Electric Motor Systems
Platform EMSA

Digitalisation in electric motor systems – Part III

Catalogue of case studies

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This report was prepared under the Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E) – Electric Motor Systems Platform (EMSA) programme. This is the third in the series of four reports published in 2024 on the digitalisation of electric motor systems, elaborated by EMSA.

The four publications:

- Digitalisation in electric motor systems – Part I: Findings for policy makers
- Digitalisation in electric motor systems – Part II: Technical recommendations for industrial end-users
- Digitalisation in electric motor systems – Part III: Catalogue of case studies
- Digitalisation in electric motor systems – Part IV: Energy consumption due to the digitalisation of electric motor systems

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Table of contents

Digitalisation in motor systems

Introduction

The International Energy Agency Technology Collaboration Programme 4E Electric Motor Systems Platform (EMSA **www.iea-4e.org/emsa**) is researching the topic of digitalisation of motor systems. Four countries are working together on this issue: Austria (lead), the Netherlands, Sweden, Switzerland. In the framework of this international collaboration, the topic of digitalisation in motor driven systems shall gain worldwide increased attention and be brought forward, through:

- Raising awareness on the energy savings potential
- Showing best practices through case studies and successful policy instruments
- Identifying barriers and potentially ways to overcome these
- Motivate and help industrial facilities to start and/or continue to reap the savings potential offered by the digitalisation of their motor systems through targeted information and case studies as «good examples»
- Closing an information gap also with regard to the energy consumption due to the digitalisation of electric motor systems
- A structured coordination and exchange with international experts and stakeholders.

In this publication, EMSA presents a number of case studies, thus concrete examples, in which digital solutions enabled the optimisation of energy use in motor systems. These are intended primarily for industrial end users as an inspiration and motivation but may also be interesting for other experts e.g. in the area of consulting, manufacturing, academia or policy making.

Digitalisation is a buzzword and hence it is important to clarify what is meant by it in this report. EMSA published a report on the Classification of digitalisation technologies for electric motor driven systems in 2022 [2]. Therein, an overview of the major digitalisation technologies that are used in the field of electric motor systems is given (see Figure 1). The case studies in this publication relate to the digital solutions presented in that report. More information on EMSA's work and other publications in the area of digitalisation in motor systems: **www.iea-4e.org/emsa/our-work/digitalisation**.

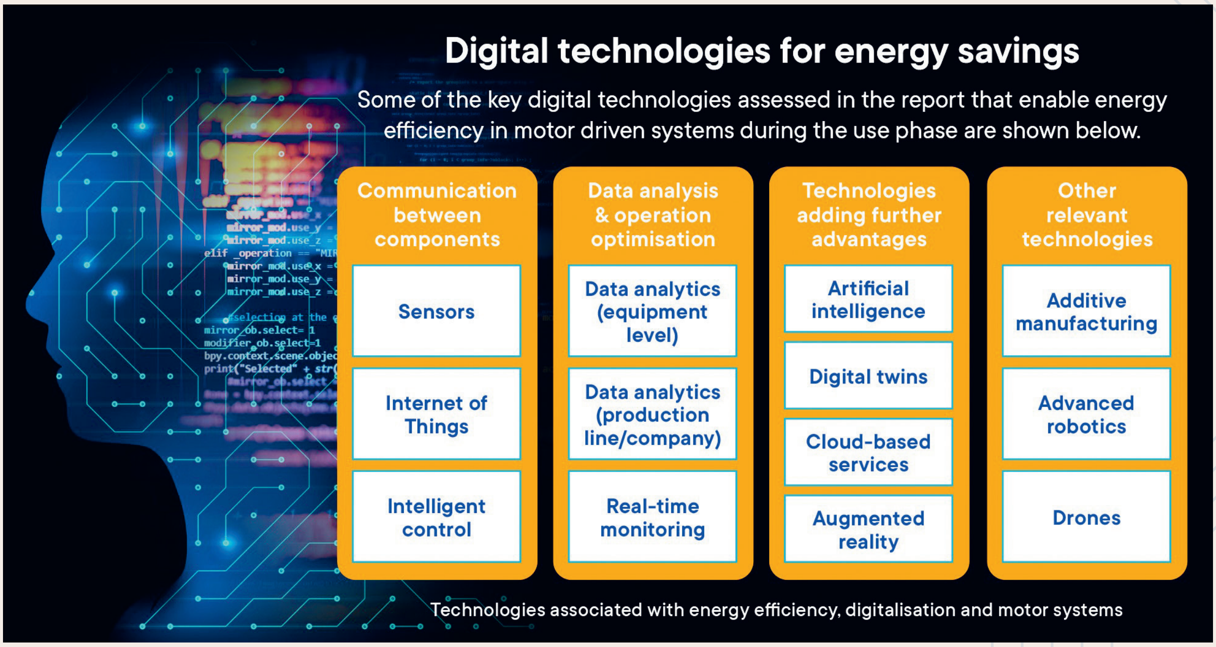


Figure 1: Digitalisation technologies analysed in the EMSA report Classification of digitalisation technologies for electric motor driven systems (2022).

Overview

In total, 8 case studies are presented in this report, from four countries. The case studies cover all major motor system applications, i.e. pump ventilation and compressor systems.

The following tables give an overview of the case studies presented. In the following, each case study is described shortly.

Case studies of digitalisation of Electric Motor Driven Systems (EMDS)						
Company	**Profile**	**EMDS affected**	**Digital solution**	**Before**	**After**	**Savings**
Yorkshire Water	Sewerage	Pump systems	Condition monitoring, control optimisation by applying electrical signature analysis	Static (set points for) operation of pumps	Adapted set-points (load) and target speeds of pumps, closer to their optimal efficiency	15 % of electric energy
PRiOT	IOT service provider	Ventilation systems	IOT sensor in air ventilation system in server facilities	Sporadic manual tests of air filter clogging	Remote detection of clogged air filters in ventilation system for servers	20 % of electric energy
IKEA	Furniture	Chillers	Advanced control combined with online performance monitoring	Non-optimised operation	Optimised operation of compressors and load shifting	20 % of electric energy
Hamilton Bonaduz	Medical solutions	Compressed air	Intelligent control, real-time monitoring	Set of DOL (on/off) air compressor units	VSD operated compressor units, intelligent control and sensors	16 % of electric energy
BMW	Automobile	Compressed air and production line electricity	Visualisation of energy consumption on production line level, clear targets in kW per line are set for the base load during non-production times	Whole production line running at higher load than necessary	Optimised energy consumption during weekends, energy monitoring on production line level	52 % of the electrical base load, 14 % of the compressed air base load have been saved
Innio Jenbacher	Gas engine	Compressed air	Definition of switch-off states for 53 production machines during weekends, energy monitoring, condition monitoring	Machines running at part load during weekends	Machines switched off automatically during weekends, monitoring of electricity and compressed air consumption for each machine	Demand for electric energy and compressed air on weekends was reduced by 30 %
Coca Cola HBC Austria	Beverage	Ventilation systems	Building automation system, VSD, production signal to ventilation system control (full, part load)	Ventilation systems only partly equipped with VSD, running at full load during non-production times	Ventilation systems fully equipped with VSDs running at half load when certain machines are switched off, ventilation system integrated into building automation system	15 % of electric energy
Smurfit Kappa	Kraft paper liner	Various	Simulation-based production planning: data analytics, real-time monitoring	Production planning based on historical data	Simulation-based production planning using real-time data	Energy intensity for paper production (kWh/m^2) could be reduced by 9 % from 2017 to 2023

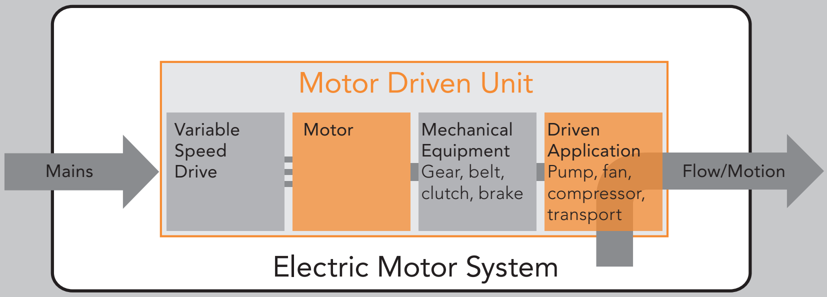
EMDS = Electric Motor Driven System; VSD = Variable Speed Drive
(shaded) cases including hardware upgrades

Table 1: Case studies – profile of companies, digital solution applied, savings.

Yorkshire Water, a water supply and sewerage company in the United Kingdom, has applied electrical signature analysis (ESA) for the condition monitoring of its pumps. The ESA solution has been installed by Samotics. In total, 4'000 stations (assets) are to be monitored 24/7. This project covers a 11.5 million EUR expenditure for hardware and services, spanning a 3-year period (2023–2025). The return on investment is expected to be below 0.5 year. The energy and CO_2 emission savings are expected to be up to 15 %.

The company **PRiOT** in Switzerland applies an IoT sensor to detect clogged air filters in ventilation systems at server sites, allowing a more accurate timing for the exchange of the filter. The main benefits are savings in electric energy, resources and costs, such as the reduction of on-site maintenance needs, quick fault detection and fast intervention, as well as savings in filter material. In a concrete example, 20 % of electric energy could be saved.

Case studies of digitalisation of Electric Motor Driven Systems (EMDS)



Company	Role of digitalisation	Power equipment	Controls: VSD	Controls: Control, sensor, gateway	Motor	Transmission	Application (PFCO)	Piping, other	Heat exchanger, other
Yorkshire Water	P		S	X					
PRiOT	P			X				S	
IKEA	A			X					
Hamilton Bonaduz	A		X	X			X	S	S
BMW	P	S						S	
Innio Jenbacher	A	S						S	
Coca Cola HBC Austria	A		X						S
Smurfit Kappa	P								

EMDS = Electric Motor Driven System; VSD = Variable Speed Drive; PFCO = pump/fan/compressor

(shaded) cases including hardware upgrades

A = active role: digitalisation has a direct influence on the energy consumption of an EMDS

P = passive role: digitalisation is an enabler for identifying savings (delivers information)

X = components added to the EMDS

S = sensor(s) added to the EMDS

Table 2: Case studies – how do measures affect the motor system.

The company **IKEA** in Sweden has done a project to test load shifting principles in cold storages in specific sites financed by The Swedish Innovation Agency Vinnova. The project was led by the company Climacheck and implemented by Caverion. The project resulted in shifting loads to nighttime when electricity prices were lower, and outdoor temperatures were lower, resulting in both lower cost for cooling and better performance of the racks. Applying the load shifting principles reduced load during peak hours with 50 %. Combined with other operational optimisation measures, a 20 % electricity saving could be achieved.

