Climate Smart Process Industry: Cost/Benefit Analysis for implementation of digitalization /RTO technology at MEVA Energy

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1. Introduction and Summary

Digitalization and Industry 4.0 are concepts that are used frequently. The perception is that implementation of digitalization could improve profitability and the environmental footprint of a company (or production process). There is however confusion on what is possible and even on what is meant by “digitalization” and/or Industry 4.0. Furthermore, although the technologies are available, the pace of digitalization implementation is slow. In order to help organizations within “Västsvenska kemi- och materialklustret” (i.e. organizations/companies that have not yet implemented digitalization in their production), get a better understanding of how implementation of digitalization could benefit their companies, a case study was performed where the cost/benefit for implementation of digitalization was determined. The “digitalization” of the MEVA production process was investigated as a case study.

It is crucial to connect the experts within digitalization with the experts within chemical production to evaluate the cost/benefits that implementation of digitalization will bring. In this project, Siemens, experts within implementation of digitalization, and MEVA Energy, experts within production of heat and energy from waste biomass, evaluated how digitalization could be implemented in the MEVA production plant.

The goal of this project was to perform a cost/benefit analysis for implementation of digitalization in the MEVA production plant. The results were presented to “Västsvenska kemi- och materialklustret” on the 7th May 2020. Further presentations will be planned for other stakeholders, e.g. other CHP companies in the region, with the main goal to get a better understanding of how implementation of digitalization at their companies could benefit them.

Initially the project focused on the implementation of Advanced Process Control (APC) and Real Time Optimization (RTO) into the MEVA process. The project however identified that the biggest saving initially would be to implement predictive maintenance. As this was a very limited investigation the decision was taken to investigate implementation of this technology in more detail.

The conclusion of the preliminary cost/benefit calculation indicate that the annual economic benefit to MEVA would be in the range 1.6 – 3.3 M SEK, with the initial cost for implementation approximately 500 k SEK, with an annual license fee of approximately 400 k SEK.

The financial saving will undoubtedly lead to environmental savings, for example less energy use due to more efficient heat exchangers, higher yields of renewable syngas, heat and power, due to optimized equipment and better understanding of the process in general.

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1 In this project the term “digitalization” means using data (through digitization) to obtain a specific goal, for example using data from sensors to optimize a process through for example Advanced Process Control (APC), Real Time Optimization (RTO), etc. “Advanced digitalization” could be seen as Digitalization 2.0, where new technologies, for example edge computing, Internet of Things, wireless and advanced sensors, 5G, advanced algorithms, AR/VR, etc. is incorporated in the optimization process. These “new” technologies when implemented into the complete value chain is often referred to as “Industry 4.0”.

It is proposed that implementation of predictive maintenance at MEVA is investigated in more detail, before a final decision is taken to invest.

2. Methodology used in the Project

The team that was set up to conduct the project was:

- Medina Sundström, Siemens, expert within “digitalization” and knowledgeable on possibilities within Siemens.
- Thomas Andersson, Siemens Digital Industries, knowledgeable on available solutions within Siemens.
- Eric Palander, MEVA, Process Control, Instrumentation expert.
- Anders Wingren, MEVA, Process Engineer, expert within the production process.
- William Mackintosh, RISE Project Leader, Generalist within chemical processing, process control and digitalization.

The team members were chosen to represent different areas of competence to cover chemical process expertise, process control and instrumentation expertise and expertise within “advanced digitalization”. Representation of all these expertise areas are essential to identify potential digitalization options that might be viable to implement into the MEVA production process.

The following activities were performed within the project:

- Identification of process parameters,
- Identify which “advanced digitalization” methods that could be implemented at Meva and
- Perform a cost/benefit analysis.

The activities are discussed in more detail below.

2.1. Identification of Process Parameters

For all the partners to get a good understanding of the MEVA production process one of the first activities planned was to have a working session where MEVA described the production process. The parameters that could impact Quality Attributes (for example gas quality) were discussed and new sensor technologies that could be used to gather more information on parameters that could be of interest were identified. The initial working session was followed up by more in-depth discussions on further parameters that could impact QA’s and new sensor technology that could be of interest.

2.2. Identify which “advanced digitalization” methods could be implemented at Meva

Various digitalization options were discussed within the project prior to a workshop that was organized by Siemens. Some of the digitalization options that were discussed are listed below:

- Advanced Process Control (APC) /Real Time Optimization (RTO),
• Predictive Maintenance,

• Setting up of digital twins, including data driven digital twins, mechanistic digital twins and “hybrid” digital twins. The digital twins would be used to accomplish APC/RTO, VR/AR and to help with operator training.

