Electric Motor Systems Platform EMSA

Digitalisation in motor systems – Part I

Findings for policy makers

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Technology Collaboration Programme

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The report was prepared under the Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E) – **Electric Motor Systems Platform** (EMSA) programme.

This is the first 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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Abstract

This report summarises the key findings of the IEA TCP 4E Electric Motor Systems Platform's (EMSA) research on digitalisation in electric motor systems between 2021 and 2024 for policy makers. It includes a summary of interviews on possibilities and barriers of digitalisation, expert inputs collected from relevant stakeholders and a detailed description of relevant policy programmes in the four participating countries of this research: Austria (lead), Netherlands, Sweden and Switzerland. The key findings of the other separate publications (Parts II, III and IV as mentioned above) are also included, to give policy makers a complete overview on this workstream. Policy recommendations and overall conclusions arising from this work are formulated at the end of this report.

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

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. Electric motor systems consume about 10 700 TWh annually worldwide and were responsible for 53% of the global electric energy consumption in 2016. [1] This corresponds approximately to the combined electricity consumption of China, the European Union (28 countries) and the USA.

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

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 platform 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

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List of abbreviations

4E	Energy Efficient End-Use Equipment
AI	Artificial Intelligence
API	Application Programming Interface
AWS	Austria Wirtschaftsservice
CAS	Certificate of Advanced Studie
CCS	Carbon Capture and Storage
CDP	Center of Digital Production
CIT	Chalmers Industriteknik
COMET	Competence Centers for Excellent Technologies
CRA	Cyber Resilience Act
CSRD	Corporate Sustainability Reporting Directive
DOL	Direct Online
EASA	Electro-Mechanical Authority
EDNA	Efficient, Demand Flexible Networked Appliances
EMDS	Electric Motor Driven Systems
EMSA	Electric Motor Systems Platform
ESA	Electrical Signature Analysis
ICT	Information and Communications Technology
IEA	International Energy Agency
HVAC	Heating, Ventilation and Air Conditioning
IOT	Internet of Things
K1-MET	Metallurgical Competence Center
MAS	Master of Advanced Studies
MBA	Master of Business Administration
MIT	SME innovation-incentive Region and Top Sectors
NIS	Network and Information Security
OPC UA	Open Platform Communications Unified Architecture
PECTA	Power Electronic Conversion Technology Platform
R&D	Research and Development
PFCO	Pump/Fan/Compressor
ROI	Return on Investment
RVO	The Netherlands Enterprise Agency
SDS-I	Smart and Digital Services Initiative
SFO	Swiss Federal Office of Energy
SiP-PiiA	Strategiskt innovationsprogram Processindustriell IT och automation
SME	Small and Medium-sized Enterprises
SSLC	Smart Sustainability in Lighting and Controls
TCP	Technology Collaboration Programme
VSD	Variable Speed Drive
WBSO	Tax Credit for Research and Development

1 Introduction

This report is part of the IEA TCP 4E Electric Motor Systems Platform's (EMSA www.iea-4e.org/emsa) workstream on "New Industrial Developments and Digitalisation in Motor Systems".

4E EMSA is a Technology Collaboration Programme (TCP) under the International Energy Agency involving 9 countries/regions. These are: Australia, Austria, Denmark, European Commission, Netherlands, New Zealand, Sweden, Switzerland, USA. The lead country is Switzerland. The aim of the cooperation is to support governments to design and implement effective policies for efficient electric motor systems. The fourth phase of the programme ran between 1 March 2019 and 28 February 2024.

Four countries have worked together on the topic of digitalisation in motor systems: Austria (lead), the Netherlands, Sweden and Switzerland.

Digitalisation is a buzzword and hence it is important to clarify what is meant by it. EMSA published a report on the *Classification of digitalisation technologies for electric motor driven systems* in 2022. Therein, an overview of the major digitalisation technologies that are used in the field of electric motor systems is provided (see Figure 1). Furthermore, EMSA conducted a survey, where barriers, drivers and potential savings were

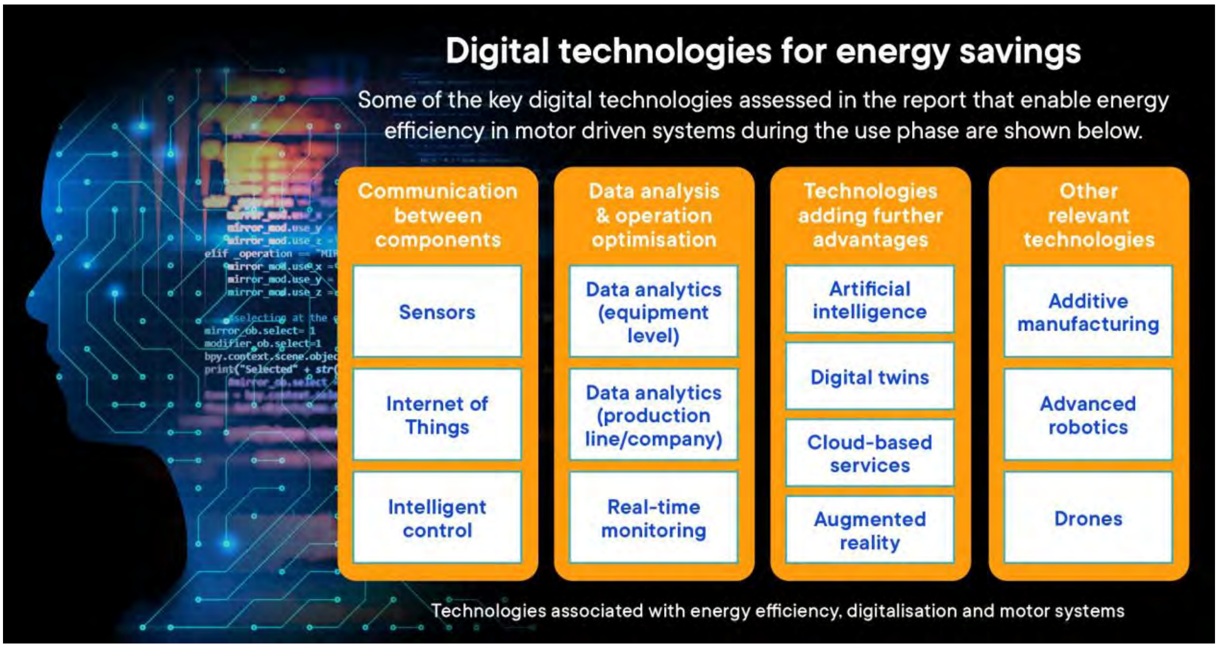


Figure 1 Digitalisation technologies analysed in the EMSA report Classification of digitalisation technologies for electric motor driven systems (2022)

Furthermore, EMSA conducted a survey on digitalisation in electric motor driven systems in 2020 with over 100 respondents worldwide. The report sheds light on the main digital technologies used in industrial facilities, the energy-saving potential attributed to digital technologies, the perceived drivers and barriers as well as the most useful mechanisms to overcome these barriers. [4]

2 Structure of this report

This report aims to give a comprehensive overview specifically to policy makers concerning the key findings from EMSA's research in the area of digitalisation in motor systems. In particular:

- Chapter 3 discusses the findings of interviews with manufacturing industries, suppliers of digitalisation solutions and energy consultancies in Austria and Sweden. The interviews aimed at gaining a better understanding of the challenges and possible solutions the industries face concerning digitalisation, as well as to analyse how authorities can facilitate digitalisation.
- Chapter 4 shows selected expert opinions by relevant stakeholders collected during a workshop organised by EMSA on the subject.
- Chapter 5 references the publication *Digitalisation in electric motor systems – Part II: Technical recommendations for industrial end-users*. [4]
- Chapter 0 presents the overview and conclusions of *Digitalisation in electric motor systems - Part III: Catalogue of case studies*. [5]
- Chapter 7 describes the main findings of *Digitalisation in electric motor systems – Part IV Energy consumption due to the digitalisation of electric motor systems*. [6]
- Chapter 8 describes in detail relevant policies for the digitalisation of motor systems from the different countries, offering a structured overview.
- Chapter 9 discusses the recommendations for policy makers based on the research findings.
- Chapter 10 provides the overall conclusions of this work.

Key findings are highlighted in a box with orange colour throughout the report.

3 Possibilities and obstacles of digitalisation in motor systems

Within the framework of EMSA's work on digitalisation, one action has been to investigate how digitalisation of electric motor systems could help improve energy efficiency of operations in industry. To gain a better understanding of the challenges and possible solutions the industries face concerning digitalisation, as well as to analyse how authorities can facilitate digitalisation, interviews with manufacturing industries, suppliers of digitalisation solutions and energy consultancies have been carried out by CIT Industriell Energi AB in 2022 in Sweden, financed by the Swedish Energy Agency, and by the Austrian Energy Agency in Austria. During the interviews, it was aimed to identify possibilities and obstacles to increased digitalisation of motor systems. These are described in more detail in the following sections. A detailed summary of the interviews made in Sweden can be found in Appendix E.

3.1 Targets and possibilities of digitalisation

Through digitalisation, production and work processes can be simplified and streamlined. For example, digitalisation can highlight opportunities for synergies or potential risks of sub optimisation. Energy efficiency is one of the many benefits of digitalisation of production and work processes in the business. Digitalisation can also create additional value, such as simplified monitoring of environmental parameters, predictability in processes and maintenance, introduction of more efficient control systems, and reduced emissions. Other benefits may include improved working conditions, quality traceability, increased access to information, and enhanced safety, see Figure 2.

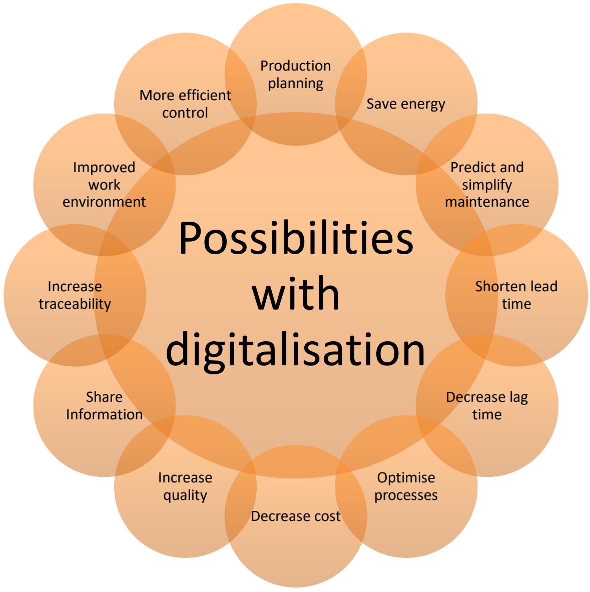


Figure 2 Digitalisation offers numerous opportunities for improvements, not only related to energy.