The companies **Hamilton** Bonaduz AG and Hamilton Medical AG producing medical devices as well as laboratory equipment at the facility in Bonaduz in Switzerland, have revamped a compressed air system in collaboration with KAESER. An adaptive air pressure management system in combination with a split solution (a mix of compressors with and without a variable speed drive) was applied. This resulted in an electric energy saving of 16 %.

The **BMW** plant in Steyr, Austria, develops and produces efficient diesel and gasoline engines, as well as novel e-mobility components. The company established a comprehensive data acquisition and monitoring system, covering electricity and compressed air consumption. This includes the visualisation of electric energy consumption on production line level. Also, base load targets in kW were set per line for non-production times. By implementing this kind of baseload-management in 2016 and 2019, to date, 52 % of the original electrical base load and 14 % of the compressed air base load have been saved.

INNIO Jenbacher manufactures gas engines in the facility in Jenbach, Austria. The company critically reviewed energy usage during the weekend and set new thresholds for energy and compressed air demand for the non-operative weekend time. Energy consumption and compressed air is being monitored through a weekly report, the analysis of which enables targeted interventions upon irregularities. As a result, the demand for electrical energy and compressed air of the monitored machines on weekends was reduced by 30 %, achieving an annual saving that corresponds to the energy consumption of approximately 200 households.

Coca-Cola HBC Austria produces beverages in Edelstal, Austria. The company equipped those ventilation systems that were not yet controlled with variable speed drives and reduced the energy demand of the ventilation systems during non-production times. The ventilation systems were integrated into the newly installed building management system. Overall, the energy demand during normal operation was reduced by about 15 %.

Smurfit Kappa, a major producer of kraft paper liner in Sweden, has implemented a simulation-based tool for production planning. Instead of merely relying on historical data and product planners' experience-based gut feeling, the tool provides data-driven decision support for production planning by taking into account real-time data. The effects are higher operational flexibility, lower electricity consumption, a smoother operation of the plant and lower maintenance costs.

Conclusions

During the collection and evaluation of the case studies, we learned the following:

1) **Digitalisation is an enabler to create transparency** in terms of when and how energy is being used. This is a **crucial first step** when it comes to the optimisation of motor systems' operation.
2) The potential **savings vary greatly**. In general, savings depend largely on the following factors:
   a. **Is the information** that is provided through the digital solution **used to implement optimisation measures**? Does this necessitate human intervention and is this intervention being followed through?
   b. **What is the starting point**, i.e. is the motor system already optimised to some level (e.g. use of a VSD)? Typically, higher savings can be achieved if the motor system is not optimised at the outset. In the case studies presented, the highest savings were achieved by simply using as much energy as is really needed [2].
3) **Energy savings are not always the primary driver but rather a side-effect** of the optimisation. Non-energy benefits play a more decisive role (e.g. avoiding downtime, decreasing maintenance cost, increasing production efficiency, extending the lifetime of equipment)[1].

1 A number of other non-energy benefits can be associated with motor system optimisation which are described in more detail in [3].

References

[1]. Kulterer, K., Dawody, J., van Werkhoven, M., Widerström, G., Classification of digitalisation technologies for electric motor driven systems, IEA 4E EMSA, 2022.
[2]. Brunner, C.U., Brechbühl, B., Glauser, H., Nipkow, J., Steinemann, U.: Betrieb ohne Nutzen, Swiss Federal Office of Energy SFOE, 2009
[3]. Werle, R., Brunner, C. U., Klingel, P.: Topmotors Fact Sheet No. 30 – Multiple benefits of energy efficiency in industry, 2019

Yorkshire Water, United Kingdom

Yorkshire Water, a water supply and sewerage company in the United Kingdom, has applied electrical signature analysis (ESA) for the condition monitoring of its pumps. The ESA solution has been installed by Samotics. In total, 4’000 assets are to be monitored 24/7. This project covers a 11.5 million EUR expenditure for hardware and services, spanning a 3-year period (2023–2025). The return on investment is expected to be below 0.5 year. The energy and CO_2 emission savings are expected to be up to 15 %.

Introduction of the company

Yorkshire Water is providing the water supply and sewerage in Yorkshire, United Kingdom. More information: **www.yorkshirewater.com**

Measures implemented

For this project, condition-based monitoring technology applying electrical signature analysis (ESA) is used. Rotating equipment is monitored through sensors in the motor control cabinet, capturing all three phases of the current and the voltage at a high frequency around the clock, see Figure 2.

Artificial intelligence provides real time energy and performance insights for the end user enabling him to eliminate unplanned downtime and energy waste. Mechanical and electrical faults detection are addressed for bearings, couplings, belts, stator and rotor faults, pump cavitation. ESA assesses operational efficiency through additional metrics and identifies efficiency improvements through adjusted control, or replacement of components. The insights are presented online through a special dashboard, and via other routes to facilitate the end user.

The ESA solution has been implemented at the majority of Yorkshire Water’s critical rotating and sewage assets. It has been installed at the 3’000 assets of the sewage section and is up and running. The 1’000 assets of the water section are in the process of being upgraded. In total, 4’000 assets are to be monitored 24/7. The ESA technology solution was provided by Samotics, from the Netherlands (more information: **www.samotics.com**).

More information on the overall project: **https://bit.ly/SYWA**

Competitive/alternative related technologies (for Condition Based Monitoring):

Real time monitoring through industrial sensors mounted on the asset, including related data collection and analysis.

- The sensors deliver vibration, thermal, acoustic or oil-based data, where monitoring can be applied 24/7/365. Sensors are mostly battery powered.
- System components: data collection equipment (sensors), a network communication infrastructure, data storage and analysis software (AI), (client) management information system / client communication dashboard.

Benefits

The following benefits were driving the measures, in order of importance:

1) Improve the reliability/increase the uptime (performance) of the asset base
2) Lower maintenance cost of submersed assets e.g. borehole pumps
3) Eliminate unplanned breakdowns, especially of critical high risk assets
4) Lower the energy use of assets, by eliminating inefficiencies/energy waste e.g. through improved control, bearings, belts, parts and components
5) Practical and critical contribution to the company’s energy efficiency strategy and electricity reduction target of 28 % by 2030.

The company will monitor assets across their sewage network and across the water production facilities and network.

The sewage network contains more than 3'000 pumps, mainly remote, small submersible pumps which are difficult and expensive to monitor with conventional means. ESA enables monitoring whilst bypasses the need to install sensors on, or even near, submerged and hard-to-reach assets. Main benefits are optimising the incidents and preventing damage to pumps, by optimising the maintenance schedule and the energy use.

The water production sites and network includes approximately 1'000 assets (pumps), where special focus is on protecting and optimising the high-risk, large energy-consuming assets with long lead times. Main benefits are improved insights into energy cost and the development and implementation of energy efficiency throughout the company, leading to a lower energy bill and overall operational cost as well as sustained operational resilience.

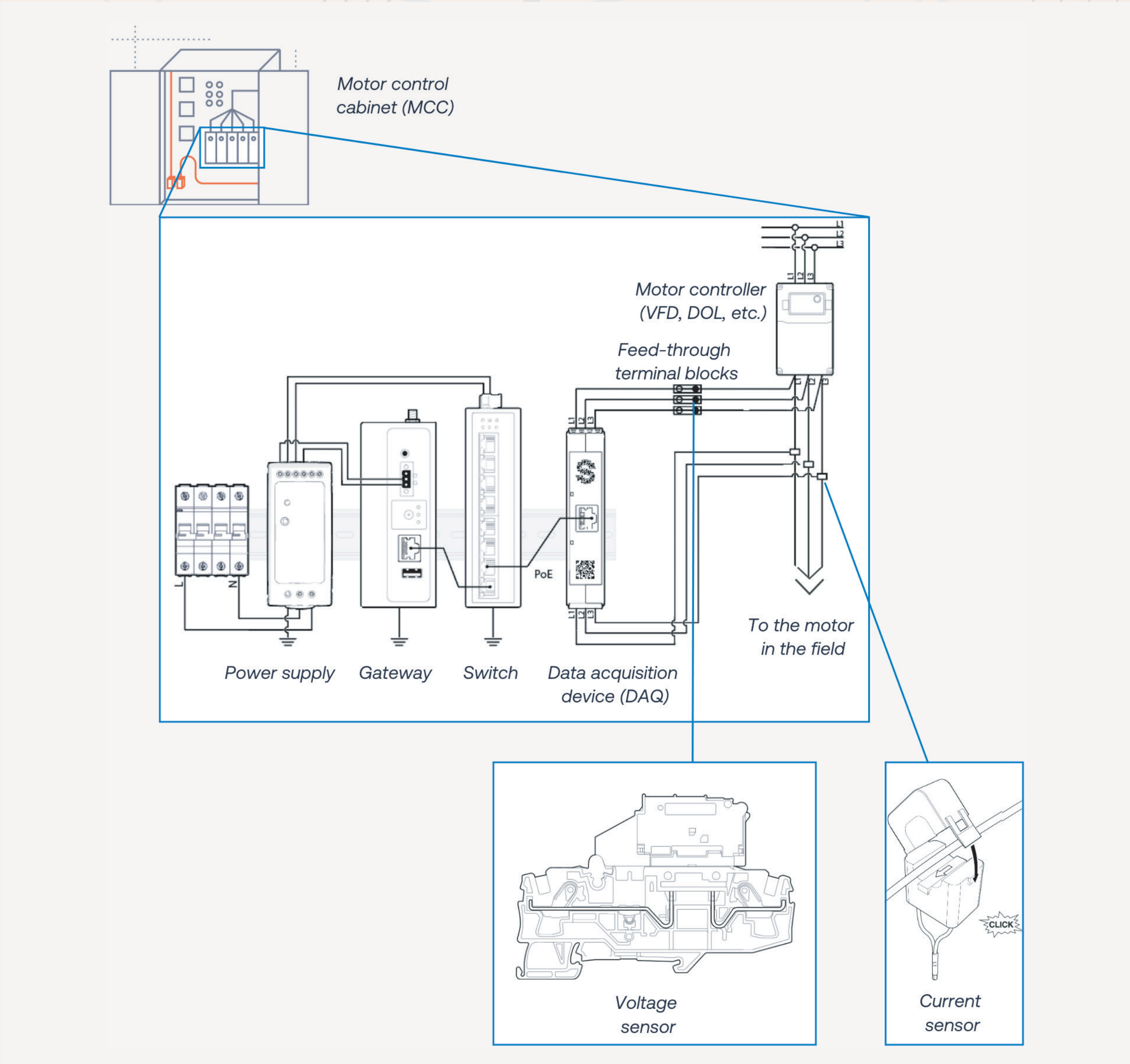


Figure 2: Electrical signature analysis sensors attached to the electrical wires in the motor control cabinet.

