

Outotec® Pretium Calciner Optimizer – Integrating Process Know-How into Daily Operations

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Abstract

As a key technology provider in the field of fluidized bed technologies, Outotec has successfully implemented digital systems in fluidized bed processing facilities in different locations worldwide. Simulation models including process know-how are transferred to the digital world and available to operators around the clock. The presented work describes the implementation of simulation models in an integrated digital system: the Outotec Pretium Calciner Optimizer. For a plant design and engineering company with decades of experience in the field of alumina calcination technology, one of the current challenges is to find ways to digitize valuable know-how and then take advantage of it in order to optimize industrial processes in terms of energy and resource efficiency. In this paper we present Outotec's approach to combining process expert know-how, detailed simulation models, and operational experience with the goal of improving customer plant operation. Using our digitalization approach, the required know-how can be made available to ensure optimum plant operation 24/7. Recent success stories demonstrate improvements in production rates on an industrial scale, reductions in utilities consumption, as well as improved emissions control to ensure compliance with environmental standards. The results should motivate the industry to follow the digital transition in ore processing even further in order to achieve even greater benefits.

Keywords: Alumina calcination technology, simulation models, digitalization know-how, operational experience, Outotec Pretium Calciner Optimizer.

1. Introduction – Digital Trends in Process Industries

The mining and process industry is currently seeing a strong trend towards increasing digitalization. Global players throughout the value chain are investing in digital solutions in order to optimize the mining and production process. Mining equipment is increasingly being fully automated and connected to downstream process steps with the goal of achieving optimization across the entire product value chain.

As a manufacturer of process plants and equipment, Outotec has identified similar needs in customer plant operations, leading to the following main drivers for digitalization, which can be observed in the alumina production sector:

- **Investment risk avoidance:** Customers tend to avoid high CAPEX investments in new plants. Instead, they focus on optimizing the operation of existing equipment or seek to achieve selected process improvements that have maximum impact on plant performance.

- **Productivity challenge:** With existing equipment, OPEX is increasingly the dominating factor in terms of a production facility's profit. Improving operational excellence can also lead to increased production with existing equipment, thus maximizing profits without high investment costs.
- **Shortage of skilled labor:** Many production sites are in remote locations, making them an unattractive workplace for operating personnel. Thus, a more autonomous operation with an improved level of equipment monitoring can maximize availability for a production site.
- **Sustainability:** With environmental regulations becoming increasingly strict in most countries around the world, operators face the challenge of reducing their emissions in order to avoid financial penalties. Furthermore, reducing energy consumption has a direct impact on OPEX.
- **Declining ore grades:** It is generally accepted that many of earth's high-grade ores have been completely depleted. The decline in ore grades means that operators face even greater challenges.
- **Technology push:** Digitalization allows information to be made available in real time, practically anywhere in the world. A digital process plant allows managers to monitor production figures from anywhere and at any time, providing a solid basis for improved decision-making.

The challenges listed above act as strong drivers for the adoption of digital technologies. These topics can be a focus for digital technology investments for production plants in general, not only in the field of alumina calcination. Given these facts, in the future digitalization will have a key role in overcoming productivity challenges, helping to improve both the level of automation and the monitoring of process plant and process equipment, as well as helping to ensure compliance with environmental regulations. Digital technologies will be able to provide operating personnel with round-the-clock assistance, thereby making the processing of lower-grade ores easier. Finally, the digitalization of process plants can be achieved for a relatively low investment cost and with manageable investment risk.

The following sections describe Outotec's approach to helping customers address these challenges in the context of an alumina calcination plant. However, the general approach is transferable and currently being applied to other process technologies. The integration of Outotec know-how into digital systems, both on the plant scale and the equipment scale, is described in chapter two. The implementation of the Outotec Pretium Calciner Optimizer in customer sites is described in chapter three. An example of a successfully executed project implementation for a digital system in fluid bed operation is presented in section four. Finally, chapter five presents a summary of the paper.

