet</td>
<td>Determination of the calorific value of the blast furnace gas for billing purposes</td>
<td>CO, CO(_2), CH(_4), H(_2), N(_2), O(_2), CO(_2)</td>
<td>ULTRAMAT 23 MicroSAM</td>
</tr>
<tr>
<td>7 At the outlet of coal silo to coal mill</td>
<td>Early detection of smouldering fires</td>
<td>CO, CH(_4)</td>
<td>ULTRAMAT 23 / In-situ CGA ULTRAMAT 23</td>
</tr>
<tr>
<td>8 At the stack of the coking plant</td>
<td>Monitoring compliance of pollutant emission with existing regulations</td>
<td>CO, NO, SO(_2), O(_2), Dust</td>
<td>ULTRAMAT 23 TPA</td>
</tr>
<tr>
<td>9 At the coal dust silo</td>
<td>Early detection of smouldering fires</td>
<td>CO</td>
<td>In-situ CGA / ULTRAMAT 23</td>
</tr>
<tr>
<td>10 At the off gas exit of coal mill</td>
<td>Monitoring compliance of dust emission with existing regulations</td>
<td>CO, Dust</td>
<td>In-situ CGA TPA</td>
</tr>
<tr>
<td>11 At the hot blast inlet</td>
<td>Monitoring the oxygen content of the hot blast in order to optimize the blast furnace process</td>
<td>O(_2)</td>
<td>OXYMAT 6/61</td>
</tr>
<tr>
<td>12 At the stack of the hot blast oven</td>
<td>Monitoring compliance of pollutant emission with existing regulations</td>
<td>CO, NO, SO(_2), O(_2), Dust</td>
<td>ULTRAMAT 23 TPA</td>
</tr>
<tr>
<td>13 At the converter off gas outlet</td>
<td>Optimizing the converter process from the composition of the converter off gas</td>
<td>CO, CO(_2), O(_2), CO, CO(_2), O(_2), H(_2), N(_2), O(_2), CO(_2)</td>
<td>In-situ CGA ULTRAMAT 23 CALOMAT 6 MicroSAM</td>
</tr>
<tr>
<td>14 At the coking gas outlet</td>
<td>Determination of the calorific value of the coke oven gas for billing purposes and early detection of explosion risk</td>
<td>CO, CH(_4), O(_2), H(_2), O(_2), Calorific value</td>
<td>ULTRAMAT 23 CALOMAT 6 In-situ CGA MicroSAM</td>
</tr>
</tbody>
</table>

**Table 1:** Sampling points, tasks and analyzers (correlated to fig. 5)
TPA: Third Party Analyzer; In-situ CGA: Continuous Gas Analyzer using in-situ technology
Advances of the in-situ measuring technique

Fig. 6 shows typical concentration recordings of CO and CO\textsubscript{2} in converter gas over a full decarbonization cycle of approximately 20 minutes from both extractive (NDIR) and in-situ laser-based CGA analyzers. Both records run parallel but the in-situ analyzer provides much faster response to process variations and better time resolution. Therefore, it is a superior “tool” to exactly determine the end-point of the decarburization and, thus saving energy and oxygen as much as possible. Furthermore, the in-situ analytics permits a much more simple sampling system with much less to now maintenance.

Measuring task
Measuring task and requirements for the new analyzer technology are:

- Continuous measurement of CO and CO\textsubscript{2} directly in the process gas stream (fig. 7) with short response time and high accuracy and reliability
- Robust device design to withstand the harsh environment and measuring conditions in a steel mill
- Cost effective design and operation

Solution with LDS 6
The Siemens LDS 6 laser in-situ gas analyzer has been installed as part of a new converter line and proved to be very much suited for this task. Only one pair of sensors (three are possible) was required to measure both CO and CO\textsubscript{2}. It is connected to the central unit via fiber optic which is up to 1 km away from the hazardous environment.

User benefits
Optimizing the converter off-gas process by real time measurement of CO and CO\textsubscript{2} with the LDS 6 means:

- Response time in the range of seconds. Therefore, termination of the process exactly in time with a saving of approximately 5 % of processing time enabling reduced energy and oxygen consumption costs.
- Improved process control and ensured steel quality
- Low maintenance efforts because of a very resistant analyzer design

Further applications
Some of the applications listed in table 1 are additionally described in dedicated case studies.
Siemens Process Analytics at a glance

Product overview

Siemens Process Analytics is a leading provider of process analyzers and process analysis systems. We offer our global customers the best solutions for their applications based on innovative analysis technologies, customized system engineering, sound knowledge of customer applications and professional support. And with Totally Integrated Automation (TIA). Siemens Process Analytics is your qualified partner for efficient solutions that integrate process analysers into automations systems in the process industry.