Motivation for optimisation measures

The strategic goal is improving the overall network's uptime and lowering the cost of energy. In the water sector, energy is approximately ⅔ of the total cost (2021). With a focus on digital technologies as enablers, the company's management has developed a strategy to implement digital solutions where deemed feasible.

Organisation

In preparing the implementation, the following organisational changes were identified:

1) Connect the ESA solution (i.e. installed sensors) with the company's data infrastructure
2) Align the individual Key Performance Indicators (KPI's) per department – e.g maintenance, energy and operation – with overall shared KPI's for energy use, energy cost, lower operational cost, higher output/performance
3) Develop a training scheme for operators on using the ESA output in their daily work
4) Mandate responsible officers/operators to implement and monitor the solutions, and report the actual improvements (data for the relevant KPIs).

For the above listed organisational changes the responsibilities are with the following departments: asset management (1) (3), digital transformation (1) (3), engineering (1) (3), IT department (1), management (2) (4), and HR (3).

Challenges encountered

The water company has an innovative focus on the enabling role of digital technology and is at the forefront of applying the technology at this scale. The full potential of the technology can only materialise when the different entities within the water company are trained and guided. For accounting, training and communication purposes the development of sound business cases is needed, especially with focus on the energy efficiency potential.

Investment

This project covers a 11.5 million EUR expenditure for hardware (sensors in motor control cabinets) and services (providing real time insights to improve the energy efficiency and resilience of its operation), spanning a 3-year period. This covers approximately 4'000 assets in the sewage and water production networks, from small submersible pumps to the large MW pumps in central pump stations.

The investment cost is 500–1'000 EUR per asset, exclusive installation cost which is covered by the water company.

The cost for monitoring services is around 500–800 EUR per asset per year (depending on factors like asset size, redundancy, type of application). This includes as well services for business case development and internal capacity building.

The return on investment applied by the water company used to be 0.5–1.0 year but has been lifted to 2–3 years (2022). Other potential benefits such as lower maintenance cost have only been used in the calculations where available and if sufficiently solid/sound.

Result

The energy and CO_2 emission savings are expected to be up to 15%. During the coming 3 years (2023–2025) the actual optimisations will be identified and assessed.

Facts

Status before and after the application of the digital technology
The example and data below refer to a comparable application at a Dutch sewage company.

System	Before	After
Motor Fan Transmission Control	5x 300 kW Aeration blowers n.a. Variable speed drive	5x 300 kW Aeration blowers n.a. Variable speed drive ESA (Electrical Signature Analysis)
Operating parameters	Pressure, inflow sewage water	Pressure, inflow sewage water + voltage + current
Operating hours	24/7, appr. 8760 h/a Load factor of at least 1 blower is low	24/7, appr. 8760 h/a
Electric energy consumption	6.0 GWh/a	5.7 GWh/a (i.e. 5% savings)
Cost of electric energy	200 EUR/MWh Total: 1.2 mln EUR	200 EUR/MWh Total: 1.14 mln EUR i.e. 60 kEUR savings

CAPEX
Investment cost: 5’000 EUR
Cost instalment (putting into service): 2’500 EUR

OPEX
Yearly cost (monitoring): 2’500 EUR/year

Payback
0.15 years

Other benefits
Slight decrease in maintenance cost as a result of the (expected) lower wear of the blower system as the on/off-cycle of at least one blower will be reduced considerably.

PRiOT, Switzerland

The company PRiOT in Switzerland applies an IoT sensor to detect clogged air filters in ventilation systems at server sites, allowing a more accurate timing for the exchange of the filter. The main benefits are savings in electric energy, resources and costs, such as the reduction of on-site maintenance needs, quick fault detection and fast intervention, as well as savings in filter material. In a concrete example, 20 % of electric energy could be saved.

Introduction of the company

PRiOT specialises in offering comprehensive IoT solutions, encompassing hardware conceptualisation, data transmission, processing and reporting. The company has been active in the market since 2019 and currently manages a network of over 5'000 connected devices. More information: **https://priot.ch**

The motor system enhanced by the digital solution

The motor systems are dedicated to ventilation within the context of regulating temperature in server sites, introducing air from the outside into the building through filters. In total, there are approximately 2'000 dispersed systems in PRiOT's portfolio equipped with the digital solution, while there are typically not more than six systems in operation at one site. Based on the analysis of the 2'000 systems, a typical motor system has the following characteristics: running on average 25 % of the time (running hours around 2'000 per year), nominal power ranging down to 0.55 kW, average airflow of 2'500 m^3/h. Overall, in Switzerland there are 8'000 ventilation systems within telecommunication infrastructure where the IoT sensor could be deployed, hence the overall potential extends beyond single systems.

Measures implemented

The implemented measures centre around demand-based filter replacement, optimising the efficiency of the system. This strategy is complemented by a comprehensive integration of digital technologies: smart sensors, Internet of Things (IoT), continuous condition monitoring, data analysis, digital twin, and cloud-based services. These technologies ultimately ensure a more precise and proactive approach to filter replacement based on the actual usage.

Benefits

In contrast to manual tests, this solution ensures the timely detection and replacement of clogged air filters, by enabling continuous monitoring through a sensor module, preventing increased energy consumption of the motor system. The technical benefits include an extension of equipment, specifically filter, lifespan by up to 50 % through an adjustment of the filter usage based on actual conditions and usage. Proactive maintenance planning reduces the likelihood of unexpected breakdowns, reducing maintenance trips and minimising emergency repair costs. Fault detection capabilities allow for intervention, minimising downtime and preventing potential equipment damage. Additionally, the digital solution can prevent unnecessary energy consumption.

Technology used for the connectivity

The collected data is wirelessly transmitted from the sensor to the cloud using LoRaWAN technology. LoRaWAN is a low-power, wide-area networking protocol designed for long-range communication between devices and the cloud. It is particularly suitable for IoT (Internet of Things) applications where low energy consumption and long-range communication are essential.

Data analysis

The pressure difference, room temperature and humidity are recorded by the Filter Monitoring Device (PRiOT FiMo). Data is transferred over LoRAWAN to the cloud-based system, where it is linked to the ventilation system, and computations are carried out to assess the filter pollution status. The cloud implementation incorporates the creation of a Digital Twin, replicating the ventilation system using measurement data to generate a virtual representation that mirrors real-world conditions.

Based on collected data, an automated filter maintenance process is put in place. This involves monitoring through the sensor, establishment of a pollution threshold according to the information on the datasheet provided by the filter manufacturer and real-time analysis against that threshold. The system is designed to predict filter replacement timing up to four weeks in advance, based on pressure difference as an indicator of filter pollution.

In instances where the analysis indicates a pollution level surpassing the predetermined threshold, an automated trigger initiates the filter maintenance process and notifications are promptly dispatched accordingly. The system allows for configured notifications via SMS, e-mail, or phone, providing users with flexibility and control through an intuitive dashboard. At the same time, an automated filter order is triggered via a data interface to the filter manufacturer.

Investment

The investment cost for each installation is approximately 1'000 EUR. The payback period, focusing solely on the reduction of maintenance costs, is less than 2 years.

Result

The power drawn by the motor depends linearly on the pressure difference. Experience shows that the power drawn by the motor is increased by approximately a factor of 2.5 when the filter is clogged. This is because the pressure difference increases by this factor from a clean state to a dirty state.

Before applying the IoT sensor, manual maintenance occurred every six months and filters were exchanged when they reached a filter pollution level of approximately 80 %, which typically occurred after 12 months of operation. In the example below, this happened earlier: after 9 months of operation, the filter was already clogged and ready for an

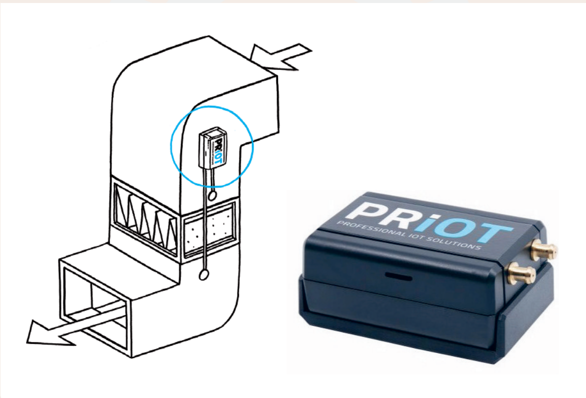


Figure 3: IoT sensor to be installed at the filter system. (Source: www.priot.ch)

Figure 4: Specific installation of the sensor for the filter system. For the pressure difference, pressure is measured within the ventilation system and in the room (ambient air pressure). (Source: www.priot.ch)

«Through the use of the PRiOT Filter Monitoring System in over 1400 installations, we can monitor the correct functioning of ventilation systems and significantly save operational costs through targeted maintenance interventions.»

Martin Hirt Resource Manager HVAC, Swisscom

exchange. Without the IoT sensor, the filter change would have happened only after 12 months of operation, hence the ventilation system would have been in operation with a polluted filter during 3 more months, consuming 6'510 kWh during 12 months. Instead, it could be exchanged after 9 months and thus consumed 5'180 kWh during 12 months. This way, 1'329 kWh (20%) could be saved.

The manual inspection of the filters allowed only a conservative approach. The goal was to avoid filter clogging until the next inspection, i.e. 6 months later. With the IoT sensor, the exact time for the filter exchange can be identified much more accurately. In cases, when the manual exchange would have happened after the filter reached a maximum pollution level, energy can be saved. In cases, when the manual exchange would have happened before the filter reached a maximum pollution level, more energy is being consumed, due to the system being in operation with a polluted filter for a longer period. The available data does not allow statistically relevant conclusions regarding the occurrence of each of these cases. Overall, it can be said, that the IoT sensor allows savings in resources and costs, which was a top priority of PRiOT and their customers.