The added values of working with digitalisation cannot be separated from each other. Often, one action can create conditions to improve and/or streamline in multiple areas. In the long term, efforts in digitalisation can make the business better prepared to handle challenges in the future, such as changes in the market or new legislation. Based on the potential cost savings or revenues 'other benefits' like increased production capacity, improved quality or better management information often show larger potentials than energy savings. Digitalisation should hence be seen as a cross-functional process, that enables data for improved decision making. Successful implementation of digitalisation should therefore also take a wider perspective on the business processes and operation.

During the interviews conducted in Austria and Sweden, some companies stated that the requirement to report and achieve targets for water, energy consumption and CO_2 emissions, is often the trigger for companies to invest in the digitalisation or electronic data collection of electrical energy and other media, such as steam, compressed air or hot water.

For example, for recording the CO_2 footprint of beverage packaging for beverage producers, key figures per kilogram or litre of product are important for sustainability management and reporting in the supply chain (energy consumption, i.e. gas and electricity, and water), which are compiled at company level. For this, all refrigeration systems, air compressors and ventilation systems are to be included in a central control system to record and document total energy consumption. Furthermore, the reporting and visualisation of such key figures leads to awareness-raising and thus prudent use of energy among employees.

Targets and possibilities of digitalisation concerning energy reduction found during the interviews include:

1. Requirements to report and achieve targets for water, energy and CO_2 consumption
2. Reduction of electricity consumption during non-production times; weekend shutdowns
3. Switching off certain energy using systems/air compressors and reducing compressed air pressure at the weekend, reducing idle-hours
4. Reporting and analysis of energy effect of different operational parameter-settings
5. Automated leak detection in compressed air systems
6. Operation of chiller systems based on weather forecasts
7. Preventive maintenance of machines (detection of pressure fluctuations in pumps, wear monitoring for electric motors)
8. Condition monitoring of machines through vibration analysis
9. Load management of different machines to profit from low price periods or to avoid high price periods
10. Simulation of systems before they are actually installed (e.g. simulation of the energy requirements of the compressed air station when installing a more efficient compressor).

3.2 Obstacles to wider implementation of digitalisation in industry

Many industries already have implemented digitalisation to some degree. In most industries, different parts of the business are digitalised, but they are not necessarily connected to each other. Connecting separated systems leads to a better picture. Some of the main obstacles found in the interviews conducted in Austria and Sweden are reported below.

3.2.1 Need for standardised data formats

The lack of standards was mentioned to have been a significant problem in the past when trying to connect different machines and systems to each other since they use different protocols. However, standardisation has been improving over the last couple of years and is less of a problem now. The open-source standard Open Platform Communications Unified Architecture (OPC UA) was mentioned to have facilitated communication and integration of systems significantly.

3.2.2 Lack of competence

All large industries agree that lack of competence is one of the major challenges today. Many different skills are required when it comes to digitalisation, both in terms of software and hardware skills. Engineers in IT, machinery and automation are needed to make digitalisation solution work as intended as well as understanding it.

3.2.3 Scarce resources

The largest challenge for smaller industries is resources (people, time and money). Compared to large industries they have significantly fewer employees and suitable competences for implementing new digitalisation technologies, and the few employees that would be suitable to be involved in digitalisation efforts usually have a lot to do. But also in bigger companies, there is sometimes only one expert in the company who has the appropriate programming skills to install a meter and integrate it into the monitoring system, for example.

3.2.4 Low awareness

Employees are often unaware of how much energy is used for compressed air, cooling or lighting. They treat it as if it were free of charge and use compressed air for cooling.

It is easier for employees to leave a machine running over the weekend instead of switching it off, as they do not have to wait 10 minutes in the morning for the next workday until the machine is ready for operation again.

There should therefore be regular meetings where employees are informed about the underlying costs, to start the process of acceptance of digital solutions and to support activities in this field.

3.2.5 Strict profitability requirements

According to the interviewees, new projects must meet static amortisation periods (return on investment - ROI) of 2.5 to less than 3 years, which is considered difficult for energy projects due to the low energy prices at the time. In one company, other benefits from preventive maintenance and longer component service lives were also taken into account, next to the reduction in energy costs, in order to have such projects approved,

3.2.6 Difficulties in data collection and handling

Due to the lack of updated diagrams of distribution systems of motor driven systems (e.g. compressed air, ventilation or pumping systems), it is difficult to find suitable measuring points and then evaluate them correctly, as it is not known which systems are currently connected. Another obstacle to setting up an energy monitoring system is, for example, the lack of central control cabinets for individual lines, which makes it difficult to measure the total electricity consumption of these lines, or the failure of meters, which impedes comparisons over time and identifying trends.

Existing equipment at industrial sites might be decades old, and it is not always straightforward to integrate them with new digital technologies.

Other system data is also required for energy analysis, in particular system operating parameters. However, these parameters are used for control purposes and are not stored in all cases. Normally, only process-relevant data is stored, e.g. temperatures in the food industry, but this is then deleted every one- to two years.

The amount of data that arises from sensors and measurements can be a challenge. In many cases, data interpretation and plausibility checks are very time-consuming. In the case of data transferred from building management systems, half of the data is sometimes unusable after data cleansing.

Partly, companies start to use artificial intelligence for this purpose. In order to use artificial intelligence, it is necessary to provide and collect data on all the different system statuses over a long period of time, which leads to a long implementation phase.

In many companies, the handling of data is not regulated: it is necessary to record whether data already exists for the respective purpose, whether the data is technically accessible, who has the right to access data, who is responsible for the data and when it is deleted.

3.2.7 Cybersecurity at risk

All industries state that cybersecurity is a risk and challenge for the implementation of digitalisation. The most severe risk in case of a cyber-attack is access to control systems. If an external party could control processes at the site it could lead to significant damage, both in terms of physical damage on equipment and employees (e.g., in case a high-temperature or high-pressure system is out of control) and in terms of economic damage. The implementation of the NIS 2 Directive (Directive (EU) 2022/2555) on measures for a high common level of cybersecurity across the European Union Union and the Cyber Resilience Act (CRA), could lead to safer data exchange, but will require quite some work for businesses.

4 Expert opinions from stakeholders

Austria, Netherlands, Switzerland and Sweden organised the international EMSA workshop "How can digitalisation in industrial electric motor-driven systems contribute to saving more energy?" on 19 September 2023. During this workshop, barriers, case studies, current and potential policies were discussed.

In the following, some selected inputs are presented.

a. According to the findings of the Electro-Mechanical Authority (EASA) **only 20% of sensors are connected**.
b. **Digitalisation is being developed for condition-based monitoring,** as **lower maintenance costs and increased uptime are the main areas of interest** for the industry. Some companies are willing to implement this, but other, more conservative companies are not.
c. **Energy efficiency cannot be achieved through digitalisation alone; the people responsible for maintenance and the IT departments must also be involved**. The human factor, in this case **the lack of human resources and knowledge**, **is** cited as **the main gap**; the **technology would** actually **be ready for use**. Specialist knowledge is required in the IT and mechanical areas as well as in power electronics.
d. **For energy efficiency, more detailed data is needed** with a more detailed temporal recording of electricity consumption than is the case with conventional electricity meters. **Digitalisation can help here, for example through smart meters**.
e. Technical challenges that still need to be overcome were also mentioned. For example, it was recommended that **there should be no application without an application programming interface (API) so that other software programmes can also be connected to such systems.**
f. When starting to deal with digitalisation, it was mentioned that **smaller projects should be carried out at the beginning in order to demonstrate the benefits of digitalisation** using concrete, quickly implementable cases in the company. The benefits to be created for the company should be clear from the outset. It should also be made clear how users can use the results.
g. Digital solutions should be demanded by the authorities and strict requirements for energy efficiency should be defined.

5 Technical recommendations

EMSA also made some recommendations for the digitalisation of motor driven systems in *Digitalisation in electric motor systems – Part II: Technical recommendations for industrial* *end-users*. [4] Firstly, there are general recommendations for the introduction of digitalisation in companies. Secondly, for pumping, ventilation and compressed air systems, more detailed recommendations were elaborated. These recommendations are based on the interviews with end-users and system providers, as described in chapter 2 of this report.

Through digitalisation, production and work processes can be simplified and streamlined. Energy efficiency is one of the many benefits of digitalisation of production and work processes in the business. Digitalisation can also create additional value, such as simplified monitoring of environmental parameters, predictability in processes and maintenance, introduction of more efficient control systems, and reduced emissions. Other benefits may include improved working conditions, quality traceability, increased access to information, and enhanced safety.

Targets and possibilities of digitalisation concerning energy and energy cost reduction found during the interviews include:

1. Requirement to report and achieve targets for water, energy and CO_2 consumption is often the trigger
2. Reduction of electricity consumption during non-production times; weekend shutdowns

Measures implemented include:

3. Switching off certain systems/air compressors and reducing compressed air pressure at the weekend, reducing idle-hours
4. Reporting and analysis of energy effect of different operational parameter-setting
5. Automated leak detection in compressed air systems
6. Operation of chiller systems based on weather forecasts
7. Preventive maintenance of machines (detection of pressure fluctuations in pumps, wear monitoring for electric motors)
8. Condition monitoring of machines through vibration analysis
9. Load management of different machines to profit from low price periods or to avoid high price periods
10. Simulation of systems before they are actually installed (e.g. simulation of the energy requirements of the compressed air station when installing a more efficient compressor).

Many industries already have implemented digitalisation to some degree. In most industries, different parts of the business are digitalised, but they are not necessarily connected to each other.

Digitalisation aimed at achieving more efficient processes and work requires collecting data and information from the relevant processes/systems. The collected information needs to be analysed and interpreted to draw conclusions about potential actions that improve efficiency. There are many different techniques and tools that can be used.

Before starting with the digitalisation of motor driven systems, the most promising systems should be identified. There are different techniques for collecting data depending on its intended use. Data can be collected at specific intervals or in real-time, from individual machines as well as from a production line or an entire facility.

Data analysis involves transforming and processing collected data to visualise relationships and enable conclusions. The information can be used to design control signals to improve production. Large amounts of data from many sources increase the complexity of describing a system in a way that mathematical formulas often cannot. Combining concepts from traditional energy management systems, such as ISO 50001, with digital technology and software applications can provide new insights into consumption and usage patterns.