• Setting up of Virtual Reality (VR) and/or Augmented Reality (AR) models that could be used in designing of the production plant, to help with operator training, etc.

After having considered all the different suggestions SIEMENS organized a workshop where the main solutions which can improve the processes, assure uptime or help manage the operation were presented. Two main areas were identified as of primary interest. The first was implementing and improving advanced process control and simulation based on SIMATIC PCS 7 + SIMATIC SIMIT + PSE gProms³.

The second one was the Equipment Predictive Analytics⁴, it is used to predict abnormal behavior based on machine learning and artificial intelligence. See Figure 1 for the main benefits of implementing Predictive Maintenance.

![Figure 1. Main benefits of implementing Predictive Maintenance.](image)

Equipment Predictive Analytics was selected for further presentation and evaluation. The main reason for this choice is that the first part of implementing this type of solution is a data analytics phase which was identified to be of potential benefit to most companies since it creates an understanding of the available data, the relation of the data and what is possible to do with it with limited effort.

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In addition to the two digitalization areas selected, other solutions from Siemens Digital Enterprise portfolio could be of interest to process industries and should be considered. Examples of other solutions of interest would be new sensor technology e.g. fiber optic temperature measurement\(^5\), new control systems and services.

### 2.3. Perform cost/benefit analysis

After identification of the “advanced digitalization” options identified at the SIEMENS workshop a cost/benefit analysis were performed with help of SIEMENS and MEVA.

For savings at MEVA the current downtime for the existing production plant at Hortlax caused by unplanned stops due to equipment failure was estimated, as well as expected downtime due to planned maintenance shut-down after implementation of predictive maintenance. The time difference was then used to calculate the increased amount of product gas produced, and ultimately the increased profit made by the increase in gas produced.

The implementation cost used is the standard Siemens cost for this type of product. These are only indicative costs and depend on the complexity of the process.

### 3. Results

The main results obtained in the project is given in this section.

#### 3.1. MEVA Production Process

#### 3.1.1. General

MEVA is a SME, with a total of 13 employees.

Meva Energy’s technology is a complete system from gasifier to syngas cleaning for production of renewable fuel gas which is fed to a power engine genset for distributed production of power and heat. Alternatively, the resulting renewable gas can be used to replace fossil gases such as natural gas or propane in e.g. an industrial drying process.

The entire system is fully automatized and is designed for continuous operation with remote monitoring. With fully automatized means that there is no need for manual operations during normal production.

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Key to get a profitable gasification process is to utilize low cost biomass. Meva Energy’s gasification technology could use fine fraction, biomass residues, i.e. sawdust, wood fibers, bark, agricultural residues etc.

According to the European Sawmill organization, about 85 million m3 of sawn softwood is being produced each year. This represents a production of saw dust and bark of about 30 million tons.

This feedstock resource is today representing a low value as it sits in the saw mills site and the low fraction character makes it difficult to transport. Pellets production is of limited value and the particle board industry is only in need of a small fraction of the saw dust produced.

A very large part of this resource is just being burned and destroyed. Utilization as fuel to produce power and heat locally at the sawmill without transport with Meva’s technology is an attractive option.

One single Meva Energy plant can convert 1 ton/hour of biomass into 3.5MW renewable syngas or 1.2 MW power and 2.4 MW of heat, hence reducing 10 300 tons of CO2/year. WWF has estimated that the technology has potential to save 75 million tons of CO2 annually from 2030.

MEVA received their first order of a full-scale commercial plant from the local utility company Pite Energi in Sweden 2011. The plant, based in the village of Hortlax in the north of Sweden, produce 1.2 MW electricity and 2.4 MW heat. Since 2018 Meva Energy is the owner of the plant and use it today as a R&D and demonstration plant and invite prospective clients and partners to visit it. This plant could potentially be used to illustrate implementation of digitalization and to demonstrate advantages to the process by implementation of Real Time Optimization (RTO).

### 3.1.2. Process Parameters of Interest

A working session was held at MEVA, Lund on the 17th January 2020 where Anders and Eric presented the complete MEVA production process.