2. Digitalization of Process Know-How

The motivation and drivers for digitalization in the context of alumina calcination technology and the process industry in general give rise to the question "What does digitalization mean?". As a plant manufacturing company with more than five decades of experience in the design, construction, commissioning, and operation of calcination plants, Outotec has accumulated comprehensive know-how on all aspects of this technology. This knowledge serves as basis for potential operational improvements; however, the global distribution of production facilities makes it challenging to utilize this knowledge base to improve daily plant operation. Put simply, it is not possible to provide local face-to-face support at customer sites at all times.

Digitalization offers a solution to these challenges as it enables technological process and detailed equipment know-how to be made available around the clock anywhere in the world.

Such know-how can, for example, be integrated into heat and mass balance simulation models [1], dynamic process models [2], models used in online observation and prediction [3], or equipment design standards. Making these simulations available at the plant site enables improved process understanding and provides operating personnel with improved situational awareness.

Process know-how can also be integrated into operational sequences to enable the reliable repetition of challenging process tasks, reducing the risk of error when compared to human operators. It can be observed that such sequences reduce the risk of unnecessary site visits and increase production time.

Going back to the question “What does digitalization mean?”, without intending to provide an all-encompassing answer to such a complex question, one possible answer could include the following statements:

- Enabling plant manufacturers to take advantage of extensive process know-how at their site
- Making process know-how available 24/7
- Distributing knowledge worldwide
- Supporting operational personnel with various aspects of plant operation

The following section discusses some examples of how Outotec integrates process know-how in Outotec Pretium solutions.

2.1. Process Simulations – The Basis for Optimization

Process simulations and process calculation models are used as an important source for plant-wide optimization solutions from Outotec. **Figure 1** shows the integration of process know-how into Outotec Pretium and thus into daily plant operation.

Outotec has installed and commissioned more than 60 calciners in the last five decades and as a result has gained extensive experience with solving customer problems. In many cases design as well as troubleshooting rely heavily on process simulations – for example, when designing greenfield plants. On the other hand, capacity improvement studies and projects require an understanding of process equipment and plant operation. In Outotec’s digitalization approach the knowledge and models are transferred to a virtual plant, which is shown in the upper right of **Figure 1**. The knowledge base can be extended with Outotec’s research and development laboratories. An understanding of material behavior and chemical reactions can be gained, which allows to integrate also quality aspects into the optimization routines. The laboratories are also equipped with test facilities to investigate fluidization phenomena, which play an important role in the operation of fluidized bed plants such as alumina calciners. In summary, the combination of real plant operation, theoretical knowledge, and laboratory testing facilities means that plant manufacturing companies possess an unrivalled knowledge base for the journey towards digitalization.

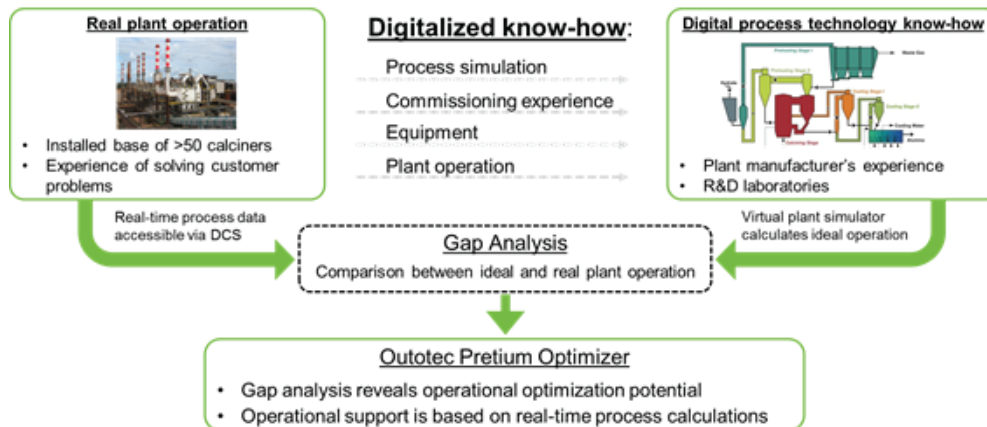


Figure 1. General scheme of process know-how integration in Outotec Pretium.

