Decarbonization of the steel industry – AI-supported production and energy management

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The production of green steel requires a comprehensive transformation process with the gradual replacement of CO_2-intensive production processes. Digitalization of the production processes is indispensable to plan and control the more complex steel production regarding logistics and efficient material and energy use. AI-supported heat schedule optimization, including material and energy demand forecasts, and combined with intelligent intra-day energy procurement is crucial here.

Reduce CO_2 emissions, cut energy consumption, develop new energy procurement strategy: The steel industry faces major challenges in both the production and processing of steel (**Fig. 2**). At the same time, companies have to optimize highly complex processes, establish new procedures and build up expertise. And they are doing so under great pressure to act. According to studies, companies that fail to take decarbonization measures are putting around 14 percent of their potential enterprise value at risk. A share that no company can afford. The industry has therefore long since embarked on the path to so-called green steel and is focusing above all on transforming steel production from the classic blast furnace route to direct reduction - led by hydrogen. The latter - replacing natural gas and coke energy with hydrogen - is seen as a key factor on the way to lower CO_2 emissions.

MASTERING COMPLEXITY IN HYBRID OPERATION

It is clear that the necessary transformation process will take place in hybrid operation, in which classic production processes and routes are gradually replaced by new ones. The industry will therefore be challenged for years or even decades to operate and coordinate new and existing production routes in parallel. This will further increase the complexity of the already multi-layered interdependencies in steel production. Companies will need to synchronize production on different routes, optimize processes, maintain quality standards, and balance cost efficiency with environmental concerns.

Fig. 1: Holistic production and energy management: climate protection and economic efficiency in harmony (Source: PSI Metals GmbH)

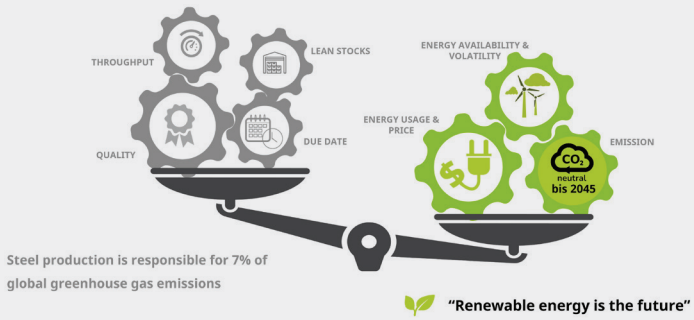

Fig. 2: The transformation process towards the production of "green steel" is multi-faceted and challenges the industry to strike a balance between cost efficiency and environmental aspects. A key lever is the intelligent management of conflicting goals (Source: PSI Metals GmbH)

In order to master this complexity and achieve the above-mentioned goals, efficient planning and heat scheduling is essential. A look at practice shows that three main levers can be used for this purpose:

1. the use of software for effective heat schedule optimization to control logistics and reduce energy consumption,
2. in combination with precise forecasting of energy and material consumption, and
3. intraday energy trading to provide the energy required for the production processes with pinpoint accuracy and to buy renewable energy at short notice or sell it at a profit.

PRODUCTION MUST FOLLOW ENERGY MANAGEMENT

The background: hydrogen- and DRI based steel production requires significantly more electrical energy than conventional production. Per ton, for example, the operation of an electric steel mill requires an additional 310 to 640 kWh, depending on the scrap and DRI mix, DRI temperature and specific slag mass. In addition, other industries will also replace fossil with renewable electrical energy, so demand will increase significantly and this will drive prices. Energy efficiency is therefore a key factor for the profitability and competitiveness of green steel production (**Table 1**). Last but not least, companies will have to adjust to the feed-in volatility of wind and solar energy in this context. This means that consumption will have to follow availability in the future, while at the same time the fluctuations will have a direct impact on energy prices. In this context, companies are required to include forecasts of available energy as well as demand in their planning and scheduling. If they can produce flexibly in times of low market prices, they can save considerable costs. In addition to efficient production control, controlling energy management is also necessary.