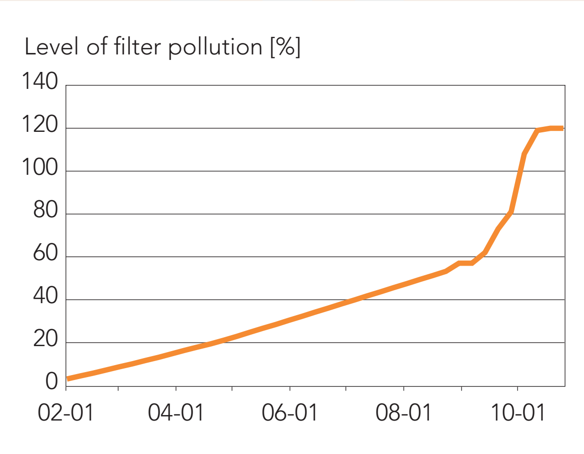


Figure 5: Evolution of filter pollution according to measured data of the IoT Sensor. (Source: PRiOT)

How satisfied is PRiOT with the achieved result?

PRiOT sees the following benefits to be the most relevant resulting from this digital solution (in order of importance):

1) Decrease in the frequency of on-site maintenance. The frequency of the trips could be reduced by a factor of three. Now this occurs every 18 months, before it was every 6 months.
2) Extension of the filter lifetime with an average of 50% from 12 to 18 months. This means savings in filter material.
3) Quick recognition of non-optimal operation, e.g. clogged filters, defect motors.
4) Savings in electric energy and electricity costs, as shown in the concrete example above.

Looking ahead, PRiOT plans to further improve data analytics using AI and Machine Learning tools. In addition, further filter manufacturers and facility management providers are being connected to the PRiOT system.

IKEA, Sweden

The company IKEA in Sweden has done a project to test load shifting principles in cold storages in specific sites financed by The Swedish Innovation Agency Vinnova. The project was led by the company Climacheck and implemented by Caverion. The project resulted in shifting loads to nighttime when electricity prices were lower, and outdoor temperatures were lower, resulting in both lower cost for cooling and better performance of the racks. Applying the load shifting principles reduced load during peak hours with 50 %. Combined with other operational optimisation measures, a 20 % electricity saving could be achieved.

Introduction of the company

IKEA is the world's largest furniture merchandiser, with stores all over the world. IKEA started in 1943 by Ingvar Kamprad and is currently legally headquartered in the Netherlands. IKEA has been the world's largest furniture retailer since 2008. In the stores, customers have access to restaurants where customers can have breakfast or lunch. There is also the possibility to buy food. Both restaurants and food shops require refrigeration to store refrigerated of cooled goods.

Globally, in 2018 the 400 restaurants had a total of 650 million guests with a turnover of 2 billion Euros. More information: **www.ikea.com**

The motor system enhanced by the digital solution

This case study describes measures undertaken in the IKEA store in Uppsala, Sweden. The store includes a restaurant and a cafeteria at the entrance. Adjacent to both operations, there are refrigeration and freezer rooms as well as display cabinets. There are also refrigeration and freezer room storage facilities in the basement. The central refrigeration system, which is a two-stage carbon dioxide system[1], serves all these refrigeration and freezer units. It is centrally controlled with Huurre «itop» control system and has ClimaCheck online performance monitoring installed. There are borehole storage and heat pumps for heating the building. Condenser heat is primarily recovered or cooled off in the borehole storage, resulting in a more consistent temperature on the warm side of the refrigeration system compared to dissipating condenser heat outdoors. These systems have additional control systems that have not been accessible and therefore are not included in this study.

The motor system affected in this case study relates mainly to the rack compressors in the system. Several compressors are frequency controlled; it is however generally common that compressors are operated in on-off mode.

Measures implemented

Two tests were carried out:

- Test 1: Lowered setpoints at night in selected rooms and counters.
- Test 2: Lowered setpoints at night in selected rooms and counters, as well as limited compressor power during the morning.

Figure 6: IKEA Uppsala. (Photo: Sven-Olof Ahlgren/ UNT arkiv)

1 See e.g. www.tandfonline.com/doi/full/10.1080/15435075.2023.2174378

It should be noted that an analysis of the type of goods was made before the tests, since some goods are more sensitive to varying temperatures (flowers, fresh vegetables, pastry) reducing the range of acceptable changes. The food was not affected by the test.
The results of Test 1, as shown in Figure 7 and Figure 8 below, demonstrated a very effective power distribution throughout the day, reducing power consumption during daytime. It also led to a decrease in electricity usage compared to before the test. The results of Test 2, Figure 8, showed an even greater reduction in power demand during the morning. However, both in the afternoon and at night, the power requirements were higher than in Test 1.
In test 2, the cold storages were cooled some degrees more than the normal setpoint during night, when the price is lower due to lower grid load. The compressors were also load limited during critical hours. The tests demonstrate that it is possible to even out power consumption throughout the day by superimposing cooling during the low-load period of the night and then utilising the stored cooling during the morning, resulting in a significant reduction in power demand.

The assessment of the facility before the tests also revealed that significant savings can be achieved through the correction of errors and deficiencies, as well as the optimisation of operations. This requires expertise. In most facilities, this aspect is often overlooked, as desired temperatures are achieved even if the system is not operating efficiently. The tests also revealed the need not only to develop smarter control systems for shifting power but also that the control systems used in current store systems are very challenging to adjust to provide optimal operating conditions. Manufacturers of control units have not adapted these systems to real-world conditions with the dynamics present in the facilities. There is a lack of opportunities to tailor the control to the inertia that a facility possesses, resulting in common operational issues in most facilities where compressors start and stop at short intervals.

Motivation for optimisation measures

The motivation for the company to implement more advanced control was first to reduce capacity at peak hours, but also to reduce energy consumption.

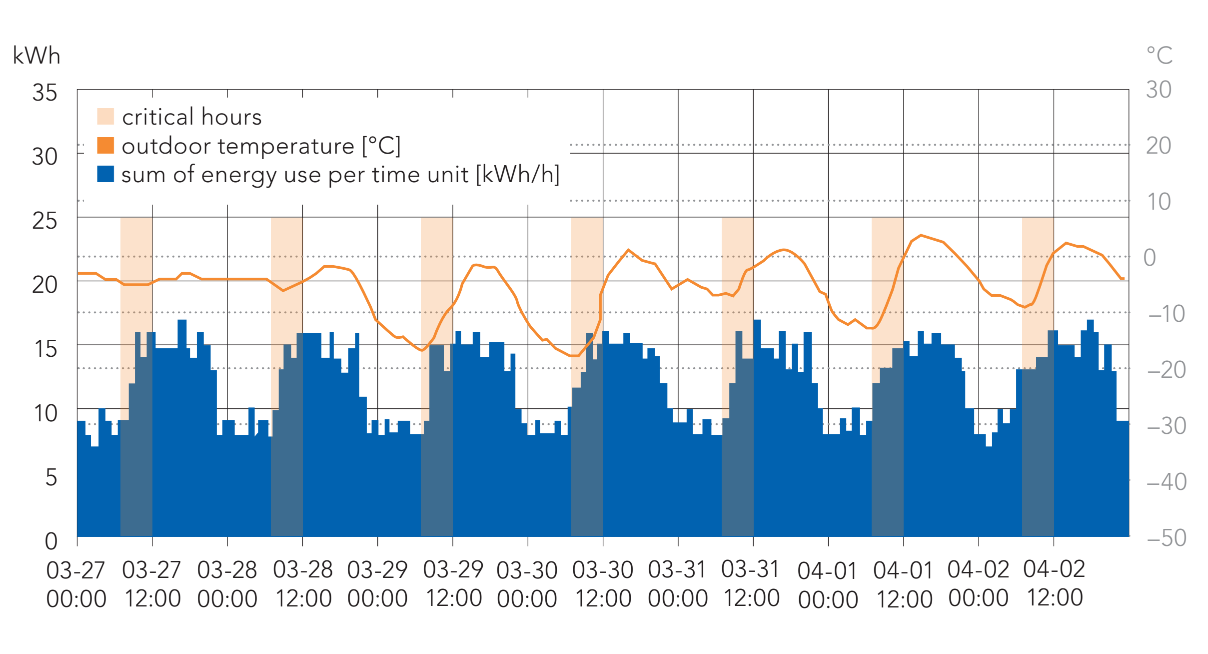


Figure 7: Baseline energy profile. The light orange boxes represent the time periods with critical hours.

Benefit

This case demonstrates advanced control combined with online performance monitoring. Based on the analysis of monitored values, the set point values could be adjusted to shift loads and set boundaries on the compressor's capacities to maximise performance as well as adapting to varying prices and requirements to reduce peak loads during critical periods.

By adjusting control parameters, the number of compressor starts could be reduced significantly, but solving the problem requires the development of more robust control algorithms that consider the time delays and inertia inherent in all control systems. This leads to significantly reduced wear and increased efficiency.

Result

The tests showed that it is possible to shift loads from daytime to nighttime, resulting in lower loads on the grid. The operation also showed lowered energy consumption of up to 20 %.

The main benefits of the implemented measures are reduced loads at grid, lower energy consumption, use of energy at hours when electricity prices are expected to be lower and better understanding of the dynamics of cold storage operation.

By operating the system more in the nighttime, better operating conditions can be achieved since the outdoor air is cooler too at night.

The increased knowledge of the dynamics of the cold storage also resulted in new operation schemes of the compressors, resulting in better start-stop operation (fewer ones).

How satisfied is IKEA with the achieved result? The company IKEA is satisfied with the results and they have the potential to implement the solution to all existing sites with similar equipment.

Credentials

The project was implemented by Huurre Caverion, the cloud based digital solution for performance and energy analytics was provided by Climacheck, the analysis was made by RISE.