Concerning specific recommendations for motor driven systems the report covers pumping, ventilation and compressed air systems.

Depending on the application and user requirements, several digitalisation options are available in the pump sector. Most options have been developed in the area of optimised maintenance and increased reliability, with energy efficiency as next area of interest. Since an emerging damage of the components of the whole drive system from motor to machine also leads to increased energy consumption, as well as operation outside the design load curve, these options are also relevant in this context.

Three types of pump monitoring technologies are described in the guide:

- Measuring the electrical power (current and voltage)
- Vibration and temperature sensoring
- Use of a Variable Speed Drive (VSD) as monitoring device.

For ventilation systems, the guide outlines digitalisation measures on the following levels:

1. Field level (sensors and actuators; connected directly or communicatively, e.g. via radio or bus systems).
2. Automation level: this contains the control devices (usually programmable microcomputers), including simple operation and signal processing, including logic and sequence controls.
3. Management level: the building management system (BMS) is located at the management level. This is the top level and is responsible for central control and the optimisation or control of operating sequences. It contains a visualisation interface on which statuses, results, statistics and evaluations can be displayed.

For compressed air systems, the following measurements are recommended and described in more detail:

- Measurement of electrical power
- Measuring the volume flow in the compressor station, in the distribution line and on machines
- Pressure measurement on compressors and in the network
- Temperature sensors in the room and directly at the in- and outlet of the compressor stage
- Bearing monitoring - vibration analysis
- Dew point measurement and measurement of compressed air quality

Furthermore, the difference between analog and digital sensors is described, and possibilities to transmit the data to different systems and their functions are shown.

6 Case studies

Within the last years EMSA collected examples for the digitalisation of electric motor driven systems in industry that proved to save energy or increase the energy efficiency. These are intended primarily for industrial end users as an inspiration but may also be interesting for other experts e.g. in the area of consulting, manufacturing, academia or policy making. In total, 8 case studies are presented in the publication *Digitalisation in electric motor systems - Part III: Catalogue of case studies*. [4] The case studies cover all major motor system applications, i.e. pump, ventilation and compressor systems.

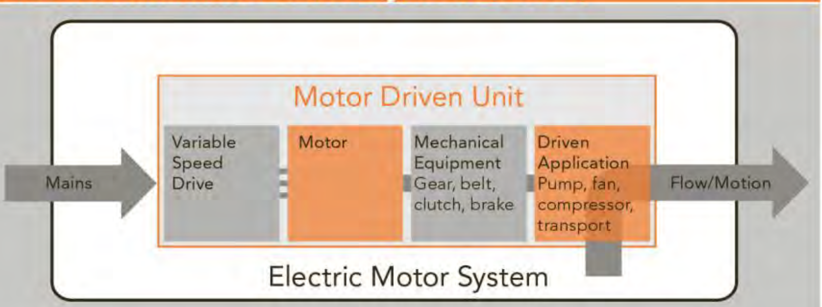
The following tables give an overview of the case studies in the catalogue.

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
■ cases including hardware upgrades

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

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



Company	Role of digital-isation	Power equip-ment	Controls		Motor	Trans-mission	Appli-cation (PFCO)	Piping, other	Heat ex-changer, other
			VSD	Control, sensor, gateway					
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
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

In the following, each case study is described shortly.

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 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.

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 frequency 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.

During the collection and evaluation of the case studies, the following conclusions were made:

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. [7]
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].

7 Energy consumption due to the digitalisation of motor systems

The introduction and rise of digitalisation in industrial electric motor systems (motor systems) is expected to enable a more energy efficient operation of motor systems. However, digital technologies also consume energy. This is being analysed in the publication *Digitalisation in electric motor systems – Part IV Energy consumption due to the digitalisation of electric motor systems*. [6] The publication focuses on motor systems in the industrial sector and addresses the following questions:

- How large is the energy consumption associated with the digitalisation of electric motor systems?
- What are the benefits and downsides of using digital technologies?
- Do the benefits outweigh the downsides?

The analysis employs the following methodology:

- Literature research
- Structure and types of digital benefits
- General analysis and decomposition of digital consumers
- Analysis of real cases
- Evaluation and key findings
- Discussion and recommendations for future research.

The rapid rise of digitalisation has been affecting various areas in the economy. Considering the substantial increase in data stream that inherently comes along with digitalisation, research interest regarding the impact on the energy effect has been growing. As for motor systems, the research on energy impact currently appears to be sparse. A comprehensive understanding related to the energy benefits and drawbacks of digitalisation in motor systems is still lacking. A crucial initial stride towards gaining a deeper understanding of this matter involves the classification of digital motor systems. [3] By analysing current research and real-life cases in industry, this analysis aims to contribute fragments to a better understanding of the impact of digital motor systems on energy consumption.

[1] A number of other non-energy benefits can be associated with motor system optimisation which are described in more detail in [8].

As for the main motives leading industrial users to the adoption of digitalised systems, energy related benefits (increase system efficiency, monitor energy consumption, avoid parasitic energy consumption) and non-energy related benefits (avoid down time, increase production efficiency, cost-effective maintenance, etc.) can be separated. While energy related benefits may reduce operational cost significantly, the primary motive for digitalisation is not per se related to saving energy but can be attributed to non-energy benefits.

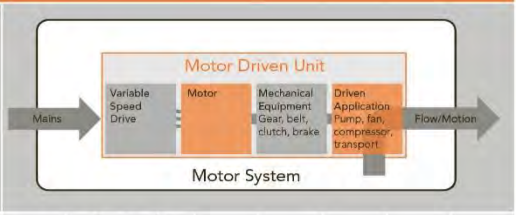
The role of digitalisation in motor systems can be looked at in different ways. In a “passive” role, as an enabler to identify savings opportunities, e.g. through monitoring of equipment. In an “active” role, having direct influence on the energy consumption of a motor system, for example, in the case of an intelligent control.

Five exemplary cases have been documented for this analysis, as follows:

- Case 1: IoT sensor in air ventilation system in server facilities to detect clogged filters
- Case 2: predictive maintenance and vibration diagnostics via smart sensor. For this case, a sensitivity analysis was made concerning data transmission, operating hours and standby consumption.
- Case 3: intelligent control of water treatment facility pump system, applying electrical signature analysis
- Case 4: a large scale field trial, using the same technology as in Case 3
- Case 5: intelligent control of an air compressor system.

For these cases, a detailed impact analysis regarding energy consumption is provided. It was possible to collect cases for all major motor systems applications, i.e. compressors, pumps and fans. Digital technologies enable motor system optimisation, which often includes hardware upgrades. In the cases presented, whenever possible, the energy savings and the source of these savings (with/without hardware upgrade) was identified. The following table (Table 3) summarises the cases presented.

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



Case	Digital aspects	Before	After	Net savings	Role of digital-isation	Power equipment	Controls		Motor	Transmission	Application (PFCO)	Piping, other	Heat exchanger, other
							VSD	Control, sensor, gateway					
1	IOT in air ventilation system in server facilities	Sporadic manual tests of air filter clogging	Detection of clogged air filters in ventilation system for servers	20.4 %	P	–	–	X	–	–	–	S	–
2	Predictive maintenance and vibration diagnostics	Visual motor inspection (or unplanned failure)	Detection of potential motor failures, which could lead to increased motor losses and downtime	n.a.	P	–	–	X	S	–	–	–	–
3	Intelligent control of water treatment facility pump system	Static (set points for) operation of pumps	Adapted set-points (load) and target speeds of pumps, closer to their optimal efficiency	5.7 %	P	–	S	X	–	–	–	–	–
4	Large scale field trial (#202 motors)	Mixture of DOL and VFD operated motors, some systems partly optimised	Improved control/ VFD operation, optimised assets including replacements and/or other optimisations	average: 11.4 %	P	X	X S	X	X	–	X	–	–
5	Intelligent control of air compressor system in large production facility	Set of DOL (on/off) air compressor units	VSD operated compressor units plus sensors and control	15.0 %	A	–	X	X	–	–	X	S	S

EMDS= Electric Motor Driven System; VSD = Variable Speed Drive, PFCO = pump/fan/compressor
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 3 Summary of cases

Depending on the 'starting point for optimisation', the applicable measures can materialise as a series of optimisations from changing set points to changing complete components like a motor, Variable Speed Drive (VSD) or pump. The studied cases show net savings (excluding digital energy consumption) ranging from 5.7% up to 20.4%. In case 4, savings for the motor systems reached up to 46%, while the average saving in subgroups of motors, e.g. those without a VSD before optimisation was 24%, those with a VSD before optimisation was 9%.

The energy consumption attributable to the digitalisation of motor systems stems from a variety of sources. Notably external network communication i.e., the use of cloud services can add to the total energy consumption when high data volumes and storage requirements are given. However, with regards to limiting factors such as battery life in smart sensors, it is much more common to work with small and compressed data sets that leave a marginal impact even when considering pessimistic values for network energy consumption. As for hardware components attributable to digitalised motor systems, sensors and local data communication or storage devices typically show a low energy consumption. There is a variety of digitalisation concepts, of which smart sensors have negligible energy consumption but some systems may show larger power usage. Generally, infrastructure necessary to facilitate digitalisation of motor systems may already be in place to a large extent. This directly limits the additional energy required for further network participants. With regards to energy intensity, we classify the type of digitalisation according to the table below. The classification distinguishes primary targets of the digitalisation which, based upon the findings, result in different typical energy consumption. This typically directly correlates with the computational complexity. It is worth noting that the baseline values for the classifications have been chosen arbitrarily considering the cases examined in this analysis.

	Smart Sensors/ IoT	**Advanced analytics**	**Adaptive control systems**
Annual energy consumption of digital system	< 10 Wh/a	10 Wh/a -200 kWh/a	> 200 kWh/a
Computational frequency	<<1 Hz	~1Hz	>1 Hz
Number of motors	1	>=1	>2
Primary target of digitalisation	Error detection	Error detection, optimisation	Energy savings, emission reduction
Assignable cases from this analysis	Case 1 Case 2	Case 2 Case 3 Case 4	Case 5

Table 4 Classification of digitalised motor systems

In the cases studied, the energy expenditure to facilitate digitalisation never exceeded 1% of the total energy consumption attributable to the motor system, but was rather insignificant. Consequently, on an overall level, the energy savings achieved through the digitalisation of motor systems far outweigh the additional energy consumption resulting from the digitalisation process. In the cases studied, what is decisive for the savings potential is to what extent systems were already optimised before the measures and to what extent measures can contribute to an optimised system operation.