In the next step, Outotec Pretium uses a real-time comparison between data from the Distributed Control System (DCS) and virtual plant data. A so-called gap analysis can be used to reveal untapped potential in the plant operation or to identify equipment or process problems. The following section describes how the Outotec Pretium Calciner Optimizer utilizes theoretical equipment know-how in plant operation.

2.2. Detailed Equipment Simulations – The Basis for Operational Improvement in Single Process Unit Operations

In addition to global or large-scale process modeling, as described in the previous section, equipment simulations represent a further relevant level of detail. They describe single pieces of equipment and plant units at a highly detailed level and thus aid the understanding of operational phenomena, which are often neglected but can heavily influence overall plant performance.

An example of this type of detailed simulation model for a very important piece of process equipment is the seal pots. As a manufacturer of this type of equipment, Outotec has extensive experience and understanding of its operation. This know-how is integrated into Outotec Pretium through continuous monitoring of seal pot operation. Comparing theoretical model-based seal pot operation with real-time measurements can be used to detect abnormal operation, which can be an indicator for a potential malfunction. In addition, further key indicators are calculated continuously. Indicators like these can be used to analyze the pressure profile of equipment or reveal short-term fluctuations. In summary, the digital system can provide ample indication for operational classification. The findings can either be presented to the operators as recommendations or can be used to automatically adjust the equipment operation. An example of seal pot monitoring is shown in **Figure 2**.

Besides seal pots, further examples where detailed equipment models can be used are cyclones, downer-riser systems, and fluid-bed coolers. The operation of fluidized equipment is highly dependent on the air velocity and requires precise understanding of the physical principles. A further example, focusing on the monitoring and health assessment of equipment using process simulation models, is used in the Outotec PORS (Plant Operability Reliability and Safety) system [4], which detects malfunctions in sulfuric acid plants.



Figure 2. Seal pot operational monitoring system.

3. Calciner Optimizer – Implementation in Customer Plants

Figure 3 shows the implementation scheme of an Outotec Pretium Optimizer at a customer site. The integration of the digital system into an existing plant including a Distributed Control System (DCS) requires several steps. The top half of the graphic shows how the DCS is connected to the Outotec ACT (Advanced Control Tools) system. The ACT system provides the platform for the digital solution and is an in-house development. The platform reads DCS process measurements and can write data back to the DCS. Typically, digital optimization systems stabilize the process, take process limitations and constraints into account, and calculate trade-offs between different process targets. The result is a more stable process with reduced operator workload and more efficient operation. In addition, modern automation technologies provided as part of a digital solution are less prone to human operating errors. This is the typical setup for advanced control systems in process plants as shown in the top half of Figure 3.