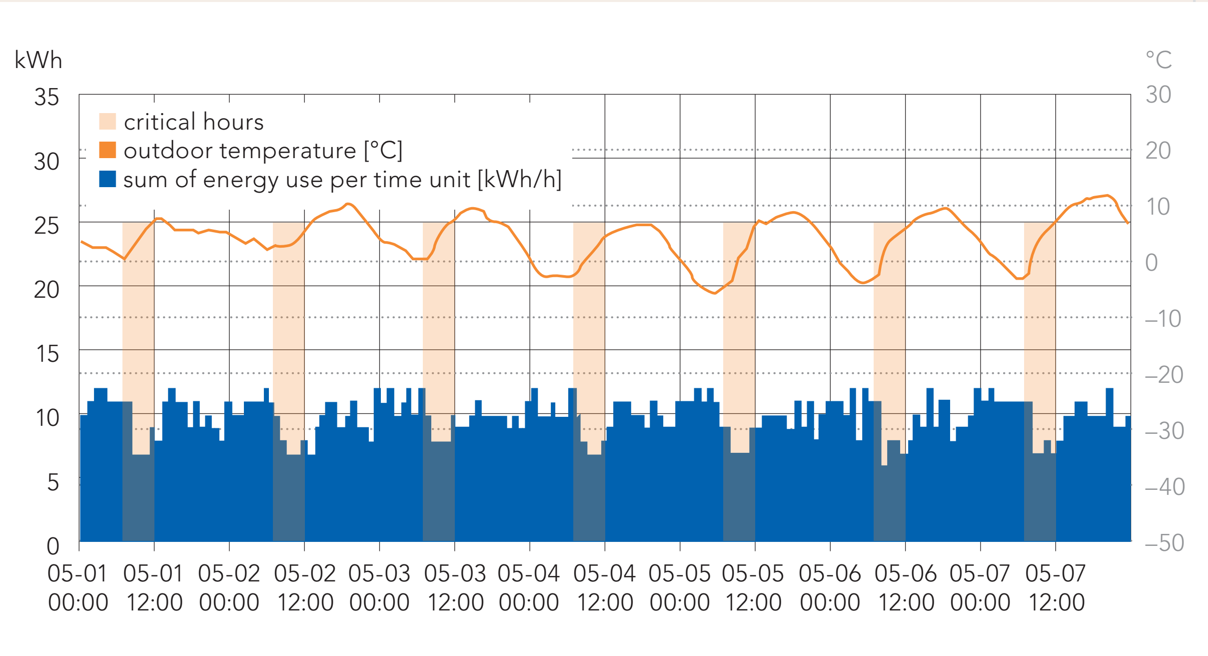


Figure 8: Energy profile after application of test 2.

Hamilton Bonaduz, Switzerland

The companies Hamilton Bonaduz AG and Hamilton Medical AG producing medical devices as well as laboratory equipment at the facility in Bonaduz in Switzerland, have revamped a compressed air system in collaboration with KAESER. An adaptive air pressure management system in combination with a split solution (a mix of compressors with and without a variable speed drive) was applied. This resulted in an electric energy saving of 16 %, assuming the same amount of air volume produced.

Introduction of the company

Hamilton Bonaduz AG is active on the market since 1966. It belongs to the Hamilton company which is specialised in the development, manufacturing and customisation of precision measurement devices, automated liquid handling workstations and sample management systems. The subsidiary in Bonaduz is producing medical equipment, in particular automated liquid handlers used for around 60% of the worldwide Covid tests. More information: **www.hamiltoncompany.com**

The motor system enhanced by the digital solution

Within the production facility of Hamilton in Bonaduz, compressed air is used to operate the production machinery at a constant air pressure of 7.5 bar. For this purpose, a compressed air system with five screw compressors is operated (one is to be operated only in case of emergency).

Two compressors are in operation since 2007 and 2008, three compressors were put into operation in 2018, 2020 and 2021 respectively. Two of the five compressors have motors equipped with a variable speed drive (VSD).

The compressed air generated by the screw compressors is used to operate machines producing parts of the liquid handlers, medical ventilators and allowing the assembly of the devices.

The compressed air system delivers 7.5 bar to the production line with an average air volume of 12.5 m³/min. The system operates 24 hours per day, whereas the different compressors operate at different operating hours, depending on the process needs (e.g. one compressor supplies the base load and operates constantly while the other compressors

Figure 9: New compressed air system with compressed air management system. (Photo: Pascal Kienast)

have less operating hours, depending on the production needs).

As the production operates 24 hours a day, the compressed air system operates all the time to achieve a constant air pressure. Night shifts are unmanned, autonomous production machines produce parts of the liquid handlers which are then used within the assembly line during the day.

Measures implemented

Over the period of two years between 2019 and 2021, two important measures were adopted:

1) A central adaptive monitor and control called Sigma Air Manager 4.0 (SAM4.0) of the supplier KAESER was installed, allowing to achieve the largest possible energy saving of the current compressed air system. On the control side, the SAM4.0 air pressure management system comprises a communication over ethernet cables to the refrigeration dryers and compressors. On the measurement and monitoring side, flex cables connect the filter system, pressure sensor, pressure dew point sensor and drainage system with the control system. The air pressure management system is connected to the internal Hamilton network, currently providing the possibility for company-wide remote monitoring.

2) Three compressors were retrofitted and a split solution put in place. The following three new compressors are now part of the system:

- two compressors equipped with a VFD (37 kW each)
- one new compressor without VFD (37 kW)

The split solution (a mix between air compressors with and without VFD) was chosen to achieve optimal overall efficiency and flexibility: the compressed air baseload is produced through compressors without VFD and the remaining variable compressed air is produced with compressors with a VFD.

Benefits

To summarise the benefits, first, the air pressure control helps to run the system at 0.5 bar lower total pressure (from 8 bar down to 7.5 bar), as the control system allows to deliver with higher precision compressed air to the production. Second, the chosen adaptive control allows a flexible expansion of the system: when a compressor is retrofitted, the digital twin of the compressor system needs to be updated and the control system is locally newly configured. The control observes the compressed air system and adapts to the optimal and most efficient operating points. Third, the adaptive control allows a dynamic control over the life cycle of the compressors

Figure 10: The newly installed compressed air management system, SIGMA 4.0. (Photo: Pascal Kienast)

and automatically adapts to the operational needs and any adaptations in the production process (e.g. increase or decrease of compressed air needs) without manual intervention by the operator or the manufacturer itself.

The following improvements were achieved with the digital solution in the compressed air system:

- much more constant pressure at the receivers,
- being able to run the compressed air system at the lowest possible total pressure level,
- the air pressure system automatically adapts to changes in the production line,
- overall, less electricity consumption.

Motivation for optimisation measures

The setup of the previous compressed air system could not adjust to the requirements of the production process. KAESER was a supplier at a different Hamilton site already, hence it was among the candidates to start the optimisation of the compressed air system in Bonaduz. In 2017, Hamilton decided to check with numerous compressed air producers about retrofit options and the proposal of KAESER was the most convincing in economic and technical terms. The exchange of a first compressor was paid back through the energy savings and the new compressed air system was put into service without problems providing the promised reliability.

Applied technology and functionalities

Two particularities of the KAESER solution in the Hamilton Bonaduz project need to be highlighted:

1) The compressed air management system SAM4.0 can control compressors of competitor brands as well, allowing to revamp existing compressed air systems with an adaptive control solution brand-independently.

2) After the production phase, the compressors are being tested on operational readiness in the lab simulating the customer's facilities in a digital twin format. The simulation starts already with the design of the compressors at KAESER's premises and ends with the production and putting into service of the compressors at the end-user. As a result, once the testing of the produced unit is completed and the compressor is delivered, only minor controlling adaption needs to be performed by the commissioning engineer on-site. Once put into operation, the compressor system detects the optimal operating points according to pressure and air volume. Furthermore, thanks to the digital twin there is a virtual ver-

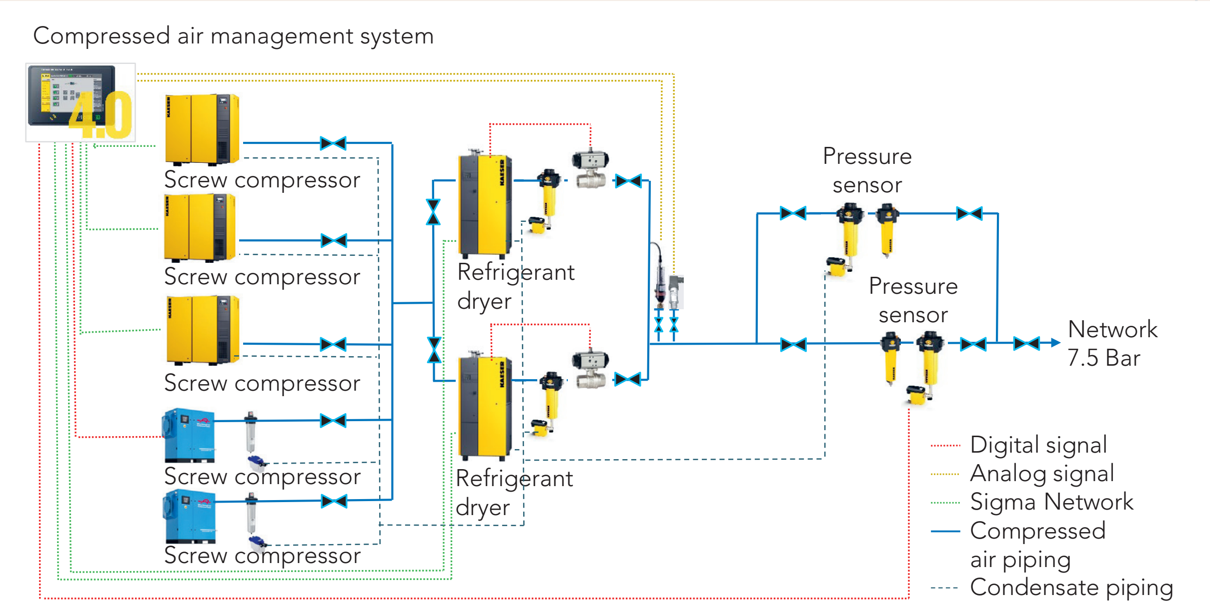


Figure 11: Simplified schematic.

sion of the compressor system in KAESER's offices, allowing remote support as well as further product support for Hamilton.
In the end, the digital twin and the adaptive compressed air management system support both the end-user and the compressed air supplier during the entire life cycle of the system.

Technology used for the connectivity

In the project an ethernet solution for immediate connectivity between the new compressor unit, the refrigeration dryer and the SAM4.0 control unit has been chosen, the older compressor unit is still controlled over dry contacts. The control system is connected over ethernet to the internal company-wide network and has the possibility to be connected to the worldwide web replicating hourly the data on a KAESER server.

The control unit is able as well to communicate over Modbus TCP, ethernet IP, ProfiNet, ProfiBus, Modbus RTU and OPC UA. Where needed dry contact is used.

Data analysis

The data is analysed locally, a controlling algorithm operates on the local SAM4.0 infrastructure. SAM4.0 controls directly and automatically each compressor with the goal to increase the overall system-wide efficiency. It automatically coordinates and optimises the balance between air pressure need and compressed air produced.
Currently, the collected data supports the operation of the air pressure system, nevertheless it is intended to support condition monitoring and predictive maintenance as well.