The sample size with the cases presented is by no means representative which is a limiting factor for aggregated conclusions. The collection of further cases would be helpful to be able to draw statistically relevant conclusions. A greater number of cases would also allow a better distinction between the types of digitalisation technologies/solutions applied with motor systems. This combined with data on the installed base of motors could create a sound basis for answering further questions, like:

1. What type of digitalisation solution suits best certain motor system setups?
2. What is the range of expected energy savings stemming from the different digitalisation technologies?
3. To what extent does digitalisation unlock additional energy savings?
4. What is the savings potential in certain sectors (energy-intensive, non-energy intensive)?

5. What is the cost-effectiveness of digitalisation and the size of programmes required for its large-scale application?

8 Policies related to digitalisation of motor systems

The aim of the research work was also to identify current policy programmes in the field of digitalisation and energy efficiency in industry that promote projects in the field of electric motor systems or could promote them in accordance with the funding conditions, such as research and investment programmes. In addition, selected training programmes in this area were researched.

The following categories of policies or programmes could be identified:

- Funding of investment costs
- Funding of research, demonstration and development projects, including know-how transfer for the categories: digitalisation, efficient production and energy
- Tax rebates
- Knowledge transfer platforms
- Capacity building programmes

For all these categories there are programmes that focus or include projects in the field of digitalisation of industrial processes and/or climate friendly technologies. Specific programmes on electric motor systems could not be identified in these countries. However, individual cases supported by these schemes were identified, some are reported in this chapter.

A comprehensive listing of all available programmes in all countries was not possible[2], the following programmes were selected on national basis as most relevant in this area (see Table 5).

[2] For example, in Austria there is also a general energy efficiency investment funding for companies, where motor optimisation can be subsidised.

Category of policy instrument	Examples of policies (mentioned in this report)
Funding of investment costs (depending on programme and purpose up to 65% are financed)	• AWS Energy & Climate, Austria • AWS Investment premium, Austria • AWS Digitalisation, Austria • Climate step, Sweden • Competitive calls for tenders (ProKilowatt), Switzerland
R&D funding (digitalisation, Industry 4.0) (depending on size of company and project type 25-100% of costs can be funded)	• COMET, Austria • Information and communication technologies of the future, Austria • Advanced digitalisation, Sweden • "Smart and Digital Services" initiative (SDS-I) (Service Innovation), Austria • Process industrial IT & Automation – Strategic innovation programme, Sweden • SME innovation-incentive Region and Top Sectors (MIT), The Netherlands
R&D funding (efficient production) (funding rate depending on project and company)	• Production of the future, Austria • Industrial leap, Sweden
R&D funding, energy (funding rate depending on project and company)	• Energy research, Austria • Energy research, Switzerland • Showcase energy projects, Austria • Research cooperation International Energy Agency, Austria • SME innovation-incentive Region and Top Sectors (MIT), The Netherlands
Start-up support (e.g. proof-of concept funding, seed capital, credit guarantee)	• Startup and Scale-up Support, The Netherlands
R&D tax incentives	• WBSO: Tax Credit for Research and Development, The Netherlands
Knowledge transfer	• Platform Industry 4.0, Austria • Industry 2025, Switzerland • Smart Industry Netherlands

Capacity building	• Master „Electrical Energy Engineering and Sustainable Energy Systems“, Austria • Master „Embedded Systems“, Austria • Master (MBA) „Twin Green & Digital Transition“, Austria • Bachelor “Mechanical engineering”, Switzerland • Bachelor “Electrical and Information Technology”, Switzerland • Bachelor “Electrical engineering and Information Technology”, Switzerland • Bachelor “Mechanical Engineering and Innovation”, Switzerland • Certificate of Advanced Studies CAS Predictive Maintenance, Switzerland • Certificate of Advanced Studies CAS Industry 4.0, Switzerland • Master of Advanced Studies MAS Industry 4.0, Switzerland • Certificate of Advanced Studies CAS Digital Industry, Switzerland • Smart Makers Academy, digital applications in manufacturing industry, The Netherlands

Table 5 Overview of policies presented in this report

8.1 Funding of investment costs

AWS Energy & Climate (AWS Energie & Klima), Austria

The objective of the funding programme “AWS Energie & Klima” is to support small and medium-sized enterprises in finding an entry into energy management adapted to their own needs. The programme covers 30% of investment costs (up to 50 000 EUR) for the energy management system, including relevant software, measurement technology (current, voltage, electrical power, volume flow, compressed air volume), and external training costs for the implementation of the energy management system.

Link: AWS Energie & Klima

AWS Investment premium (AWS Investitionsprämie), Austria

“AWS Investitionsprämie” is a funding programme that incentivises companies to invest in depreciable fixed assets. The programme aims to promote investments, growth and employment opportunities. The funding amount is 7% of the eligible investments and 14% for investments in the fields of ecology, digitalisation and health. The minimum funding amount is 5 000 EUR up to a maximum of 50 million EUR. The programme covers funding for digital technologies such as artificial intelligence, cloud computing, big data, digital measurement technologies and simulation facilities.

Link: AWS Investitionsprämie

AWS Digitalisation (AWS Digitalisierung), Austria

“AWS Digitalisierung” is a funding programme that supports manufacturing companies or production-related companies in the introduction of digital technologies. The programme covers funding for studies to improve internal processes with respect to efficiency, investments in equipment that can apply Industry 4.0 concepts such as hardware and software, robotic systems, control technologies, rapid prototyping, manufacturing, and more.

The programme also supports the development of digital competencies for low-skilled employees. The funding is in a form of grant with a funding amount up to 500 000 EUR per company and per project.

Link: AWS Digitalisierung

Climate step (Klimatklivet), Sweden

The programme "Klimatklivet" supports climate investments in many different areas, for example investments to switch to renewable fuels and renewable energy, build charging infrastructure or switch to more circular production methods. The important thing is that the climate investment contributes to reduced emissions of greenhouse gases and that the measure could not have been implemented without financial support.

Companies can receive 20-65 percent in support, in accordance with EU state aid rules. Municipalities, non-profit associations, condominium associations and others that do not act on an economic market and that are not counted as companies can receive a maximum of 50 percent of the investment cost in support.

Since the start in 2015, 5 246 projects have been granted, from 350 EUR to 18 million EUR project budget.

Link: Klimatklivet

More details can be found in **Appendix A**.

Competitive calls for tenders (ProKilowatt), Switzerland

The competitive calls for tenders offer subsidies for saving electric energy. The subsidy can be up to 30% of the total investment cost. Several technologies are subsidised, including motor systems. Bids can be submitted on a competitive basis and selected programmes and projects are accepted for funding. This is to ensure competition and hence cost-efficiency of the funding. For motor systems, typical measures included retrofits. So far, these did not include digitalisation aspects, although these are not excluded. The competitive nature of this policy instrument is a limiting factor for going deep into system optimisation which is often cost-intensive. [9]

Link: Competitive calls for tenders

8.2 R&D funding (digitalisation, Industry 4.0)

COMET, Austria

COMET (Competence Centers for Excellent Technologies) is a central funding programme in Austria and a cluster of centres where scientists collaborate with industrial researchers on strategic research projects. The COMET programme is dedicated to addressing strategic projects with a primary emphasis on crucial sectors vital to the Austrian economy, including climate, digitalisation, mobility and health. The programme is financed by the federal government, the federal states, the participating companies and research organisations. The network comprises 23 centres, with examples such as K1-MET (Metallurgical Competence Center), CDP (Center for Digital Production), Linz Center of Mechatronics, Austrian Smart Systems Integration Research Center.

Link: COMET

Information and communication technologies of the future (Informations- und Kommunikationstechnologie (IKT) der Zukunft), Austria

The funding programme "IKT der Zukunft" supports research-intensive innovation and technology development in the field of information and communication technologies. For example in the period of 2012 to 2014, there were projects funded in the area of energy efficiency and intelligent energy networks and systems. The programme covers industrial research (with a maximum funding rate of 85%) and experimental development (with a maximum funding rate of 60%). Studies can be funded up to 100% if needed. The maximum funding amount is 2 million EUR per project. The programme covers the following eligible costs: personnel costs, R&D investments, travel expenses, material and equipment costs and third-party costs.

Link: IKT der Zukunft

Advanced Digitalisation (Avancerad Digitalisering), Sweden

The programme "Avancerad Digitalisering" co-finances projects that focus on high-tech advances in the areas of secure digital platforms, cyber security, AI end-to-end, edge, cloud, 5G/6G networks, autonomous systems, data-driven development, model- and simulation-driven development and software development. Target group of this programme are small and medium-sized enterprises, large companies, research institutes and public authorities. The Advanced Digitalisation programme in Sweden has six overarching goals. These goals are to:

- Contribute to the next generation of advanced, powerful and secure digital solutions developed in Sweden.
- Strengthen Sweden's attractiveness in terms of research and innovation investments.
- Ensure increased competitiveness for the industry operating in Sweden.
- Contribute to raising the competence and implementation ability of Swedish business in the area of advanced digitalisation.
- Constitute a collaboration platform and function as a knowledge hub for other Swedish initiatives in the field of digitalisation.
- Contribute to society's digital transformation, sustainable development and the work to achieve the Swedish environmental goals.

Link: Avancerad Digitalisering

More details to be found in **Appendix B**.

"Smart and Digital Services" initiative (SDS-I), Austria

The "Smart and Digital Services" initiative (SDS-I) is a funding programme that supports projects in the field of Industry 4.0 or projects that apply blockchain technology. The target group of the initiative are small and medium-sized enterprises, large enterprises, universities and colleges, research institutions and startups. In addition, manufacturing companies and service providers such as logistics companies, software development companies, recycling companies and engineering offices that develop innovative services with R&D character in the context of Industry 4.0 can also submit proposals. The programme supports projects that deal with monitoring systems, simulations, predictive maintenance, and the introduction of new technologies such as augmented reality.

Link: "Smart and Digital Services" initiative

Process industrial IT & Automation – Strategic innovation programme (Strategiskt innovationsprogram Processindustriell IT och automation (SIP PiiA)), Sweden

The initiative "Strategiskt innovationsprogram Processindustriell IT och automation (SIP PiiA)" managed to get funding via the investment in strategic innovation programs in 2013 with the task of strengthening the digitalisation of Swedish process industry. PiiA is one of the 17 strategic innovation programmes funded by Vinnova, Formas and the Swedish Energy Agency. Target group of this programme are process industries, research institutes and consultants. By forging new collaborations between industrial companies, technology companies and research partners, new techniques, working methods and tools are explored and implemented. More and more technology companies are adapting their products to industry. Through IndTech, Swedish process industry becomes smarter and more efficient, thereby more sustainable and less environmentally destructive.