A block flow diagram of a gasification plant is presented in Figure 2. The fuel e.g. wood chips, agricultural residues, wood pellets, waste woods must be grinded to a fine flour (below 1 mm) and possibly also dried (moisture below 12%) before it can be used as fuel in the cyclonic gasifier. The transport of the fuel from the fuel handling section of the plant to the gasifier is done pneumatically using the gasification air as carrier media.
Figure 2. Block flow diagram of a Meva gasification plant converting biomass into syngas in a CHP application

In the gasifier, wood powder is converted into permanent gases, tar, char and possibly soot. Larger char particles are collected at the bottom of the gasifier whereas smaller char and soot particles leave the gasifier with the gas through the vortex finder tube. The residence time in the gasifier is short, about 1 second.

The gas is cooled and purified. Initial cooling is carried out in a water quench. Water is sprayed into the hot gas stream with an almost instantaneous temperature drop from 950 °C to 90 °C. During the cooling process, heavy tars condense and are captured in the excess quench water which drains to a holding tank.

From the quench, the gas flows to a venturi scrubber operating at a pressure drop of about 100 mbar. In the venturi, particles larger than 1 µm is separated from the gas and water drains to a holding tank. The gas is further cooled to 40 °C in a random packing scrubber.

The final step in the gas cleaning system is the wet electrostatic precipitator (WESP) where small tar droplets, i.e., aerosols and soot are captured. Finally, the purified gas is sent to the internal combustion engine for power and heat production.

Water from the quench, the scrubber and from the venturi is drained to a holding tank and from there pumped to the centrifuge where tar and particulates are separated from the water. Purified water is cooled in a plate and shell heat exchanger and then recirculated.
In general, the production process consists of the reactor, which is the heart of the process, and a purification section that purifies the gas produced in the reactor. The parameters of interest during the reaction/gasification is generic for this type of reaction. Parameters include the characteristics of the feed material, design of reactor, feed rate, air/fuel mixture, temperature, pressure, etc. Parameters that impact downstream processing are also generic for the different purification steps.

The exact parameters that influence the MEVA process is proprietary information and will not be reported. The project concluded that predictive maintenance is an area of more interest for MEVA than RTO/APC.

3.1.3. New sensor technology of interest

Real time measurement of syngas composition is very difficult but would, if implemented, be of great advantage when it comes to controlling and optimization of the gasification process. Given the short residence time in the gasifier the instrument needs a very short response time, 0.1 s or shorter to be meaningful. One very interesting and promising technique is TDLAS (Tunable Diode Laser absorption spectroscopy) which can in addition to certain non-condensable gas components also measure particulates e.g. soot and char. The TDLAS could be installed directly on the exit pipe from the gasifier and does not require any obstruction or slip stream of the gas flow.

Previously, RISE ETC’s diagnostic team has developed a number of novel optical sensors for real-time measurements of T (gases and solids), CO, CO₂, H₂O, soot, the moisture content in fuels and biomass powder mass flow fluctuations, that could be of interest to the MEVA process and should be investigated further.

The performance of the novel sensors and their new advanced features were successfully demonstrated in laboratory and pilot-scale tests. Application of the sensors to industrial processes has been initiated. For more information on the setup of the TDLAS measurement in the RISE ETC gasifier see Figure 3.

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5 Real-time in situ multi-parameter TDLAS sensing in the reactor core of an entrained-flow biomass gasifier
3.2. Digitalization Proposal Siemens

From the comprehensive portfolio of digitalization solutions Siemens support to the process industry it was selected to start with something small which would create both understanding and improve the plant uptime and availability. The proposed service is a standard offering which assists a customer to gain further understanding of his data and how it is correlated and if and how it would be possible to build a model for machine learning and prediction of the process.

The proposed solution would start with an initial discussion and understanding of the process control philosophy, process flow diagrams, P&IDs, FMEA. This will provide a process understanding of the process. Next step would be to view historical data from process, driving power supply, 3rd party monitoring systems etc. and tags mapping provision to understand the available data from the plant.

Figure 3. TDLAS measurements in the RISE ETC gasifier (RISE ETC & UmU)

Figure 4. Illustration of the initial correlation identification.
Identify correlations between the sensors by correlations coefficients based on historical data and domain knowhow (see Figure 4 for illustration of the initial correlation identification process).

![Figure 4. Example of initial correlation identification process.]

**Figure 5.** Example of correlation analysis.

Next step is the data and model evaluation phase. During this phase data is reviewed and assessed in order to create first draft of machine learning algorithms and target sensors (see Figure 5 for an example of the correlation analysis).