AI-SUPPORTED HEAT SCHEDULE OPTIMIZATION

An important adjusting screw for a sustainable manufacturing process is the heat schedule optimization, which meticulously clocks the melt shop and thus helps, among other things, to avoid sequence interruptions. Even the shortest stoppages or delays lead to throughput problems and increased energy consumption due to higher tapping temperatures or additional heating. The Berlin software manufacturer PSI Metals, for example, has integrated a corresponding module for heat schedule optimization into its production management solution together with its sister company PSI FLS Fuzzy Logik & Neuro Systeme. In interaction with the automation systems, the Qualicision Online Heat Scheduler continuously calculates balanced work schedules for each heat. The core of this module is an AI-based decision support based on freely configurable and flexibly prioritizable key performance indicators (KPIs) as well as Qualitative Labeling (Information box).

REDUCED ENERGY CONSUMPTION

When creating optimized heat schedules, supporting IT solutions have to take into account a large number of influencing factors that are crucial for the production of CO_2-free green steel. In particular, demand and availability forecasts of various input materials and required energy as well as exact information on transport logistics are among the most important key figures in a hybrid steel plant for

Table 1: The favored hydrogen-based production of steel requires significantly more electrical energy than the conventional approach. Energy efficiency is consequently a key factor for the economic viability and competitiveness of "green steel production." (Source: CO_2 emissions and energy intensity by production process in 2021)

	CO_2 emission intensity by production route in tons of CO_2 per ton of crude steel	Energy intensity by production route in G) per ton of crude steel castings
Global average	1.91	21.31
BF-BOF	2.32	24.43
Scrap-EAF	0.67	10.04
DRI-EAFI	1.65	25.29

Qualitative Labeling of Process Data with Qualicision AI

Learning AI methods for business process optimization and real-time decision support require automatically processed data. This means that they must already be assigned a meaning before the learning process. This is because, unlike speech recognition, for example, new data patterns are continuously created here and must be relearned on an ongoing basis. This can only be done by software and automatically. Qualitative Labeling is such a method. With its help, interactions can be automatically identified in historicized and current data by means of goal conflict analysis - in the form of self-calculated classes of data patterns that are presented to users for confirmation or correction. Qualitatively labeled data consequently build a bridge between data patterns in the raw data and their meaning in the real world of the process in question. In this way, they create the prerequisite for continuous process improvement in combination with qualitative, optimization-based AI methods (Qualicision AI).

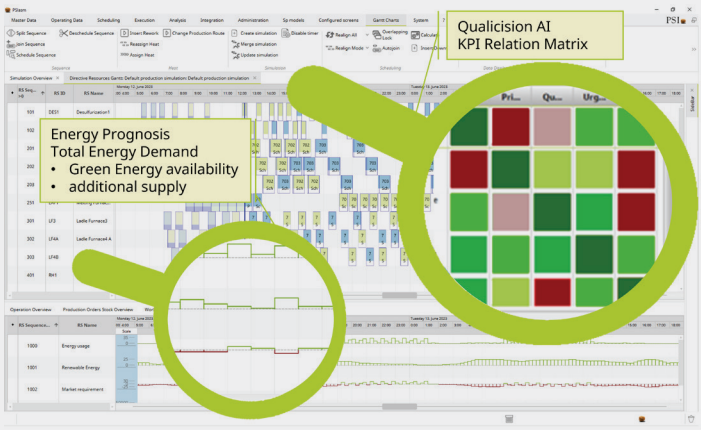

Fig. 3: The PSImetals Online Heat Scheduler visualizes the relationship between energy forecast, total energy demand and Qualicision AI-based KPIs. The matrix shows the mutual dependencies between the KPIs (Source: PSI Metals GmbH)

planning and scheduling. The Online Heat Scheduler as part of the production management system PSImetals has been enhanced with Qualicision AI functionality and calculates, for example, all required treatment and transport steps with their durations, defines the optimal start and end times, assigns the appropriate equipment and available resources and automatically balances conflicting goals. In real-time, the system also takes into account changes and delays, ensuring that heats in a sequence are always transferred at the scheduled time and at the required temperature. The operator can also simulate and compare different scenarios to decide for the right solution for a specific production problem. For example, he can add process steps, change heat sequences, or shorten treatment, transport, and buffer times. Time optimization in particular has a significant impact on reducing energy consumption and thus on the CO_2 footprint. The result: optimized sequences, ideal tapping temperatures, reduced buffer times, and less resource input and energy consumption.