PiiA guides the industry to find new collaborations to test new technology and develop their working methods. PiiA also works with external intelligence and dissemination of good examples both within PiiA's portfolio and from the lessons we can learn from other countries and investments.

Link: SIP PiiA

More details to be found in **Appendix C**.

SME innovation-incentive Region and Top Sectors (MIT), Netherlands

The MIT scheme was introduced in 2013 as a national instrument and has had since 2015 also a regional part. It is a combined national and regional R&D and innovation instrument. The aim of the MIT is twofold: 1) to promote innovation in Small and Medium-sized Enterprises (SMEs) and 2) to improve the ability of SMEs to join the 'Knowledge and Innovation Agenda' drawn up by the Topsectors at national level. This agenda covers key technologies like e.g. Digital Technologies, Climate & Energy, Circular Economy, Advanced materials and more. Note: the Topsectors include nine sectors e.g. Agri and Food, Chemistry, Energy, Logistics and more, with ICT as a horizontal theme in all nine. In the five years 2017-2021, a total of almost 300 million EUR was invested in MIT. In terms of budget, the R&D collaboration projects and the feasibility projects are the most extensive sub-instruments; on average a total of 1 600 companies used the MIT during this period.

One of the themes within the Topsector Energy is digitalisation of the energy system.

Link: https://www.rvo.nl/onderwerpen/mit

8.3 R&D funding (efficient production)

Production of the future (Produktion der Zukunft), Austria

The funding programme „Produktion der Zukunft“ aims to enable efficient resource and raw material utilisation, as well as efficient production technologies and flexible production. With the programme, cooperative projects of industrial research or experimental development, R&D infrastructures (pilot factories), innovation laboratories, individual projects of experimental development and knowledge transfer can be funded.

Link: Produktion der Zukunft

Industrial leap (Industriklivet), Sweden

The programme "Industriklivet" supports preliminary studies, research, pilot and demonstration projects and investments in the areas such as process industries' greenhouse gas emissions, negative emissions (CCS) and strategically important measures in industry. The goal is to decrease process industry related greenhouse gas emissions.

The 147 granted projects range from 15 000 EUR to 25 million EUR public funding, with complementary private funding so that a total project volume of 775 million EUR has been activated.

Industriklivet's focus during the first years was on the most emission-intensive industries. Through Industriklivet's expansion in 2019 and 2021, other areas are now also covered, such as biogenic emissions from the pulp and paper industry as well as electricity and district heating.

Link: Industriklivet

More details to be found in **Appendix D**.

8.4 R&D funding (energy)

Energy Research (Energieforschung), Austria

The "Energieforschung" programme, supported by the Climate and Energy Fund, serves as an initiative for financing energy innovations in Austria. With emphasis on emerging trends like digitalisation, the programme aims to support innovative developments in clean energy technologies throughout the country. The primary objective is to strengthen Austria's international position as a country of energy innovation and to enhance its export opportunities. The programme funds research and development of energy solutions through the whole value chain, from idea up to full functionality. Examples include data generation, provision and analysis, digitisation of integrated regional energy systems, digitisation of industrial energy systems. The programme has a maximum financing rate according to the instrument, and there is no upper limit.

Link: Energieforschung

Energy research (Energieforschung), Switzerland

The Swiss Federal Office of Energy (SFOE) promotes application-oriented energy research. It provides Swiss research institutions with access to the research programmes of the International Energy Agency (IEA) and the European Union. The SFOE supports innovative processes at the interface between research, industry and the market. These include pilot- and demonstration programmes, knowledge and technology transfer and dedicated research programmes for electricity technologies, industrial processes, heat pump and refrigeration technologies and other areas (see Figure 3). Motor systems and digitalisation are largely covered under the electricity technologies research programme.

Link: Energy research

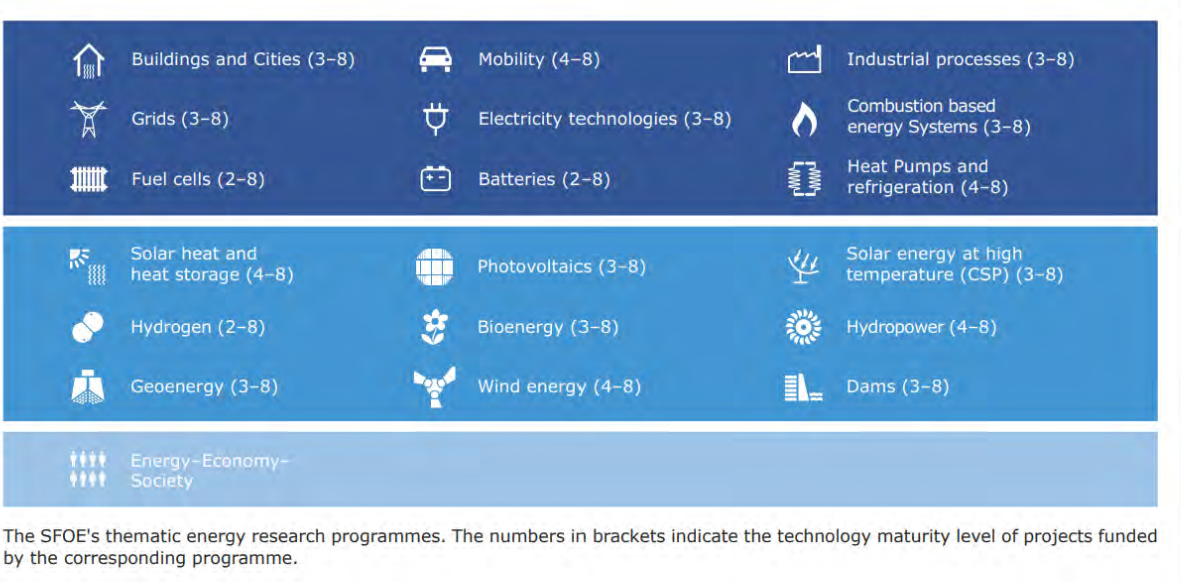


Figure 3 Swiss thematic energy research programmes ***Error! Reference source not found.***

Showcase energy projects (Vorzeigeregion Energie), Austria

The objective of this funding programme is to support the demonstration and development of new energy technologies originating from Austria. The focus is on fostering secure and affordable energy and mobility systems. The programme's funding is directed towards accelerating the market introduction of innovative Austrian energy technologies.

Link: Vorzeigeregion Energie

Research cooperation International Energy Agency

As part of this programme, Austria engages in the “Technology Collaboration Programmes”. The emphasis lies on Austrian involvement in the research activities of the International Energy Agency, with a commitment to disseminating results and facilitating network activities. The programme allocates funds to projects in the field of energy in buildings and communities, district heating and cooling, hybrid and electric vehicles, industrial energy technologies and systems, smart grid systems and more.

Link: Research cooperation International Energy Agency

SME innovation-incentive Region and Top Sectors (MIT), Netherlands

Description, see above in chapter “R&D Funding (digitalisation, Industry 4.0).

8.5 Start-up support

Startup and Scale-up Support, Netherlands

The Netherlands Enterprise Agency (RVO) offers special support for innovative startups with upscaling potential. This consist of funding, a national and international network, and personal advice from startup experts.

RVO has as well a FastLane for High-potential Startups and Scale-ups providing intensive help to each startup or scale-up, helping it to find the right support at the right time.

Link: Startup and Scale-up Support

8.6 R&D tax incentives

WBSO: Tax Credit for Research and Development, Netherlands

The WBSO reimburses part of the wage costs of an R&D project, as well as - for larger companies - a deduction for other costs and expenses of the R&D project, such as the purchase of materials, is available. The total tax rebatement for R&D in companies amounts to appr. 800 million EUR/year on average.

Link: WBSO: Tax Credit for Research and Development

8.7 Knowledge transfer

Industry 2025 (Industrie 2025), Switzerland

"Industrie 2025" is a platform for knowledge transfer and networking in the area of Industry 4.0 in Switzerland. The goal of the initiative is to drive the digital transformation in Swiss industry. It brings together stakeholders, structures and deepens existing knowledge and experience, and makes these freely available. It ensures the introduction, support and anchoring of Industry 4.0 concepts in value creation networks and production companies. This is achieved through a wide range of activities, such as conferences, workshops, showcasing best practices, organised factory tours, working groups addressing different topics, e.g. digital strategy, digital business models, digital twin, smart data, Industry 4.0 security, Industry 4.0 standards and other services.

Link: Industry 2025

Platform Industry 4.0 Austria (Plattform Industrie 4.0)

The Association "Industry 4.0 Austria – the Platform for Smart Production" was founded in 2015. In a broad alliance, important social, political, economic and scientific players are actively involved in shaping the future of production and work. The aim is to contribute to an increasing future prosperity for all people in Austria. The goal is to make the best possible use of new technological developments and innovations of digitalisation (Industry 4.0) for companies and employees equally and to shape the change in a socially acceptable way.

Due to the increasing relevance of the topic, the expert group "Circular Production" (formerly "Resource and Energy Efficiency") was created in 2021. This group focuses on the dedicated exchange and discussion of the interface between Industry 4.0 and sustainability. Through the exchange of experience and mutual learning, science, research and society should take measures that contribute to both a sustainable future and the innovative strength of Austria as a business location.

Link: Platform Industry 4.0 Austria

Smart Industry Netherlands

This government supported network programme has started in 2014. The focus is to facilitate and support manufacturing companies in their smart digital transformations. With flexible, advanced manufacturing technologies and solutions, the involved companies will realise substantial energy and material savings and contribute to a sustainable and competitive economy. The program has been prolonged through the Scale-up Agenda 2022-2026 for a further roll out of ‘smart digitalisation’ to the manufacturing industries; one important educational route is the ‘Smart Makers Academy’, see next chapter Capacity building.

Links: Smart Industry (in Dutch)

8.8 Capacity building

In the following paragraphs, capacity buidling programmes in Austria and Switzerland are described, where digitalisation in industry are combined with sustainable energy aspects.

Master „Electrical Energy Engineering and Sustainable Energy Systems“, Austria

The Master’s program in “Electrical Energy Engineering and Sustainable Energy Systems” at the Vienna University of Technology focuses on the development and design of individual components to complete solutions for electrical energy systems. It also covers the analysis and modelling of the transformation to a sustainable CO_2-neutral energy system. The program emphasizes the development and application of technologies for renewable energy conversion and their integration into sustainable and digital energy systems, taking into account technical, economic, and ecological aspects.