The third step is to consolidate the data and determine modes of operation and healthy periods in order to know which data to train the model on (see Figure 6 for an example of identification modes of operation).

![Figure 6. Example of identification of modes of operation.]

**Figure 6.** Example of identification of modes of operation.
After completion of the consolidation phase the models are refined and trained on the identified periods. Further the models are validated using the historical data and prepared to be deployed to the end user application (see Figure 7 for an example of selection of training periods).

**Figure 7.** Example of selection of training periods.

The final phase includes consolidation of the models, site deployment and training followed by analysis of the first results and live data. Equipment Predictive Analysis is then up and running and for the user to receive alerts and review the current and predicted status (see Figure 8 for an illustration of training of the data model a live operation).

**Figure 8.** Illustration of training of the data model and live operation.

The illustration below (Figure 9) shows an event which tripped the equipment with little warning and heads up prior to the trip by the DCS system. The anomaly detection picked up the deviations earlier.
The graph shows the measured and the predicted value of the compressor pressure during the event. The images at the bottom shows the dashboard before the trip and illustrates how the warnings escalated prior to the trip.

**Advanced compressor monitoring**

![Graph showing measured and predicted values of compressor pressure]

*Figure 9.* Illustration of a use case where the model is presented at three points in time and where the anomaly was detected several hours before the DCS alarm.

### 3.3. Cost/Benefit Outcome

A feasibility study and proof of concept study for the implementation of Predictive Maintenance (as described in Error! Reference source not found.) usually cost approximately 100-250 k SEK, depending on the quality and availability of data, unique terms and conditions, and the complexity of the process. For the MEVA process the feasibility study is estimated to cost approximately 100 k SEK.

The implementation phase, depending on how much already have been implemented, cost approximately 350 to 950 k SEK. For the MEVA project the initial estimation for the implementation phase is estimated to cost approximately 400 k SEK. The total implementation cost (feasibility cost plus implementation cost) would therefore be approximately 500 k SEK for the MEVA process.

The annual license fee for the software is approximately 400 k SEK.

The project has identified the following savings, benefits or opportunities for increased revenue that could be realized by implementation of Predictive Maintenance at MEVA. The figures are based on opportunities in a Meva double plant where 2 reactors are used in parallel i.e. a 10 MW gasification plant.
BENEFITS MADE POSSIBLE BY DIGITISATION

<table>
<thead>
<tr>
<th>Description</th>
<th>ANNUAL COST SAVINGS/ INCREASED REVENUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fewer unexpected stops due to better preventive maintenance result in increased plant availability</td>
<td>250-500 k SEK</td>
</tr>
<tr>
<td>Fewer stops with better coordination and maintenance planning provide increased plant availability (include more equipment into maintenance plan that require maintenance within a certain period of time after start-up).</td>
<td>300-600 k SEK</td>
</tr>
<tr>
<td>Shortened downtime due to easier troubleshooting during unexpected stops.</td>
<td>300-600 k SEK</td>
</tr>
<tr>
<td>More optimized production with a better understanding of key parameters that affect production</td>
<td>300-600 k SEK</td>
</tr>
<tr>
<td>Stable gas quality with fuel quality measurement, optimal reactor operation and optimal gas treatment.</td>
<td>150-300 k SEK</td>
</tr>
<tr>
<td>Make visible the need for maintenance of equipment that become less efficient over time.</td>
<td>45-90 k SEK</td>
</tr>
<tr>
<td>Online evaluation of parameters affecting CGE to optimize other Meva plants</td>
<td>300-600 k SEK</td>
</tr>
</tbody>
</table>

Total >>>>>                                                                                                                                          1.6 – 3,3 M SEK

The conclusion that can be drawn is that plant interruptions are expensive and should be avoided. The CGE (cold gas efficiency) change needs to be permanent for the cost to be significant. The item that can be individually largest is if a plant damages market confidence but the size of this is kept off the project and is not listed above.

It is important to note that the digitalization process implementation itself creates some of the opportunities, so the cost of investment does not automatically provide the increased revenue or cost savings shown. Routines, work processes, planning, other operational tools, culture and, not least, experience from previous installations are important parameters that need to be included. For the sake of simplicity, the internal MEVA costs related to implementation of predictive maintenance is not included into the cost/benefit analysis, but will be considered in the more detailed investigation.
The project focused on the process and exploitation and assumed that everything around it is available and functioning. It is estimated that total revenue/savings will increase by SEK 1.6-3.3 million per annum as a result of implemented digitization for a dual Meva plant. The main parameters are that the plant has a stable high utilization and that the risk of unplanned stops is kept to a minimum.