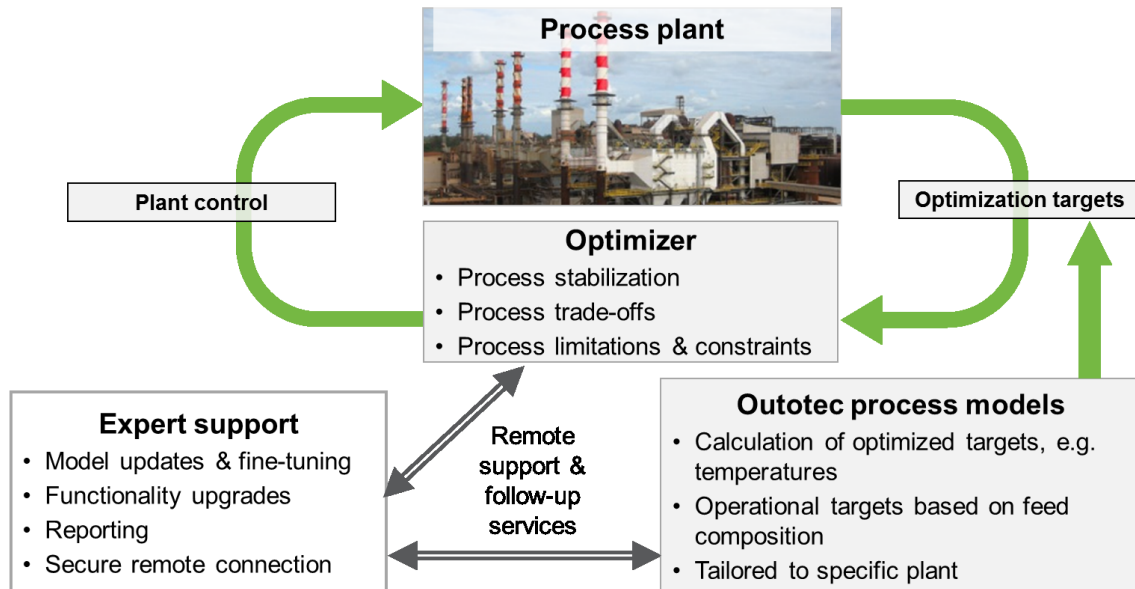


Figure 3. Implementation scheme for Outotec Pretium Optimizer at a customer site.

Process know-how is integrated as new features within Outotec digital solutions and placed on top of process stabilization schemes. The lower half of **Figure 3** shows how Outotec integrates its process know-how into the process optimization. Process models, as described in chapter 2, are used to calculate targets for the optimization. To do so, process and equipment simulations are run in near real-time.

As an example, in fluidized bed operations different material compositions in the feed mixture require adjusted temperature set points. In manually operated plants and those with limited control schemes, these set points are chosen by operating personnel, typically based on operational instructions. It can be observed that these set points are not changed if the plant is up and running and generating product, even though the plant is not operating optimally. One result of this might be unnecessarily high energy consumption. Having process models in place that choose the set points based on the feed composition will allow faster, more reliable, and automated adjustment of these set points.

Outotec has identified several reasons why it is critical to closely follow up on the optimizer after commissioning:

- **Process model updates:** Process and equipment models are tailored to the specific plant behavior. However, aging effects, redesigns, or equipment changes and modifications require model adjustment according to the new behavior. As they form a major part of the digital system, simulation models must be kept up to date so that the optimization algorithms can rely on the model calculations.
- **Functionality upgrades:** Especially when delivered and supported by the plant manufacturing and technology provider, a digital system will frequently be updated with new features. Closely monitoring the performance of the digital system provides an understanding of which feature upgrades will further improve plant performance. In addition, process and equipment simulation models are continuously being improved, and these improvements will be added to the optimization system at the plant site.
- **Reporting and process support:** The views of process experts are included in periodic reports. These reports focus primarily on the operation and utilization of the digital system, but also include the views of Outotec experts to enable a deeper understanding of process bottlenecks and potential plant improvements.

- **Remote connection:** Outotec is connected remotely to the digital optimization systems at the customer site via secure and proven technology. This allows process model updates and functionality upgrades to be performed remotely. In addition, a remote connection allows for the fastest possible response times in case of any change in customer requirements or tailoring requests for the digital system.

A graphical user interface is provided via a dedicated screen in the control room. The screen should be positioned in such a way that it provides operational awareness for the operator.

3.1. Solution Implementation Steps

The first step in the delivery of a digital product to site is the clarification and implementation of the IT solution. This includes the IT setup at site as well as an agreement on remote access. It should be noted that the remote access connection only provides external access to the PC/server or virtual machine that has the Outotec ACT platform installed. Accessing the customer's own infrastructure is normally strictly forbidden.

The next step is to implement the Outotec Pretium Optimizer. This includes the tailoring of the digital solution to the customer site as well as the connection to the single DCS tags and measurements. During this time the simulation models are also tailored to the specific plant. After successfully performing several safety checks, commissioning of the Outotec Pretium Optimizer can start. This is usually done during a site visit from Outotec process and digitalization experts. Further fine-tuning happens after commissioning.