From demanding analysis tasks in the chemical, oil & gas and petrochemical industry to combustion control in power plants to emission monitoring at waste incineration plants, the highly accurate and reliable Siemens gas chromatographs and continuous analysers will always do the job.

Siemens process Analytics offers a wide and innovative portfolio designed to meet all user requirements for comprehensive products and solutions.

Our Products

The product line of Siemens Process Analytics comprises

- extractive and in-situ continuous gas analyzers (fig. 8-11)
- process gas chromatographs (fig. 12-13)
- sampling systems
- auxiliary equipment

Analyzers and chromatographs are available in different versions for rack or field mounting, explosion protection, corrosion resistant etc.

A flexible networking concept allows interfacing to DCS and maintenance stations via 4-20 mA, PROFIBUS, OPC, Modbus or industrial ethernet.
**Product scope**

Siemens Continuous Gas Analyzers and Process Gas Chromatographs

**Extractive Continuous Gas Analyzers (CGA)**

**ULTRAMAT 23**
The ULTRAMAT 23 is a cost-effective multicomponent analyser for the measurement of up to 3 infrared sensitive gases (NDIR principle) plus oxygen (electrochemical cell). The ULTRAMAT 23 is suitable for a wide range of standard applications. Calibration using ambient air eliminates the need of expensive calibration gases.

**CALOMAT 6/62**
The CALOMAT 6 uses the thermal conductivity detection (TCD) method to measure the concentration of certain process gases, preferably hydrogen. The CALOMAT 62 applies the TCD method as well and is specially designed for use in application with corrosive gases such as chlorine.

**OXYMAT 6/61/64**
The OXYMAT 6 uses the paramagnetic measuring method and can be used in applications for process control, emission monitoring and quality assurance. Due to its ultrafast response, the OXYMAT 6 is perfect for monitoring safety-relevant plants. The corrosion-proof design allows analysis in the presence of highly corrosive gases. The OXYMAT 61 is a low-cost oxygen analyser for standard applications. The OXYMAT 64 is a gas analyzer based on ZrO2 technology to measure smallest oxygen concentrations in pure gas applications.

**FIDAMAT 6**
The FIDAMAT 6 measures the total hydrocarbon content in air or even in high-boiling gas mixtures. It covers nearly all requirements, from trace hydrocarbon detection in pure gases to measurement of high hydrocarbon concentrations, even in the presence of corrosive gases.

**Process Gas Chromatographs (Process GC)**

**MAXUM edition II**
MAXUM edition II is very well suited to be used in rough industrial environments and performs a wide range of duties in the chemical and petrochemical industries and refineries. MAXUM II features e.g. a flexible, energy saving single or dual oven concept, valveless sampling and column switching, and parallel chromatography using multiple single trains as well as a wide range of detectors such as TCD, FID, FPD, PDHID, PDECD and PDPID.

**MicroSAM**
MicroSAM is a very compact explosion-proof micro process chromatograph. Using silicon-based micromechanical components it combines miniaturization with increased performance at the same time. MicroSAM is easy to use and its rugged and small design allows mounting right at the sampling point. MicroSAM features drastically reduced cycle times, provides valveless sample injection and column switching and saves installation, maintenance, and service costs.

**SITRANS CV**
SITRANS CV is a micro process gas chromatograph especially designed for reliable, exact and fast analysis of natural gas. The rugged and compact design makes SITRANS CV suitable for extreme areas of use, e.g. off-shore exploration or direct mounting on a pipeline. The special software "CV Control" meets the requirements of the natural gas market, e.g. custody transfer.

**ULTRAMAT 6**
The ULTRAMAT 6 uses the NDIR measuring principle and can be used in all applications from emission monitoring to process control even in the presence of highly corrosive gases. ULTRAMAT 6 is able to measure up to 4 infrared sensitive components in a single unit.

**ULTRAMAT 6 / OXYMAT 6**
Both analyzer benches can be combined in one housing to form a multicomponent device for measuring up to two IR components and oxygen.