Investment

Specifically, for the SAM4.0 control unit the investment cost was close to 10'000 EUR. The cost for the three revamped compressor units was around 80'000 EUR. To put the compressor system into operation, further installation and piping cost of around 10'000 EUR was needed.
For the SAM4.0 the payback was 2.2 years, whereas for the entire revamped compressor unit system the payback was 8.85 years.
For the exchange of compressor 2 it was possible to benefit from a Swiss subsidy programme called Effizienz+ (by EnAW).

«The high energy efficiency, the compressed air system at Industry 4.0 level, as well as the expert guidance convinced me to choose the KAESER control system.»

Achim Sax, Director Facilities Hamilton Services AG

Result

The overall efficiency gain can be expressed as follow: the system is currently producing one m^3 air with 106 Wh electric energy, whereas before the retrofit the system needed 126 Wh for one m^3 of air. In fact, Hamilton decided to install compressors with a higher capacity than before in order to expand the production. However, assuming that the compressed air system would have produced the same amount of compressed air as before the retrofit, overall, it would have saved 16% in electric energy. From these savings:

- one part is achieved by running the compressed air system at the lowest possible total system pressure (5%),
- one part is thanks to the SAM 4.0 and the optimised control of the compressor system (6%),
- and the rest due to the revamping of the compressor units (5%).

Quantifying the exact share of the savings attributable solely to the digital solution proves challenging. On the one hand, 6% is derived from the optimised control of the compressor system facilitated by the intelligent control. On the other hand, some part of the savings resulting from reduced system pressure (5%) can also be linked to intelligent control.

«We are proud of the successful optimisation of our compressed air system, a crucial medium for our operations. By improving the control system, we increased its reliability and achieved a higher level of efficiency in our industrial plant. This has delivered a significant return on investment, enhancing our overall operational performance.»
Gianina Viglino-Caviezel, President and CFO Hamilton Services AG

How satisfied is Hamilton with the achieved result?

Initially, there were few controls in the overall compressed air system and the system was not optimally designed for the air pressure needs. Through a monitoring and control of the compressed air system, as well as through the use of VFDs, the air pressure production was improved stepwise, to be resilient and automatically adapt to changing production needs. Hamilton expects to further optimise their maintenance and receive further proactive support by KAESER regarding condition monitoring and predictive maintenance. Hamilton appreciated how the supplier advised and accompanied them throughout the whole process of optimising the compressed air system. Ensuring quality and security of compressed air supply is of high priority to Hamilton which could be met. Overall, Hamilton is highly satisfied with the results.

Facts

Before optimisation	After SAM and 3 new compressors, 2 with VFD
Compressor system	
4 screw compressors: • Worthington RLR 60 V7 T (built in 2010, rated power: 45 kW) • Worthington RLR 40 B (built in 2010, rated power: 30 kW) • Worthington RLR 20 B (built in 2008, rated power: 15 kW) • Worthington RLR 20 B (built in 2007, rated power: 15 kW)	SAM4.0 control system, 4 screw compressors: • KAESER BSD 75 SFC (built in 2018, rated power: 47.6 kW) • KAESER BSD 75 SFC (built in 2020, rated power: 47.6 kW) • KAESER BSD 75 (built in 2021, rated power: 43.2 kW) • Worthington RLR 20 B (built in: 2008, rated power: 15 kW) • Emergency unit: Worthington RLR 20 B (built in 2007, rated power: 15 kW)
Digital technology applied	
–	Intelligent control, real-time monitoring and digital twin
Air volume produced	
3’874’262 m³	5’117’319 m³ *)
Operating hours	
ca. 8’736 h/a	8’396 h/a
Electric energy consumption	
487’654 kWh/a	544’156 kWh/a *)
Energy per m³ compressed air	
126 Wh/m³	106 Wh/m³ *)
Specific power	
7.55 kW/(m³*min)	6.38 kW/(m³*min)
Cost of electric energy	
58’518.44 EUR (@0.12 EUR/kWh)	81’623 EUR (@0.15 EUR/kWh)
At produced air volume of 3’874’262 m³ and 0.15 EUR/kWh: • Theoretical energy savings per year: 16 % • Total investment cost (including SAM 4.0 and compressor retrofits): 100’000 EUR • Theoretical payback of 9 years *) The increase in air volume produced and energy consumption are due to an expansion of the production. At the same time, the specific energy consumption is lower, making the system overall more efficient.	

BMW, Austria

The BMW Group Plant in Steyr, Austria, develops and produces efficient diesel and gasoline engines, as well as novel e-mobility components. The company established a comprehensive data acquisition and monitoring system, covering electricity and compressed air consumption. This includes the visualization of electric energy consumption on production line level. Also, base load targets in kW were set per line for non-production times. By implementing this kind of baseload-management in 2016 and 2019, respectively, 52 % of the original electrical base load and 14 % of the compressed air base load have been saved.

Introduction of the company

At the BMW Group plant in Steyr, Austria, around 4,500 people develop and produce the mobility of the future every day with passion and innovative strength – from efficient diesel and gasoline engines to novel e-mobility components such as housings for the latest generation of electric drives. More than 1 million engines and 11.1 million core components – including connecting rods, cylinder heads, cylinder housings and crankshafts – leave the Steyr Plant every year. More information: **www.bmwgroup-werke.com/steyr**
In the so-called InnoLab, the ideas of the future in the area of digitalization are tested and tried out. These include human-robot collaborations and data gloves to support employees in production and logistics activities. Employees can carry out the safety status check of equipment completely paperless on site using an app on a mobile device. Thus, processes in this technological field can not only be made more time-efficient, but also more sustainable.

Measures implemented

A comprehensive energy data acquisition system has been established in production itself. It covers different levels, from the plant energy supply to small consumers in individual machines like machine tools, processing machines, component washing machines and measuring machines. At present, various consumptions, like the electricity or compressed air consumption of individual production lines

Figure 12: The BMW Group plant in Steyr, Austria.

are already recorded and monitored centrally and also visualised directly on site.
Currently, the electrical power consumption of various consumers per line is recorded in order to be able to calculate the energy consumption per piece or shift produced. In addition, the degree of machine utilisation is shown in the form of efficiency classes A–F.
Cooling water, cold water, cooling lubricants and heat will also be integrated into the further data acquisition. This will be realised by means of a multi-channel measuring device. For some manufacturing lines, measurements for every energy carrier consumed are already available.
Clear targets in kW per line are set for the base load during non-production times. The respective control centres are responsible for achieving the set base load target values after the end of production of the last shift before weekends. Figure 13 shows the monitoring method.

Benefit

A weekly evaluation of these weekend shutdowns reveals irregularities. A fully automated report is sent to the responsible departments every Monday to ensure overruns in energy consumptions on weekends are recognised and avoided in future.

Result

By implementing this kind of baseload-management in 2016 and 2019, respectively, 52% of the original electrical base load and 14% of the compressed air base load have been saved in mechanical production.

Value

The additional energy consumption required for data acquisition, as well as for computing power and on-site mapping is negligible, as many of these measures are also integrated into further data acquisition and evaluation processes, such as for quality assurance, process control and plant management.
This process is supported by comprehensive accompanying measures, including target definition and measure derivation, cross-plant learning processes to identify best practices, forecasting and benchmarking. Furthermore, the plant implements energy efficiency projects with savings in GWh ranges every year. This fact supports the BMW Group's efficiency approach which is well established throughout the company.

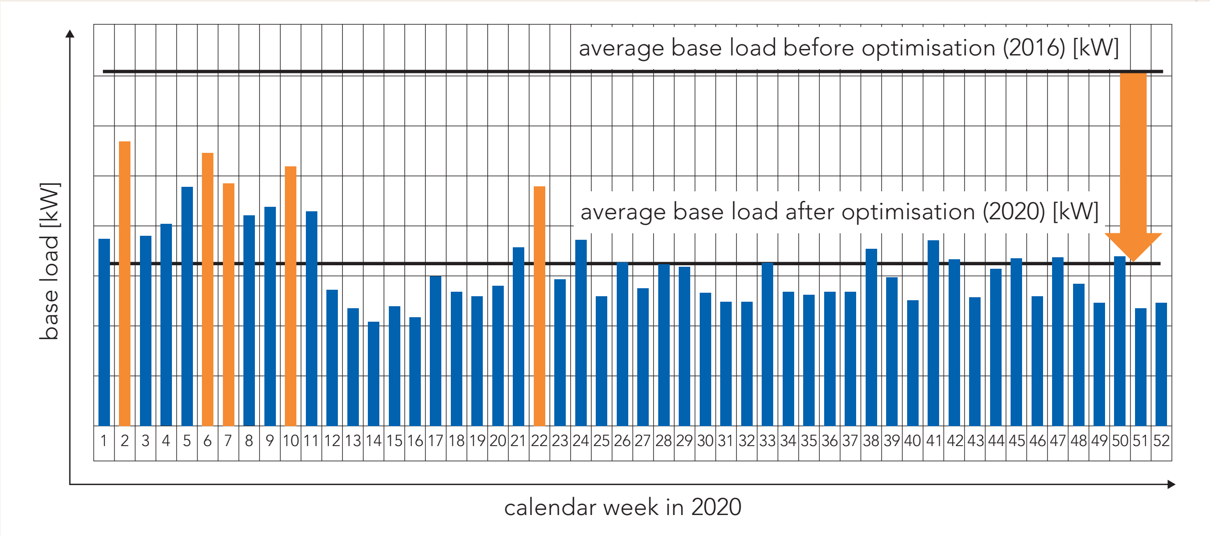


Figure 13: Illustration of the base load values of the crankshaft lines per calendar week in 2020. Orange bars represent the exceedances of the base load target values on the respective weekend.

INNIO Jenbacher, Austria

INNIO Group manufactures Jenbacher energy solutions at the advanced manufacturing site in Jenbach, Austria. The company critically reviewed energy usage during the weekend and set new thresholds for energy and compressed air demand for the non-operative weekend time. Energy consumption and compressed air is being monitored through a weekly report, the analysis of which enables targeted interventions upon irregularities. As a result of these measures, the demand for electrical energy and compressed air on weekends was reduced by around 30 %, achieving an annual saving that corresponds to the energy consumption of approximately 200 households.

Introduction of the company

INNIO Group is driven by a strong commitment to sustainable energy solutions and innovation in manufacturing. INNIO Group's Jenbacher product portfolio includes high efficient engines in the power range from 250 kW to 10.6 MW, which are used worldwide in various industries. To date, more than 26'000 engines have been delivered worldwide, providing an output of approximately 38 GW of electrical energy (klimaaktiv, 2022). More information: **www.innio.com/en**

Motivation for optimisation measures

INNIO Group's motivation for this project was born out of a desire to further reduce the environmental footprint of its operations, increase efficiency and foster a culture of sustainability. This commitment is evident in INNIO Group's adaption of Industry 4.0, which includes onsite 3D printing of parts and a comprehensive energy management system. The latter employs artificial intelligence to offer suggestions for enhancing economic efficiency by specifying energy management parameters and augmenting the transparency of the production site in Jenbach.