ACCURATELY BALANCED ENERGY CONSUMPTION FORECASTS

The production of climate-friendly steel – especially in the transition years in hybrid operation – is inextricably linked to precise planning and scheduling of energy consumption. Planning and energy demand forecasting must therefore be closely linked to align production with availability and price, while at the same time being able to transmit the forecasts to energy management systems or energy suppliers. This is also the only way to ensure a stable power grid – both for the plant and for the entire transition and distribution network. To successfully predict the energy requirements of a steel plant, the most important energy-consuming processes must be known (**Fig. 3**). For processes with constant energy consumption, prediction is easy. For processes with fluctuating energy consumption, on the other hand, the energy requirement depends on the products and process parameters of the production lines and, above all, on the time frame. For this purpose, the Qualicision Online Heat Scheduler determines basic data: It calculates the required energy per production and production phase, taking into account the current production time – for processes with constant as well as fluctuating energy requirements. The key factor here is the automated, continuous adjustment of production schedules, taking into account the availability of equipment as well as resources such as hot metal, DRI or energy. In addition, the Qualicision Online Heat Scheduler also forecasts these further, so-called "secondary resources", based on quality-dependent input mix or energy consumption.

In practice, a planner can also immediately transmit the energy demand forecast for energy procurement in the course of the production release of the production schedule optimized with the Qualicision Online Heat Scheduler. An adjustment of the demand forecasts takes place automatically with each recalculation of the production schedule as a result of the production progress or – in case of necessary changes – as a result of disturbances or interruptions.

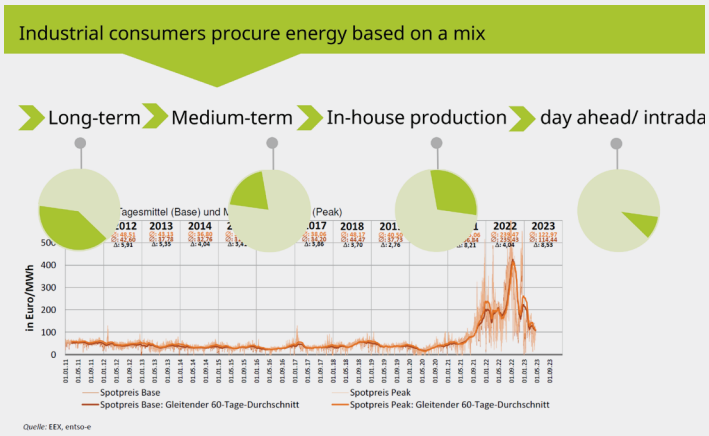

Fig. 4: The illustration of the historical development of the spot price and the shares of energy procurement in the different procurement categories illustrates the urgency to adapt the energy trading strategies as well (Source: PSI Metals GmbH)

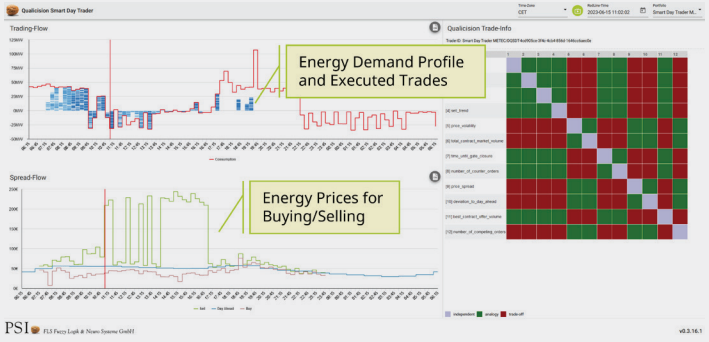

Fig. 5: The Qualicision Smart Day Trader dashboard displays open positions, transacted contracts as well as the corresponding market price situation and the Qualicision AI-based KPI relationship matrix (Source: PSI Energy Markets)

OPTIMIZED ENERGY PROCUREMENT

Furthermore, in the face of rising and volatile electricity prices, the aim must be to save costs through closer cooperation between energy planning and procurement, thereby safeguarding or even increasing competitiveness. Industrial consumers typically purchase electrical energy based on a mix of long- and medium-term contracts and taking into account self-generated energy (**Fig. 4**). Today, daily and intra-day energy trading plays only a minor role for many industrial electricity consumers. With the conversion of the steel industry to Green DRI and possibly Electric Arc Furnace steel route, the plants require significantly more electricity and at the same time produce less of their own energy. Here, too, companies are facing a key change process: adapting their energy trading strategy.