In the following months operation with Outotec Pretium Optimizer typically increases up to 100 %. Adjustments to the models and the graphical interface are made during this time, and operation with the digital system is closely followed remotely. When the system is fully operational with the expected operation time close to 100 %, the frequency of remote adjustments and upgrades declines. This phase is the lifetime of the digital product. During the digital product lifetime, functionality upgrades are made as required, as described in chapter 3.

In this phase further Outotec process know-how is utilized to debottleneck the plant or further improve performance. In this sense digitalization is part of a modernization journey for a process plant. This approach is discussed in detail in [5]. By combining digital systems with process know-how and manufacturing capability, operating plants benefit from the best possible level of support when seeking to achieve operational excellence.

3.2. Features of the Calciner Optimizer

The combination of advanced control and optimization features with process know-how and process and equipment simulation are summarized below:

- **Advanced control loops:** Stabilization of the process on top of classical PID control loops
- **Operational advice systems for operators:** The utilization of digitalized process know-how assists the operators. The system compares many process variables at once and takes their combinations into account. Human operators instead tend to focus mainly on single variables and compare these against limitations or constraints. Including multiple variables in the assessment, which is based on process understanding and executed in the digital system, creates comprehensive situational awareness and covers the whole plant. Crossover effects are no longer hidden. The results are provided as advice to the operators to assist them in the daily operation of the plant.

- **Process optimization system:** Further enhancing the features of the operational advice system and including mathematical optimization algorithms allow for near fully automated plant operation, close to the possible optimum. In this case, the process optimization provides the guidelines for advanced control loops. This optimizes operation and makes the manufacturer's process understanding available on site around the clock.
- **Health monitoring:** While the simulation models provide the expected plant operation, the DCS provides data on the actual plant operation to the Outotec Pretium solution. A difference between the two indicates that there is malfunctioning equipment. In addition, drifts between measured and simulated values indicate equipment degradation. Such information is integrated into health-monitoring features.
- **Smart sensors:** Process simulation models are also used as part of smart sensors. As an example, hydrate moisture can be estimated by solving the mathematical models around the alumina calciner feeding section. Such smart sensors provide additional information that would not be available without the inclusion of process and equipment models in a digital system. Further examples of smart sensors include solutions for product quality estimation.

4. Digitalization – References in Fluidized Bed Plant Operations

Fluidized bed customers around the world are increasingly adopting digital systems. There is an increasing interest in adopting the latest technology and using process know-how to enhance daily operation. A few examples developed and delivered by Outotec are presented below.

4.1. Roaster Optimizer

Today, Outotec customers operate fluidized bed zinc roasting plants close to 100 % of the time using Outotec Pretium digital systems. The improvements compared to traditional operation are:

- Production increase of more than 5 %
- Significant reduction of emissions
- Significant improvement in product quality (25 % better quality value)

While the production increase is a result of plant stabilization and optimization, the improvement in product quality is achieved after including product quality models into the optimization. In addition, reduction in emissions is a result of the process model being included in the optimization system.

4.2. Training Solutions

Training prior to commissioning was held in pyrite roaster plants and in waste-to-energy power plants. Dynamic process simulation models are used to create a close-to-reality training environment, giving operators the opportunity to familiarize themselves with plant behavior before commencing work. They learn to understand the consequences of their actions as well as the correct countermeasures in critical operational situations. As an example, **Figure 4** shows a screenshot of a dynamic training simulator for a fluidized bed waste-to-energy power plant.