Measures implemented

A testament to INNIO Group's innovative and sustainability-focused approach is the project «energy shutdown over the weekend». The project arose from a detailed review of energy usage within the facility and the understanding that even seemingly minor modifi-

Figure 14: Production machines. (Source: INNIO Jenbacher)

cations can lead to significant efficiency gains and cost savings.
Over several weeks a pilot area consisting of around 55 production machines was evaluated to identify which machines remained switched on during the weekend after the shift ended. INNIO Group organized a series of workshops and brainstorming sessions with its operating and maintenance staff, fostering a collaborative atmosphere where every idea was considered valuable. The staff was encouraged to provide inputs, highlight potential issues and suggest practical solutions. Subsequently, the team defined precise switch-off states and implemented technical measures on the machines.

Benefit

The company now generates a weekly report showing the measured electrical energy and compressed air demand, along with the associated CO_2 generation over the non-operating weekend time. This shows at a glance whether the defined threshold of energy demand for compressed air and electricity has been reached. The benefits of this approach extend beyond energy savings, including better equipment life cycle management and preventive maintenance planning, contributing to the overall reliability and cost-efficiency of INNIO Group's operations.

Data analysis

INNIO Group acts upon this data through a robust decision-making process. The data is analysed and evaluated by experienced employees, who identify top consumers and outliers among similar production machines. This results in immediate identification of inefficiencies and targeted intervention.

«The combination of measurement data, visualisation, evaluation by experienced employees and anticipatory measures enables us to operate the production machines economically and avert events at an early stage.»
Rudolf Raunig, head of infrastructure at INNIO in Jenbach

Result

As a result of these measures, the demand for electrical energy and compressed air on weekends was reduced by around 30%, achieving an annual saving that corresponds to the energy consumption of approximately 200 households (basis for calculation: oesterreichsenergie.at).
Furthermore, the energy measurement system allows for better condition monitoring, revealing incidents like the disconnection of a compressed air hose from a spindle unit and built-in air chokes being blown out.
Such findings resulted in immediate action to stop the compressed air loss, which corresponded to a third of the full-load compressed air demand. In another case, two different air leaks were detected. One of them increased the baseline consumption while another leakage increased the peak consumption.

Value

INNIO Group further builds on these successful initiatives with other measures to reinforce its sustainability and efficiency objectives. The focus remains on technology-enabled, data-driven operations management to continue reducing INNIO Group's environmental footprint.

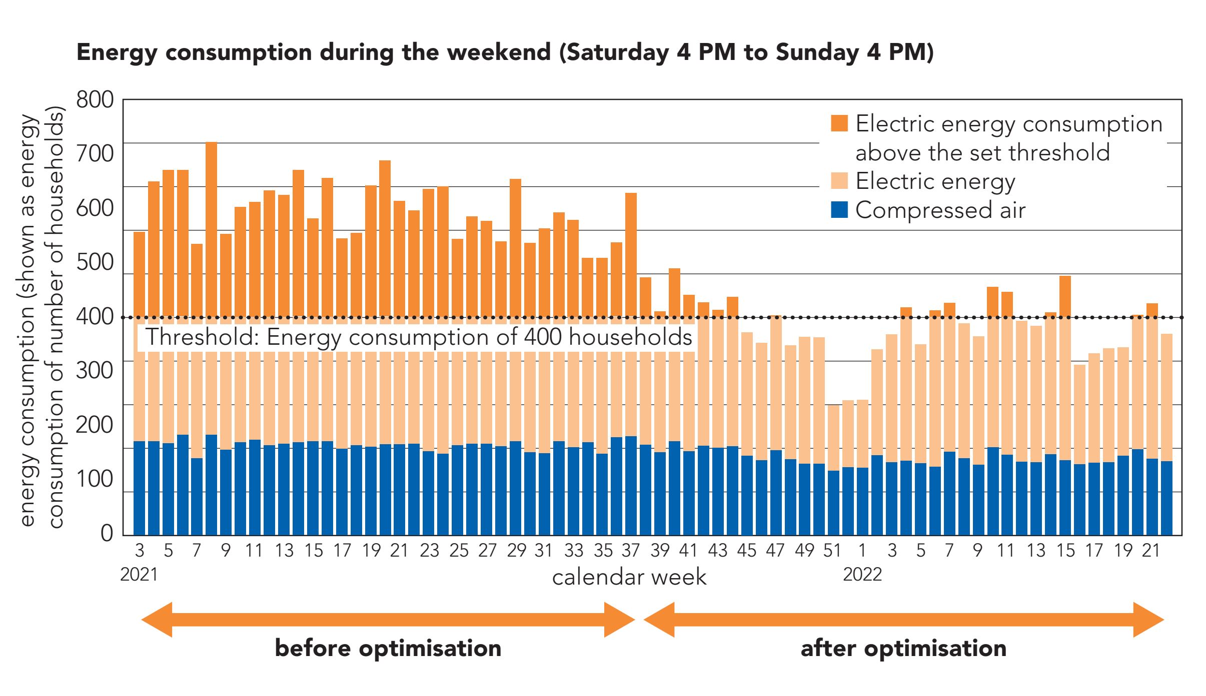


Figure 15: Electricity (light and dark orange) and compressed air (blue) consumption on weekends before and after project (shown as energy consumption of number of households). The dotted line shows the defined threshold. (Source: INNIO Jenbacher)

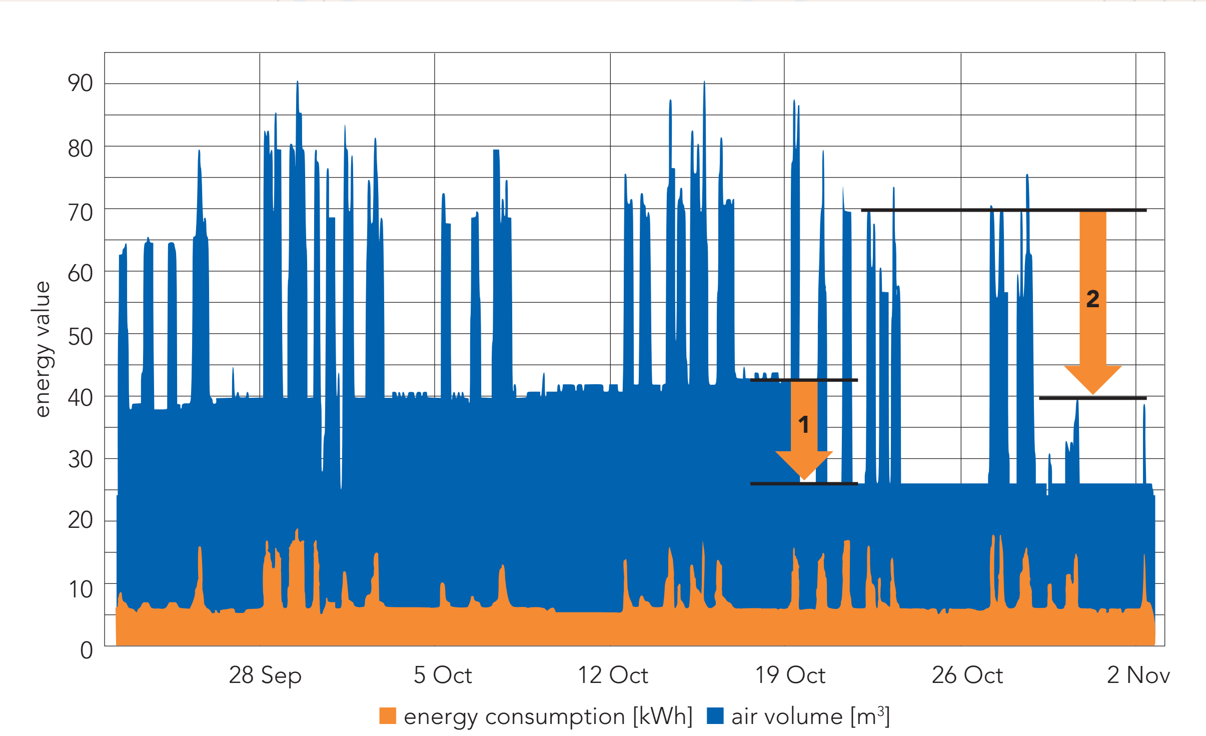


Figure 16: Extract from the operating status report to indicate the required air volume before and after an event on a machine. (Source: INNIO Jenbacher)
Marker 1 Remedy of the first event: the baseline consumption has been significantly reduced.
Marker 2 Remedy of the second event: peak consumption has been significantly reduced.

Coca-Cola HBC, Austria

Coca-Cola HBC Austria produces beverages in Edelstal, Austria. The company equipped those ventilation systems that were not yet controlled with variable speed drives and reduced the energy demand of the ventilation systems during non-production times. The ventilation systems were integrated into the newly installed building management system. Overall, the energy demand during normal operation was reduced by about 15 %.

Introduction of the company

Coca-Cola HBC Austria is one of the largest companies in Austria in the non-alcoholic beverages segment and a licensed bottler for The Coca-Cola Company. The majority of the beverages sold by Coca-Cola HBC Austria are produced locally, at the production and logistics centre in Edelstal, Burgenland. The company employs around 800 people in Austria – in the production and logistics centre and in regional sales centres and distribution warehouses. Sustainability has a high priority in the company and is seen as an essential part of the corporate strategy. More information: https://at.coca-colahellenic.com/en

Measures implemented

In the project to reduce the energy demand during non-production times, the significant energy demand of the ventilation systems during these times was recognised.

The largest 18 ventilation systems in the plant consume about 10 % of the total electricity demand (about 3 GWh before optimisation). Seven of these ventilation systems, in the electrical power range between 9.5 kW and 28 kW (total installed power 155 kW) with an air volume flow of 23'000 m^3/h to 43'000 m^3/h, supply fresh air to halls with production lines, storage rooms and water treatment plants. However, these were previously not controllable according to demand and did not have a variable speed drive (VSD) installed. Seven other of these systems (including 80'000 m^3/h systems with installed capacities of 60 kW supply air, 30 kW extract air per system) already had a VSD installed, but were mostly running at 50 Hz (so full load).