Link: Electrical Energy Engineering and Sustainable Energy Systems

Master „Embedded Systems“, Austria

The Master's program in Embedded Systems at the Vienna University of Technology provides students with a foundation in analog and digital circuit designs, Mixed-Signal circuits, and System-on-Chips development. Students can gain expertise in designing application-specific Embedded Systems, handling system requirements, and ensuring security aspects through system verification. The curriculum covers circuit technology, systems engineering, requirements engineering, and circuit design, offering a theoretical and methodological base. The program allows specialisation in areas like automation, robotics, and energy networks.

Link: Embedded Systems

Master (MBA) „Twin Green & Digital Transition“, Austria

The Executive MBA in Green and Digital Transition at the Technical University of Graz is a program that aims to help corporate managers understand and implement the digital and “green” transition to more sustainability as a holistic and integrative process. The program is designed to last for 18 months (3 semesters) and is taught in English and German. Upon completion of the program, participants will be awarded an Executive Master of Business Administration in Green and Digital Transition (EMBA) degree.

The master programme contains several modules. For example, the “Advanced Digital Technologies” course is designed to provide an overview of established and emerging digital technologies, their maturity, and their implications. It covers topics such as Artificial Intelligence, Big Data, Virtual Reality, Blockchain, and Cybersecurity. Another course “Energy & Green Production” is designed to provide an overview of the Austrian energy system, its technical and regulatory background, and the challenges it faces in the context of climate neutrality. The course also covers topics such as energy system analysis, energy efficiency measures, and optimisation of energy systems.

Link: Twin Green & Digital Transition

Bachelor „Mechanical engineering" / Bern University of Applied Sciences, Switzerland

During this degree programme, participants can select from one of the following specialisations: product development, digitalisation in mechanical engineering or process optimisation. In the specialisation digitalisation in mechanical engineering, the focus is on the interplay of mechatronics, sensor technology and digital communication.

Link: Mechanical engineering

Bachelor „Electrical and Information Technology" / Bern University of Applied Sciences, Switzerland

Participants connect key concepts of electrical engineering with modern, programmable electronics and IT. The following technical specialisations are offered: electric mobility; electrical energy systems; embedded systems; automation, control and robotics; communication technologies.

Link: Electrical and Information Technology

Bachelor "Electrical engineering and Information Technology" / University of Applied Sciences and Arts Northwestern Switzerland

Participants can choose from two specialisations: electric power systems and drives or embedded systems design. Topics included in the electric power systems and drives specialisation: modern power electronics, advanced control algorithms, innovative measurement and sensor technology, and digitalisation.

Link: Electrical engineering and Information Technology

Bachelor "Mechanical Engineering and Innovation" / Eastern Switzerland University of Applied Sciences, Switzerland

One of the focal study topics is digitalisation. Topics treated: digitalisation in industry, handling product data, data systems, artificial intelligence, machine learning.

Link: Mechanical Engineering and Innovation

Certificate of Advanced Studies CAS Predictive Maintenance /Zurich University of Applied Sciences, Switzerland

Participants understand modern data-based processes in maintenance, such as predictive maintenance, condition monitoring and fault diagnosis. They recognise and use the potential of digitalisation technologies and plant data. They can develop a digitalisation strategy for the maintenance and operation of machines.

Link: CAS Predictive Maintenance

Certificate of Advanced Studies CAS Industry 4.0 / Zurich University of Applied Sciences, Switzerland

This programme includes the following modules: cyber-physical mechatronic systems (CPS) and smart factory concepts, Internet of Things (IoT), Smart Services (including maintenance), new manufacturing technologies and business models.

Link: CAS Industry 4.0

The two aforementioned CAS programmes are part of the **Master of Advanced Studies MAS Industry 4.0** at the Zurich University of Applied Sciences n Switzerland.

Certificate of Advanced Studies CAS Digital Industry / University of Applied Sciences and Arts Northwestern Switzerland

This programme focuses on how to implement a digitalisation strategy in a company. Participants understand digital processes, the latest technologies such as IoT, data analytics, digital twin, machine learning, smart factory concepts, etc., change management and future trends of the digital industry.

Link: CAS Digital Industry

Smart Makers Academy / part of Smart Industry Platform, Netherlands

The Smart Makers Academy is part of the Dutch Smart Industry scale-up agenda 2022-2026 and European Digital Innovation hubs. Together with Smart Industry Field Labs and public-private partnerships, knowledge and skills programmes are developed by so called "Learning Communities"; with the overall target of increasing the level of knowledge and skills of digitalisation at (SME) companies in the technical sector.

Link: Toolbox Smart Makers Academy (in English)

8.9 Projects

Project "KI4HVACS" (2022-2024), Austria

This project was financed with the funding programme "Energieforschung". The objective is to develop a machine learning model for HVAC (Heating, Ventilation, Air Conditioning) systems, capable of analysing various operational states to optimise performance and enable predictive maintenance. In this way the model not only aims to prevent wear and reduce costs but also mitigate their impact on the overall planned energy consumption. Anticipated outcomes include an energy saving potential of up to 30% and cost reductions of approximately 40% when compared to conventional systems. The practical validation of the model will be tested on real systems.

Link: KI4HVACS

Project „datalytics4HVAC" (2021-2026), Austria

The objective of this project is the development of modular and scalable inspection and diagnosis methods for automated operational performance and fault detection analysis of building services systems (HVAC systems). Methods such as model-based analyses and machine learning should be implemented. To validate the analytical methods, two existing office buildings along with two residential buildings will be tested.

Link: datalytics4HVAC

8.10 Conclusions on policies

The analysis of political instruments in Austria revealed that there are already many industry-specific programmes that include the topics of digitalisation and energy efficiency, particularly in the area of research and development. Although electric motor systems are not explicitly addressed, they can be included in research proposals. There is also the possibility of investment subsidies in this area. Another finding is that there is not yet a programme for large companies that promotes sensor technology and energy data acquisition.

Policies in Switzerland relate either to digitalisation in a broader sense, not focusing on motor systems specifically, or to energy efficiency in industry and in motor systems on a broader level, focusing less on digitalisation. As for the capacity building programmes, some of these do offer targeted information on the digitalisation of electric motor systems.

In the Netherlands, digitalisation is part of a broad knowledge and innovation programme, with links to sustainability and circularity. Participation and cooperation by industrial companies, research institutes and educational organisations is key. Within digitalisation the focus lays on developing the enabling function of digitalisation i.e. for sustainability purposes. It is up to interested stakeholders to develop specific projects on digitalisation in electric motor systems.

Digitalisation in Sweden has a long tradition, already in the early -90'ies the government supported computerisation through private loans to buy home computers. This raised the computer awareness significantly in Sweden.
Since a large part of Swedish industry is process-based (pulp & paper, chemicals, food), process control software has been implemented in large industries for a long time. To increase competitiveness of the Swedish small and medium sized industry, many research and innovation programmes have focused on digitalisation. Swedish "tradition" is that research and innovation programmes lead to involvement of interested actors and addresses relevant problems in industry that private businesses and academia can join forces to solve. By working on these problems, also general knowledge is acquired. They also grow awareness and build networks of actors.

Currently, some large programmes/initiatives are "SIP PiiA", "Klimatklivet", "Industriklivet" and "Avancerad Digitalisering". These four instruments are described in the Appendix in more detail.

Challenges that are not addressed by any initiative are the upcoming development and implementation of the NIS2 and CRA (Cyber Resilience Act) directives. These complex issues are on the horizon for all businesses to tackle, independent of size. Some support scheme to guide and help businesses understand these acts would probably be valuable.

9 Policy recommendations

Finally, based on the interviews, policy programmes' analysis and discussions with stakeholders, selected recommendations for supporting digitalisation in this area were derived:

1. **Policy makers should define clear energy savings targets for industrial companies**; as the actual energy use and savings potential is often not known, the starting point could be a mandatory more detailed analysis. The defined targets translate to clear requirements for companies to 1) save energy and 2) demonstrate the savings. Digitalisation technologies are a prerequisite to help achieve both goals. They fit into a larger need for transparency in business operations e.g. with the new EC Corporate Sustainability Reporting Directive (CSRD) (i.e. sustainability reporting, covering categories beyond just carbon, including pollution, water, waste, and biodiversity).
2. In general, **companies should set up a monitoring system for the main energy consumers**; for example, a mandatory monitoring system should be installed if the electrical output of an air compressor exceeds a certain level. In general, uniform interfaces (e.g. OPC UA) should be prescribed and standards for measurements in the energy sector for production plants should be drawn up. Control system manufacturers should therefore also be obliged to make the data available for export in an easily editable form.
3. If mandatory monitoring systems are not feasible, since finding available resources is such a crucial challenge **for smaller companies**, monetary support could help. If the **cost for installing a monitoring system or installing more sensors would be subsidised**, it could increase the willingness to invest in digitalisation technologies.
4. In general, **energy efficiency through digitalisation should be promoted more broadly, e.g. via a dedicated network. An independent institution or website should promote the energy benefits of digitalisation of systems**, for example through case studies. A dedicated platform should provide independent information on providers, guidelines and standards and describe the most important digitalisation technologies. The first step should not be to present complex solutions for digital twins and deep learning, but simple, robust solutions for data collection and predictive maintenance. A large number of abbreviations make it difficult for laypeople to get to grips with the topic, so the most important terms should be explained.
5. **A contact person could be established to start the implementation of digitalisation solutions in companies**. In general, all information materials on energy efficiency in companies should also include digitalisation solutions, e.g. for energy data collection.
6. For both smaller and larger industrial companies, finding the right consultants who specialise in the digitalisation of specific processes is a challenge. **Setting up a certification scheme for consultants or listing consultants indicating their special competencies**, e.g. in the framework of subsidy programmes or within the energy efficiency directive, could be a solution to this.
7. Furthermore, **training and capacity building measures** in this area **should be strengthened**. This can be done on a part-time basis via short, specific webinars that are also free of charge. These would serve to help small and medium-sized enterprises take the first steps towards digitalisation. Multi-day courses on this topic could be provided by training organisations. The focus would be on taking energy aspects into account when digitalising existing processes and machines. In addition to technicians, management is also an important factor in the implementation of company-wide digitalisation solutions, so training courses are also useful for this target group.