Classic concepts essentially aim to procure a basic level of energy over the long term. Sales forecasts, expected production times and shift models for the relevant production lines and routes serve as the basis for the calculation. In the medium term, the forecasts are replaced by confirmed customer orders and the energy procurement is adjusted to the exact shift planning for each production line. This approach no longer does justice to the current circumstances – neither with regard to short-term changes in production, which are associated with significantly higher fluctuations in energy requirements, nor with regard to the availability of regenerative energy and the associated rising and volatile electricity prices. This applies, for example, to the necessary interruption of a longer casting sequence. As a rule, this requires the casting system to be reset, which takes about 45 minutes. During this time, on the one hand, the melt produced must be kept warm, and on the other hand, all further sequences are delayed by the duration of the changeover time of the plant. This has an enormous impact on the energy requirement per time window – or the updated energy requirement profile differs significantly from the forecast based on which the energy was procured.

EFFICIENTLY CLOSING ENERGY GAPS USING INTRA-DAY TRADING

If the forecast changes during the day due to certain factors, the gap between actual energy demand and procured energy quantity is particularly large. In this case, the energy demand can be higher (positive difference) or lower (negative difference) than the procured energy quantity. These discrepancies can be balanced out by means of intra-day trading, or with a daily energy exchange. For this purpose, first companies rely on specialized software that automatically identifies and executes trading opportunities to close the energy gaps, thereby not only covering the energy demand exactly, but also generating trading profits if possible.

The PSImarket Qualicision Smart Day Trader, for example, uses complex qualitative labeled AI algorithms, technical indicators and statistical models for AI-based optimization of short-term trading. The automated action functions are based on strategies, rules and conditions that companies flexibly define in advance. For example, a rule might be: Always buy when the bid price is as far below the mean product price as possible, sell at the highest possible prices. The following rule is also standard: If possible, close the open positions completely by the (previously) defined time. Each rule is then cast into key performance indicators (KPIs), which the system continuously calculates and checks for each market order. In this way, it provides the basis for making optimized trading decisions (**Fig. 5**).

MAKING ECOLOGICAL TRADING DECISIONS WITH GREEN POWER CERTIFICATION

Another major advantage of such systems is that they can also be used to efficiently compensate for short-term changes, thus ensuring the necessary balance between economic and ecological considerations. However, because there is currently no green power certification on the short-term markets, green power still loses its eco-quality here and, together with conventional electrical energy, becomes anonymous gray power. However, one thing is already certain: With the expansion of the trading markets to include such additional labeling of the bids, the system can also take the ecological aspect into account in trading decisions through an additional Qualicision KPI.

All in all, with the help of an integrated production and energy management solution, companies can master the complexity of "green steel production" and make decisions that take equal account of ecological, technical and economic objectives.

SEAMLESS INTERACTION CREATES ADVANTAGES

The conversion to "green steel production" is without alternative – as is the use of efficient planning and scheduling management. In order to master the complexity during the transition phase in hybrid operation and beyond, it will be particularly important to optimize production planning, including heat schedules, energy consumption and energy trading. Here, companies will benefit in particular from solutions that are already based on an integrated system platform (**Fig. 6**) that enables the seamless interaction of these three key aspects.

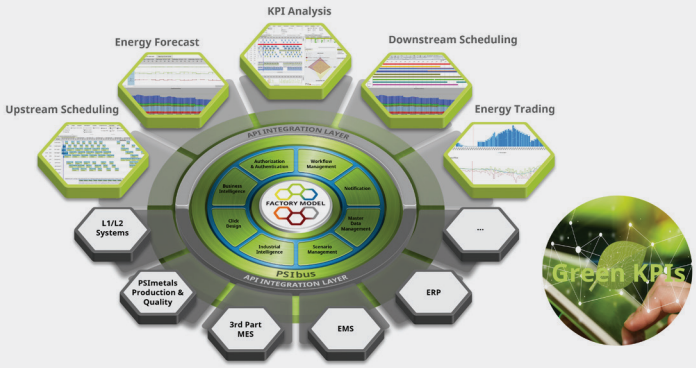

Fig. 6: In the future, steel producers will be dependent on system platforms that integrate detailed production planning, energy management and energy trading (Source: PSI Metals GmbH)

REFERENCES

[1] Data on global crude steel production using DRI is not currently collected; denominator in this calculation calculated by Worldsteel data management team based on information from Worldsteel collection databases.

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