Even on non-production days, ventilation systems were running in full operation or at full load to secure the air exchange necessary for quality reasons on production days. This had led to an increased air exchange and thus to a higher electricity demand.

First, those systems that were not yet controlled via VSDs were equipped with these drives to enable a demand-based air exchange rate.

Then the critical production machines (bottling plants) were defined, during whose operation the ventilation systems must in any case deliver the full air volume flow. In the event that these machines are switched off, a hygienic minimum volume flow (of mostly 50 %) was defined. In the course of this, the minimum air exchange rate was checked and the systems were also readjusted for the full load case.

Figure 17: Ventilation system at Coca-Cola HBC Austria.

For these volume flows (measured by mobile measuring devices in the air duct), the resulting pressure was determined for each ventilation system and this value was used as target value for the control. The on/off status of the production machines now triggers the corresponding control of the ventilation (either half and full volume flow or the determined target pressure). For this purpose, the signal from the production machine is transmitted directly to the control system. The ventilation controller controls the frequency converters of the main fan-motors, pumps and valves for heating and cooling coils based on parameters measured by pressure and temperature sensors. Partly, new controllers had to be installed, as the older ones could not be connected to the newly installed building management system (BMS). For communication between components and automation systems BACnet, Ethernet and/or OPC-UA protocols are used.

A building management system (BMS) was also installed for energy-efficient use. This reduces the air volumes on non-production days to a necessary minimum through the stored setting of the required target pressures in combination with the control system. Examples of data from the ventilation controller visualised centrally in the user interface of the BMS are the load factor of the fan (as percentage based on frequency of the frequency converter), the current pressure increase by the fans in the extract and supply air lines, the position of dampers and the opening status of the mixing valves for heating and cooling coils, and temperatures in the supply and extract air lines. Furthermore, error messages are displayed centrally in the system and their elimination can be tracked centrally.

In addition, the project introduced the control of the recirculation dampers depending on the outside temperature in order to temper the hall via outside air. Only when this is no longer possible are the heating and cooling registers switched on. This measure will also lead to a reduction in heating and cooling requirements.

Result

All ventilation systems are integrated into the energy monitoring system via the electrical distribution cabinets. This shows that the energy demand during normal operation was reduced by about 15%.

The payback time of this project was less than 3 years.

Smurfit Kappa, Sweden

Smurfit Kappa, a major producer of kraft paper liner in Sweden, has implemented a simulation-based tool for production planning. Instead of merely relying on historical data and product planners' experience-based gut feeling, the tool provides data-driven decision support for production planning by taking into account real-time data. The effects are higher operational flexibility, lower electricity consumption, a smoother operation of the plant and lower maintenance costs.

Introduction of the company

Smurfit Kappa is a major producer of kraft paper liner in Sweden, a product used for corrugated fibreboard. Smurfit Kappa plant in Piteå, Sweden was commissioned in 1962 and modernised several times. The maximum production capacity is around 700'000 tons of final product per year. More information: **www.smurfitkappa.com**

The motor system enhanced by the digital solution

Electric motors are being used at multiple places in the production process. The production line is operated continuously apart from maintenance stops. However, some parts of the process can be run intermittently.

Figure 18: Smurfit Kappa plant in Piteå, Sweden. (Source: www.smurfitkappa.com)

Measures implemented

A simulation-based production planning tool was introduced and daily routines changed, such as short planning meetings every morning to use data generated by the system for fine-tuning of plant operations.

A major difference between the old production planning process and the simulation-based solution is the use of real-time data, which allows for higher accuracy in predictions, especially when projecting production volumes several days in advance. By using this data in a comprehensive model of the whole production process, a high prediction accuracy is achieved.

To adapt electricity consumption to fluctuating prices, some processes that can be run independently from the continuous production process (e.g. drying or treatment of recovered paper) were planned to be operated intermittently to avoid high prices. The planning tool facilitates this adaptation strategy by connecting the independent processes and defining which product buffers are needed, thus cutting the need for excessive buffered volumes.

Motivation for optimisation measures

Historically, production planning in the plant was a task executed manually by operators, planners, and production engineers. Their toolbox was gradually extended to contain spreadsheets and simple models based on MS Excel. However, the company often experienced discrepancies in production volumes, electricity consumption and feedstock levels when comparing their Excel-based prediction with the actual outcome.

Also, a need for higher operational flexibility emerged, forcing the company to leave steady-state operation more frequently. This started roughly two years ago, when a decrease in overall production capacity and a higher demand for paper with lower grammage, yielding less weight despite constant or increasing square meters produced, caused lower weight-based production volumes and an increasing need for higher flexibility. In addition, the overall demand for kraft liner became more volatile, both due to Russia's war on Ukraine and late repercussions of the Covid crisis. This meant the plant had to be run on part-load more often. Without a production planning tool using real-time data (as opposed to static models based on year-old measurements), swift load changes had not been possible.

Data analysis

This solution is based on the company's existing data collection- and analysis equipment.
The input data is coming from Smurfit Kappa's order management system as well as their control system. All are standard systems and are washed, summed in an Oracle database before being transferred to the PaperFront database, developed in MS SQL Server. In the PaperFront database all settings and results are stored for further presentation. All input data are in real time.
The output data, hence all results and settings are stored in a MS SQL Server database. The results are presented in the simulation tool, ExtendSim.
The underlying model is based on a product called PaperFront that is developed for use in pulp and paper industry, since 2004. It is in use by several large manufacturers and mills. The model of Smurfit Kappa Piteå was gradually developed and improved. The development to get a trustworthy model took about two calendar years in total. The model is based on standard blocks that are used to build and describe the scope. A development of a model like this involves a lot of validation procedures.

The scope is to simulate the ordered production for the next 7 days per minute and plan the input flows and energy use. The production covers a large amount of energy consuming equipment like pumps, agitators, conveyor belts and other.

Benefit

By being able to plan production volumes for the coming days, the production of kraft liner can be adapted to fulfil both customer orders of the primary product and the continued delivery of byproducts such as heat to district heating and electricity to the grid while evening out load demands. The latter reduces wear on critical equipment like the recovery boiler, which does not have to be operated as aggressively, resulting in lower maintenance cost and higher projected lifetime.
This solution allows higher flexibility when reacting to unforeseen changes in demand and/or electricity prices.
Optimisation can be made either towards lower total energy consumption, low electricity prices, limited power consumption (thus avoiding net surcharges) or defined final product output.

Investment

As no further sensors or other hardware was installed, the investment cost is limited to the implementation of the software, including education of personnel, and changing of daily routines. On top, a cost is incurred for using the modelling software.
Regarding the return on investment, company feedback indicates the payback time has been short, less than 2 years.

Result

The energy intensity for paper production, measured in kWh/m², could be reduced by 9 % from 2017 to 2023. The corresponding decrease for sulphate production (in kWh/ton) is 4 %[1], see Figure 19.

Using available data, the savings are hard to quantify. On top of short-term savings through decreased energy intensity in the production process, lower maintenance costs are projected as the process can be adapted to run more smoothly, which in turn causes less machine wear.

Credentials

The digital solution was provided by Frontway, a company specialising in process simulation and -optimisation.

1 It is unclear how much of these savings actually originate from the planning tool, but the interviewed company believes that its contribution has been substantial.

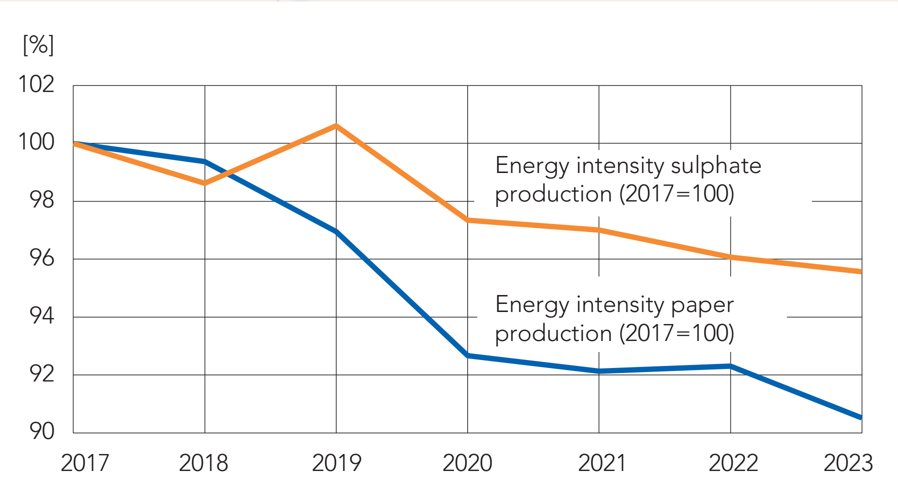


Figure 19: Development of the energy intensity of paper and sulphate production between 2017 and 2023.

Further information

About the Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP)

The Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP), has been supporting governments to coordinate effective energy efficiency policies since 2008. Fourteen countries and one region have joined together under the 4E TCP to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. However, the 4E TCP is more than a forum for sharing information: it pools resources and expertise on a wide range of projects designed to meet the policy needs of participating governments. Members of 4E find this an efficient use of scarce funds which results in outcomes that are far more comprehensive and authoritative than can be achieved by individual jurisdictions. The 4E TCP is established under the auspices of the International Energy Agency (IEA) as a functionally and legally autonomous body.

Current members of 4E TCP are: Australia, Austria, Canada, China, Denmark, European Commission, France, Japan, Korea, Netherlands, New Zealand, Switzerland, Sweden, UK and USA.

The main collaborative research and development activities under 4E include the

- Electric Motor Systems Platform (EMSA)
- Efficient, Demand Flexible Networked Appliances (EDNA) Platform
- Smart Sustainability in Lighting and Controls (SSLC) Platform
- Power Electronic Conversion Technology Platform (PECTA)

Further information on the 4E TCP is available from: **www.iea-4e.org**

4E Efficient Electrical End-Use Equipm International Energy Agency

About the 4E TCP Electric Motor Systems Platform (EMSA)

Electric motor systems consume about 10'700 TWh annually worldwide and were responsible for 53% of the global electric energy consumption in 2016. This corresponds approximately to the combined electricity consumption of China, the European Union (28 countries) and the USA. The goal of the Electric Motor Systems Platform EMSA is to increase energy efficiency and reduce greenhouse gas emissions worldwide by promoting highly efficient electric motor systems in the EMSA member countries, industrialised countries, emerging economies and developing countries.

Further information on EMSA is available at: **www.iea-4e.org/emsa**

4E Electric Motor Systems Platform EMSA

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