8. In the area of research, a research project focusing on the digitalisation and optimisation of electric motor systems in companies could be useful. The target group would be small and medium-sized enterprises in various sectors. **Typical systems, such as compressed air, refrigeration, pump or ventilation systems, which are often found in all sectors, should be analysed. Accompanying guidelines should be drawn up** based on the experience gained on how to analyse and digitalise these systems[3]. In addition to implementation, the project would also include documenting the savings. The results could then be disseminated via networks.
9. Similarly to energy audits**, 'digitalisation audits/scans' could be pushed** – potentially in combination with other existing policies or frameworks **- to establish companies' readiness level for digital technologies and which result in company-specific strategies for digitalisation**. Measures to be implemented should be identified. Since it is generally difficult to estimate the economic benefits of digitalisation, relevant guidelines and recommendations could help companies with that. If monetary support cannot be linked to profitability criteria, it could be given if the company can show that they are working on digitalisation, for example by having an assigned employee/group that aims to move the digitalisation work forward. Hence, **the company could get monetary support (or tax reductions)** on this basis.

[3] With [4] EMSA makes a first step in offering recommendations for specific systems.

10 Conclusions

This report presents the results of several workstreams from EMSA's research in the area of digitalisation of electric motor systems. The report shows all results, however, it presents in detail the results most relevant for policy makers.

The interviews revealed that the promotion of digitalisation solutions does not only have technical obstacles that can be solved by standardisation in this area. Other obstacles are of an organisational and financial nature, such as scarce resources, low awareness, strict profitability requirements, etc. Furthermore, they have shown, that the primary goal of digitalisation is not necessarily saving energy, as it enables many other benefits in production companies.

When researching the technical recommendations for digitalisation, it became clear that many different providers offer solutions, from sensors to their own clouds. This is a problem for companies that have a large number of systems from different manufacturers installed in their plant, as they have to work with parallel systems. There is currently no solution from the manufacturer in this regard. This means that the next step would be to transfer the data to a standardised system.

The case studies have shown that digitalisation solutions can lead to relevant savings in electric motor systems. Typically, higher savings can be achieved if the motor system is not optimised from the outset. High savings can also be achieved by using energy only when it is really needed. [7] The most crucial contribution of digitalisation solutions is to create transparency in terms of when and how (much) energy is being used.

The analysis of the energy consumption caused by the digitalisation of motor systems has shown in all cases that this remained under 1% of the analysed motor system's total energy consumption and was negligible. The benefits gained far outweighed the downsides of digitalisation in all cases.

The analysis of policy instruments revealed that there are already many industry-specific programmes that include the topics of digitalisation, competitiveness and energy efficiency, not only in the area of research and development, but also in (support of) business development (starts-ups, scale-ups) and capacity building. Although electric motor systems are not explicitly addressed in many of these programmes, they can be included e.g. in research proposals.

The Electric Motor Systems Platform EMSA will focus on demand flexibility and load management from 2024, but will continue to monitor digitalisation solutions in this area.

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12 Appendix

Appendix A: Details on Climate step (Klimatklivet), Sweden

Country:	**Sweden**
Name of policy (national language):	Klimatklivet
Name of policy (English):	Climate step
Managing organization:	Naturvårdsverket (The Swedish EPA)
Regional or national:	National
Internet link:	https://www.naturvardsverket.se/klimatklivet
Internet link to English description:	N.A.
Target group/ Companies impacted:	Climate step is the investment support that makes it possible to invest in fossil-free future technology and green transition. It can be applied for by companies, municipalities, regions and organisations throughout Sweden. The climate step is partly financed by the EU's recovery fund, NextGenerationEU.
Type of instrument (categorization):	Investment support to transition to fossil free technology
Type of incentive (e.g. EUR):	SEK
Budget:	13,7 Bn SEK since start, 4 Bn SEK 2024, 2,9 Bn SEK 2025 & 2026 respectively
Active time period:	2015 - 2028
Description:	Climate investments in many different areas can receive support from Klimatklivet, for example investments to switch to renewable fuels and renewable energy, build charging infrastructure or switch to more circular production methods. The important thing is that the climate investment contributes to reduced emissions of greenhouse gases and that the measure could not have been implemented without financial support. Companies can receive 20-65 percent in support, in accordance with EU state aid rules. Municipalities, non-profit associations, condominium associations and others that do not act on an economic market and that are not counted as companies can receive a maximum of 50 percent of the investment cost in support. Since the start in 2015, 5 246 projects have been granted, from 4 kSEK to 210MSEK project budget.
Example of success story (already published):	Steel company Ovako in Hofors has taken a big step to change with a new plant where hydrogen is produced for fossil-free heating of steel. In recent years, the number of granted applications to Klimatklivet has increased sharply in areas such as biogas, charging infrastructure and electrification, circular flows and agriculture.
Positive experiences (published):	In an evaluation in 2020, the evaluators write:" Based on applications, the Swedish Environmental Protection Agency has estimated that the annual emission reductions were 1.1 million tonnes of greenhouse gases (CO_2-e) from the projects receiving grants between 2016 and 2018. The evaluation of additional

	impacts examines how much of these emission reductions occurred due to Klimatklivet. The quantification of the additional impact for awarded projects is based on a survey. The results indicate that approximately 82 per cent of the estimated greenhouse gas emission reductions have been additional in the sense that they would not have occurred without Klimatklivet. The assessment of the impacts of Klimatklivet on Sweden's environmental objectives shows that measures linked to biogas and charging infrastructure have positive impacts on many environmental goals"
Negative experiences (published):	None.
Lessons learned:	-
Side effects: (NEBs)	Energy benefits are the side effect in this programme, that is focused on lowering CO_2 emissions.
Evaluation by EMSA members (questions below):	
• **Does it include/consider energy efficiency aspects?**	Yes, if the energy efficiency action includes decreases in CO_2 emissions. Until today, 103 energy efficiency projects have been granted, saving about 25 tCO_2e
• **Does it include/consider digitalization aspects?**	It can include investments in digitalisation to reduce CO_2 emissions. The project database is not publicly available, so it has not been possible to evaluate the number of projects that include digitalisation.
• **Is it applicable to electric motors?**	It could be, but the project must show decreased CO_2 emissions through the actions involving electric motors. In Sweden, electricity has very low associated CO_2 emissions, hence electricity savings do not generally mean CO_2 savings. This is different in an international context.
• **Is it applicable to other countries?**	Yes

Appendix B: Details on Advanced Digitalisation (Avancerad Digitalisering), Sweden

Country:	**Sweden**
Name of policy (national language):	**Avancerad Digitalisering**
Name of policy (English):	Advanced Digitalisation
Managing organization:	Vinnova, ABB, Ericsson, Saab & Teknikföretagen
Regional or national:	National
Internet link:	https://www.avanceraddigitalisering.se/
Internet link to English description:	n.a.
Target group/ Companies impacted:	SME, large companies, research institutes, public authorities
Type of instrument (categorization):	Research and innovation, demonstration, professional education
Type of incentive (e.g. EUR):	SEK
Budget:	2 Billion Sek/year (50/50 Government/industry)
Active time period:	2023-2033
Description:	The work in this programme follows six overarching goals: - contribute to the next generation of advanced, powerful and secure digital solutions - developed in Sweden. - strengthen Sweden's attractiveness in terms of research and innovation investments. - ensure increased competitiveness for the industry operating in Sweden. - contribute to raising the competence and implementation ability of Swedish business in the area of advanced digitalisation. - constitute a collaboration platform and function as a knowledge hub for other Swedish initiatives in the field of digitalisation. - contribute to society's digital transformation, sustainable development and the work to achieve the Swedish environmental goals. Intervention areas include: - Dialogue and collaboration - Learning and competence development - Research & Innovation - Environments for test and demo The programme Advanced Digitalisation co-finances projects that focus on high-tech advances in the areas of secure digital platforms, cyber security, AI end-to-end, edge, cloud, 5G/6G networks, autonomous systems, data-driven development, model- and simulation-driven development and software development.
Example of success story (already published):	Not yet. However, since the start, 92 projects have been financed with about 965 MSEK.
Positive experiences (published):	Not yet.

Negative experiences (published):	Not yet.
Lessons learned:	Not yet.
Side effects: (NEBs)	It is noticeable that three large industrial companies and the Swedish industry association join forces with the Swedish authority for innovation (Vinnova). It shows how important this programme is to them.
Evaluation by EMSA members (questions below):	
• **Does it include/consider energy efficiency aspects?**	Energy efficiency is not mentioned in the programme texts. Of the 92 projects started until now, no projects are directed to energy efficiency.
• **Does it include/consider digitalization aspects?**	Yes. Of the projects started, many look at AI for applications in X, where X can be any industry.
• **Is it applicable to electric motors?**	The programme is broad, so electric motors could be included as long as a project fits the framework of the programme. For example, application of a digital twin model of a motor could fit well with the programme.
• **Is it applicable to other countries?**	Yes.

Appendix C: Details on Process industrial IT & Automation – Strategic innovation programme (Strategiskt innovationsprogram Processindustriell IT och automation (SIP PiiA)), Sweden

Country:	**Sweden**
Name of policy (national language):	**Strategiskt innovationsprogram Processindustriell IT och automation (SIP PiiA)**
Name of policy (English):	Process industrial IT & Automation – Strategic innovation programme
Managing organization:	RISE (www.ri.se)
Regional or national:	National
Internet link:	https://sip-piia.se/
Internet link to English description:	https://sip-piia.se/en/
Target group/ Companies impacted:	Process industries, research institutes, consultants
Type of instrument (categorization):	Research and innovation to strengthen the digitalisation of Swedish process industry
Type of incentive (e.g. EUR):	SEK
Budget:	53 MSEK/year
Active time period:	2014-2026
Description:	The initiative managed to get funding via the investment in strategic innovation programs in 2013 with the task of strengthening the digitalisation of Swedish process industry. PiiA is one of the 17 strategic innovation programs funded by Vinnova, Formas and the Swedish Energy Agency. By forging new collaborations between industrial companies, technology companies and research partners, new techniques, working methods and tools are explored and implemented. More and more technology companies are adapting their products to industry. Through IndTech, Swedish process industry becomes smarter and more efficient, thereby more sustainable and less environmentally destructive. PiiA guides the industry to find new collaborations to test new technology and develop their working methods. PiiA also works with external intelligence and dissemination of good examples both within PiiA's portfolio and from the lessons we can learn from other countries and investments.
Example of success story (already published):	Pulp mills can halve electricity consumption with smart technology Industry studies - The consequences of digitalisation on the raw materials and process industry
Positive experiences (published):	In the sixth year evaluation of the programme, it was concluded: "According to the assessment of the evaluation, PiiA has had a significant knowledge-raising effect at system level which to a large extent derives from an extensive exchange of knowledge between actors within the framework of the projects. Knowledge transfer takes place in several different directions between companies in raw materials and process industry, technology suppliers and R&D executors and includes

	knowledge of general as well as conditions and needs within the raw material and process industry and knowledge of specific technical applications such as knowledge of working methods.”
Negative experiences (published):	-
Lessons learned:	PiiA with its strong focus on application and industry's needs risk missing out on interesting research questions and scientific results not being produced. This has been addressed by arranging events in conjunction with research schools, e.g. https://indtech-graduateschool.se/ and https://www.es.mdu.se/reliant/.
Side effects: (NEBs)	Through industry-academia consortia formed in PiiA, many EU projects have been applied for.
Evaluation by EMSA members (questions below):	
• **Does it include/consider energy efficiency aspects?**	The programme include, but is not focused on energy efficiency aspects. Since the programme is very broad, energy is one of the aspects treated alongside with productivity, safety, quality etcetera.
• **Does it include/consider digitalization aspects?**	It is focused on digitalisation.
• **Is it applicable to electric motors?**	Yes.
• **Is it applicable to other countries?**	The programme format could very well be applied in other countries.