**In-situ Continuous Gas Analyzers (CGA)**

**LDS 6**
LDS 6 is a high-performance in-situ process gas analyser. The measurement (through the sensor) occurs directly in the process stream, no extractive sample line is required. The central unit is separated from the sensor by using fiber optics. Measurements are carried out in real time. This enables a pro-active control of dynamic processes and allows fast, cost-saving corrections.

**SITRANS SL**
SITRANS SL is a compact transmitter-like designed gas analyzer for fast in-situ measurements of oxygen concentration in process gases. The measuring principle is based on the diode laser technology and almost free of cross-interferences. The analyzer consists of a transmitter and receiver unit which are mounted directly at the process.
Analytical solutions are always driven by the customer’s requirements. We offer an integrated design covering all steps from sampling point and sample preparation up to complete analyser cabinets or for installation in analyser shelters (fig. 15). This includes also signal processing and communications to the control room and process control system.

We rely on many years of world-wide experience in process automation and engineering and a collection of specialized knowledge in key industries and industrial sectors. We provide Siemens quality from a single source with a function warranty for the entire system.

Read more in chapter “Our services”.

Fig. 15 Analyzer house (shelter)

Fig. 16 Networking for DCS integration and maintenance support

DCS: Distributed Control System
ASM: Analyzer System Manager
CEMS: Continuous Emission Monitoring System

Fig. 17 Communication technologies

Analyzer networking for data communication

Engineering and manufacturing of process analytical solutions increasingly comprises “networking”. It is getting a standard requirement in the process industry to connect analyzers and analyzer systems to a communication network to provide for continuous and direct data transfer from and to the analyzers. The two objectives are (fig. 16)

• To integrate the analyzer and analyzer systems seamless into the PCS/DCS system of the plant and
• To allow direct access to the analyzers or systems from a maintenance station to ensure correct and reliable operation including preventive or predictive maintenance (fig. 17).

Siemens Process Analytics provides networking solutions to meet the demands of both objectives.
Siemens Process Analytics – Our Services

Siemens Process Analytics is your competent and reliable partner worldwide for Service, Support and Consulting. Our resources for that are

- **Expertise**
  As a manufacturer of a broad variety of analyzers, we are very much experienced in engineering and manufacturing of analytical systems and analyzer houses. We are familiar with communication networks, well trained in service and maintenance and familiar with many industrial processes and industries. Thus, Siemens Process Analytics owns a unique blend of overall analytical expertise and experience.

- **Global presence**
  With our strategically located centers of competence in Germany, USA, Singapore, Dubai and Shanghai, we are globally present and acquainted with all respective local and regional requirements, codes and standards. All centers are networked together.

**Service portfolio**

Our wide portfolio of services is segmented into Consulting, Support and Service. It comprises really all measures, actions and advises that may be required by our clients throughout the entire lifecycle of their plant:

- Site survey
- Installation check
- Functionality tests
- Site acceptance test
- Instruction of plant personnel on site
- Preventive maintenance
- On site repair
- Remote fault clearance
- Spare part stock evaluation
- Spare part management
- Professional training center
- Process optimisation
- Internet-based hotline
- FEED for Process Analytics
- Technical consulting

**FEED for Process Analytics**

Front End Engineering and Design (FEED for PA) is part of the planning and engineering phase of a plant construction or modification project and is done after conceptual business planning and prior to detail design. During the FEED phase, best opportunities exist for costs and time savings for the project, as during this phase most of the entire costs are defined and changes have least impact to the project. Siemens Process Analytics holds a unique blend of expertise in analytical technologies, applications and in providing complete analytical solutions to many industries.

Based on its expertise in analytical technology, application and engineering, Siemens Process Analytics offer a wide scope of FEED services focused on analysing principles, sampling technologies, application solutions as well as communication system and given standards (all related to analytics) to support our clients in maximizing performance and efficiency of their projects.

Whether you are plant operators or belong to an EPC Contractor you will benefit in various ways from FEED for Process Analytics by Siemens:

- Analytics and industry know how available, right from the beginning of the project
- Superior analyzer system performance with high availability
- Established studies, that lead to realistic investment decisions
- Fast and clear design of the analyzer system specifications, drawings and documentation
- Little project management and coordination effort, due to one responsible contact person and less time involvement
- Additional expertise on demand, without having the costs, the effort and the risks of building up the capacities
- Lowest possible Total Costs of Ownership (TCO) along the lifecycle regarding investment costs, consumptions, utilities supply and maintenance.

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Additional information:

For additional information please contact:
E-Mail: processanalytics.automation@siemens.com

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