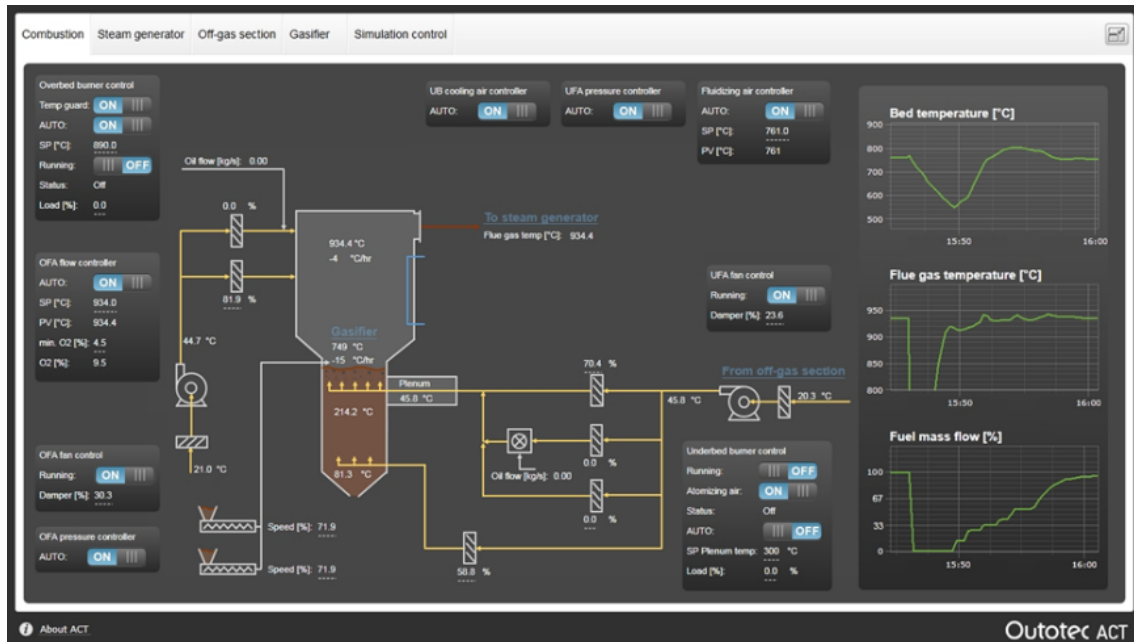


Figure 4. Screenshot of a fluidized bed process training simulator [2].

4.3. Perficiency – How We Measure Success

In addition to the obvious assessment of operational improvements through digitalization by throughput, energy savings, and so on, Outotec has introduced the perficiency rating [5,6]. It is an extension of the well-known OEE and TEEP ratings, which serve as evaluation criteria for production process performance [7–11]. However, neither OEE nor TEEP criteria include process efficiency; perficiency extends these ratings with an efficiency evaluation. The word perficiency is a combination of process performance and process efficiency.

The process efficiency rating comprises assessments for the following:

- **Energy efficiency:** How well is the process using the energy content in the fuel? This includes both energy utilization for endothermal processes, e.g. alumina calcination, as well as energy recovery of exothermal processes, e.g. roasting.
- **Raw material:** How much of the raw material is recovered in the process? Most processes typically have a very high recovery rate and thus a very high rating.
- **Utility material:** Evaluates the consumption of utilities in a process. Utilities include things like oxygen, which is used in the roasting processes, and diesel, which is often used to start up alumina calcination plants.
- **Environmental:** Emissions of harmful or toxic substances, such as NO_x or SO_2 , are evaluated in the environmental rating; dust emissions are also taken into account. The rating represents factors that potentially harm the environment.

The four ratings for process efficiency have a significant impact on the profitability of the plant. However, the perficiency rating is a purely technical rating and does not take local regulations into account. Individual regulations, for example emission limits that may differ from site to site, are not considered. The perficiency rating compares the operation of the plant with a worldwide benchmark. However, individual process targets make sense for every individual customer.

The extension of OEE and TEEP towards process efficiency helps operators to identify operational and technological bottlenecks. **Figure 5** shows an example calculation where the energy efficiency shows a poor rating of 83 %, resulting in a process efficiency of just 73 %. In the case of such a rating, improvements would be recommended. An improvement can either be realized through improved operation enabled by digitalization, through modernization of the process equipment, or by a combination of the two.