The result of digitization within the project shows possibilities for Meva’s processing plant to run as optimized as possible while reducing the risk of unexpected stops.

Further investigations are required before a final decision is made on investing into a predictive maintenance system.

4. Conclusions

The goal of this project was to perform a cost/benefit analysis for implementation of digitalization in the MEVA production plant. The results were presented to West Sweden Chemicals and Materials Cluster on the 7th May 2020. Further presentations will be planned for other stakeholders, e.g. other CHP companies in the region, with the main goal to get a better understanding of how implementation of digitalization at their companies could benefit them.

Parameters that could impact Quality Attributes (for example gas quality) in the MEVA production process were identified. Potential new sensor technologies were identified that could facilitate RTO/APC and predictive maintenance. Some of the new sensor technologies identified include TDLAS, video monitoring of the reaction and fiber technology to measure temperature in the reactor.

The project concluded that predictive maintenance was the technology of choice to investigate initially. The preliminary cost/benefit analysis for the implementation of predictive maintenance in the MEVA production process indicate that the project will be profitable. The implementation cost would be approximately in the range 450 k SEK to 1200 k SEK (initial estimation approximately 500 k SEK), with a yearly license fee of approximately 400 k SEK. The total predicted savings would be in the range of 1.6 to 3.3 M SEK/ annum. These are preliminary figures and further studies are required to confirm the savings that could be realized.

Further advantages for the implementation of “advanced digitalization” at MEVA are as follows:

- By optimizing the management of data MEVA would probably get a better understanding of their production process. Furthermore, the implementation of Advanced Maintenance could be the first step in the implementation of RTO/APC. This would probably result in a more robust process, that would lead to potential customers having more confidence in the MEVA plant.

- Environmental savings will automatically follow once Advanced Maintenance is implemented. Some potential savings would be made by operating unit operations optimally, for example the optimum use of heat exchangers and optimization of the CGE.

It is proposed that more detailed cost/benefit analysis be performed, before a decision on investment is made by MEVA. Projects could either be financed commercially, alternatively grant financing could be an option. Within the West Sweden Chemicals and Materials Cluster a continuation project could be to investigate the implementation of advanced sensor technology at
MEVA, combined with a more detailed feasibility study conducted by Siemens to investigate the implementation cost of Predictive Maintenance at MEVA.

In general, Predictive Maintenance, in some circumstances, could be easier to implement compared to RTO/APC. The savings made by implementation of Predictive Maintenance could also be substantial. One example is a mining operation where SKF has placed 8,000 sensors on the production lines, monitoring 2,400 critical assets, such as pumps, fans, gearboxes and large rotating grinding mills. As a result of digitalization, SKF has been able to document that the predictive maintenance measures that have been implemented are saving the company almost €8 million per year.\(^7\) A further example is the project “Det smarta digitala sågverk” where digitalization was implemented at the Moelven sawmill. This resulted in a reduction of unplanned stops in production and a better understanding of the energy use within the factory. The goal of the project is to increase the process efficiency by 15% and to reduce energy consumption by 10%\(^8\).

To summarize, the project can conclude that implementation of “advanced digitalization” would undoubtedly benefit MEVA. The only activity remaining before a decision can be made to invest, and subsequently benefiting from “advanced digitalization” that would benefit the environment, is to perform a more detailed cost/benefit analysis. Securing financing sources to perform this final cost/benefit analysis is the next phase of this exiting possibility. Furthermore, implementation of predictive maintenance could be a good first step in the implementation of “advanced digitalization” technology to improve both the profitability of a process and reduce the environmental impact of the process.

In general, when considering the implementation of “advanced digitalization”, it is recommended that companies first perform a cost/benefit analysis for the implementation. It is critical to discuss different alternatives with experts within the area, as the costs for implementation could be considerable, depending on how much of the infrastructure required for the implementation is in place, and how well the production process is understood and monitored. The conclusion of this project is that the implementation of “predictive maintenance”, which in general is easier to implement than other areas of “advanced digitalization”, for example RTO, is a very good start in the implementation of “advanced digitalization”. Once the first step to “advanced digitalization” is taken the subsequent steps should be easier to implement.

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\(^8\) https://etn.se/index.php/reportage/66685-sveriges-smartaste-sagverk-skapas-i-karlskoga.html