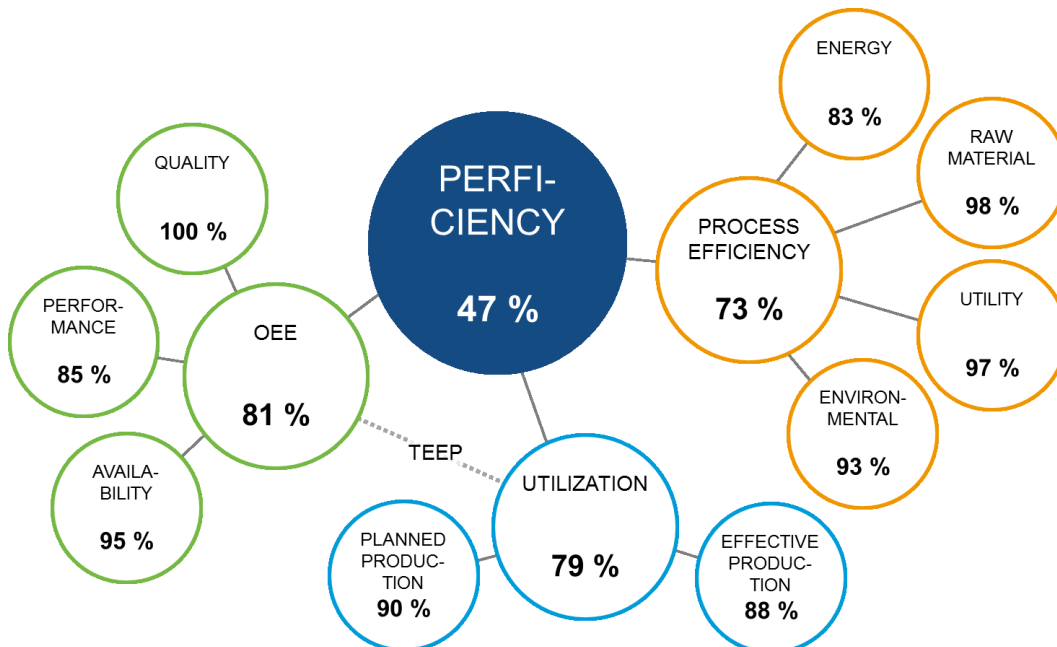


Figure 5. Example Perficiency calculation.

A perficiency evaluation of Outotec Pretium Roaster Optimizer implementations show a significant (up to 7 %) improvement.

5. Conclusion and Outlook

The demand for increased automation and operational optimization of process plants is increasing in the process industry. Consequently, Outotec has developed the Outotec Pretium Calciner Optimizer. Outotec has identified the utilization of process understanding, know-how, and simulation models as the key factor for successful utilization of modern digital solutions. Digitalization can therefore be understood as the inclusion of know-how and process expertise in daily plant operation. Two main models have been identified: process simulation models and detailed equipment models. While process simulation models focus more on the overall global or large-scale process level, detailed equipment models are used to evaluate the performance of individual pieces of equipment. Both models play an essential role in advanced process control schemes or operator advisory systems, as well as in smart sensors or health-monitoring algorithms. It can be concluded that a comprehensive digital system will not be able to achieve the desired level of performance without the inclusion of process understanding.

Outotec has implemented several Pretium systems in fluid bed operations in recent years. The Outotec Pretium Roaster Optimizer shows excellent performance in the zinc roasting process, increasing throughput by more than five percent while significantly improving product quality. The Perficiency ratings, Outotec's technological rating for process plants, show improvements of up to seven percent for these comprehensive key performance indicators.

Outotec is currently rolling out digital systems for various processes, including alumina calcination plants and iron ore pellet plants. Results are expected to be in the same range as measured using the Outotec Pretium Roaster Optimizer. Analyses show high potential for energy consumption optimization with both technologies. Results are expected within the next year.

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