Appendix D: Details on Industrial leap (Industriklivet), Sweden

Country:	**Sweden**
Name of policy (national language):	Industriklivet
Name of policy (English):	Industrial leap
Managing organization:	Energimyndigheten (Swedish energy authority)
Regional or national:	National
Internet link:	https://www.energimyndigheten.se/forskning-och-innovation/forskning/industri/industriklivet/
Internet link to English description:	https://www.energimyndigheten.se/en/innovations-r--d/energyintensive-industry/the-industrial-leap/
Target group/ Companies impacted:	Industry
Type of instrument (categorization):	Research, pre-studies, implementation of technology
Type of incentive (e.g. EUR):	SEK
Budget:	1,3 Bn SEK 2023 (2,17 Bn SEK funding, 5,08 Bn SEK cofinancing during 2018-2023)
Active time period:	2018-2030
Description:	Within Industriklivet, grants can be made for preliminary studies, research, pilot and demonstration projects and investments in the following three areas: - Process industries' greenhouse gas emissions - Negative emissions (CCS) - Strategically important measures in industry The goal is to decrease process industry related greenhouse gas emissions. The 147 granted projects range from 180 kSEK to 295 MSEK public funding, with complementary private funding so that a total project volume of 9 Bn SEK has been activated. Industriklivet's focus during the first years was on the most emission-intensive industries. Through Industriklivet's expansion in 2019 and 2021, other areas are now also covered, such as biogenic emissions from the pulp and paper industry as well as electricity and district heating.
Example of success story (already published):	Two of the largest projects that have been granted support, "Project AIR – CCU with H2 electrolysis for production of sustainable methanol" and HYBRIT Pilot Fossil free iron- steel and H2-production" are among the largest transition projects towards electrification of industry Sweden has seen.
Positive experiences (published):	Industriklivet's beneficiaries work with long-term projects. In many cases, it is about identifying and eliminating obstacles to be able to change production processes or to achieve specific sub-goals, rather than launching concrete products that reduce emissions in the short term, within the project period. Among the projects there are certainly already several commercialisable products and systems that have direct effects on emission levels,

	but it will be some time before we see major reductions in all industries. In an evaluation, it appears that the beneficiaries see Industriklivet as a platform for technologies and processes to grow.
Negative experiences (published):	None identified
Lessons learned:	-
Side effects: (NEBs)	The programme has given grants to quite many CCS pre-study projects. A synthesis shows that a large knowledge base has been built up which, among other things, can include new and returning customers for the benefit of the applicant. Likewise, those who wish to gain a deeper understanding of the development of bio-CCS in Sweden and the conditions that characterise the industry's future choice of path are favoured of this accumulated knowledge.
Evaluation by EMSA members (questions below):	
• **Does it include/consider energy efficiency aspects?**	Yes, but the energy efficiency projects must show decreased greenhouse gas emissions.
• **Does it include/consider digitalization aspects?**	It can include investments in digitalisation to reduce greenhouse gas emissions. The project database shows few projects with digitalisation only, but one example is "AI assisted carbon capture in biomass-based cogeneration plants"
• **Is it applicable to electric motors?**	It could be, but projects must show decreased greenhouse gas emissions through the actions involving electric motors. In Sweden, electricity has very low associated CO_2 emissions, hence electricity savings do not generally mean CO_2 savings. This is different in an international context.
• **Is it applicable to other countries?**	Yes.

Appendix E: Summary of interviews in Sweden

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EMSA digitalisation interviews

A Swedish perspective

Abstract

The International Energy Agency's technical collaboration program Energy Efficient End-use Equipment sets out to promote energy efficiency as a key aspect in sustainable energy systems. A sub-project focuses on innovation and digitalisation in which the Swedish Energy Agency is a project participant.

Digitalisation is considered to have an enormous potential for industries in form of increased productivity and competitiveness. To gain understanding of the challenges and possible solutions the industries face concerning digitalisation, as well as to analyse how authorities can facilitate digitalisation, interviews with manufacturing industries and suppliers of digitalisation solutions have been carried out by CIT Industriell Energi AB and financed by the Swedish Energy Agency.

The large industries that have been interviewed in this project have been working with digitalisation for a long time. Many of the large industries answer that energy efficiency is rarely the sole motivation for digitalisation but can be part of it. All large industries agree that lack of competence is one of the major challenges today. Many different skills are required when it comes to digitalisation, both in terms of software and hardware skills.

Smaller industries tend to have accomplished significantly less than the large industries when it comes to digitalisation. If they are looking into digitalisation concepts, it usually involves installing more sensors in their process or modernizing their economic/business system. The largest challenge for smaller industries is resources.

The interviewed suppliers provide digitalisation solutions in many different forms. The goal of digital twins and predictive maintenance is generally to achieve an efficient and continuous process, which often indirectly benefits energy efficiency. For installing more sensors and getting a better understanding of the process, energy efficiency can be a more prominent sale argument.

It is likely that authorities can make more difference by directing efforts to facilitate digitalisation in those industries that have less profound experience with digitalisation technologies. Information measures, including good examples, are the most straightforward type of measures that the energy agency can provide. A website focused on digitalisation technologies and its connection to energy- and resource efficiency should be the first measure to implement. A similar measure suggested is to have a digitalisation advisor/division at the energy agency that can provide information and advice regarding digitalisation.

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1 Introduction

The International Energy Agency's (IEA) technical collaboration program (TCP) Energy Efficient End-use Equipment (4E) sets out to promote energy efficiency as a key aspect in sustainable energy systems. An annex to this TCP is the Electric Motor Systems Annex (EMSA) which aims to raise awareness and provide guidance and tools to utilize efficient motor systems worldwide. A sub-project to EMSA focuses on innovation and digitalisation in which the Swedish Energy Agency is a project participant. It is the digitalisation part of this sub-project that the current report concerns.

Digitalisation is considered to have an enormous potential for industries in form of increased productivity and competitiveness. Digitalisation in this context means to use digital technologies to change and optimize industrial processes and equipment. Digital technologies include a wide range of technologies, from basic sensors to advanced concepts like digital twins and machine learning. An often-used term when reading or discussing industrial digitalisation is Industry 4.0 which hints at a fourth 'revolution' in the industry.

This report compiles interviews that were carried out in April-June 2022 regarding digitalisation in Swedish industries. The aim of the interviews was to gain understanding of the challenges and possible solutions the industries face concerning digitalisation, as well as to analyse how authorities can facilitate digitalisation. The report is financed by the Swedish Energy Agency.

1.1 Brief background

The scientific literature and available reports constitute a vast body of information which will not be thoroughly reviewed here. However, some selected literature sources are covered to provide context.

A previous report[1] published by EMSA provides a comprehensive overview of digitalisation technologies relevant for motor driven systems and categorizes them in four different levels: Communication between components, Data analysis & operation optimisation, Technologies adding further advantages and, Other relevant technologies. These levels are visualised along with included technologies in Figure 1. A conclusion is that all reported digital technologies can be used to increase energy efficiency but that it is difficult to attribute actual energy savings to

[1] Kulterer et al. (2022), Classification of digitalization technologies for electric motor driven systems, https://www.iea-4e.org/wp-content/uploads/2022/06/EMSA_report_classification_2022june.pdf

specific technologies. The reason is that energy efficiency is not usually the motivation for implementing a digital technology. Thus, it is rare with real-life examples that present how much energy a digital application has saved. The current work can be seen as a spin-off from that study, and a parallel work with finding relevant case studies is being performed.

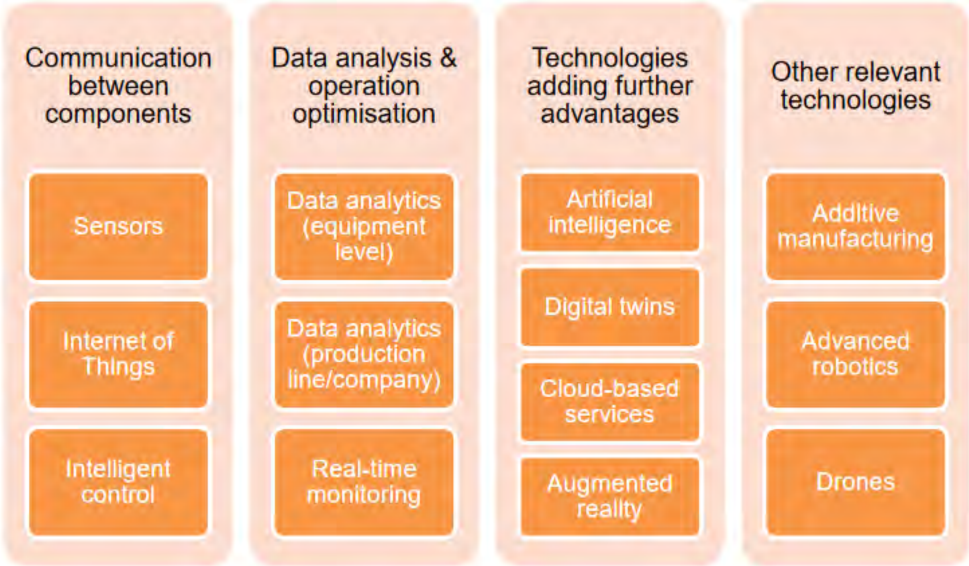

Figure 1. Summary of digital technologies presented in the EMSA-report *Classification of digitalisation technologies*

In the TCP Industrial Energy-related Technologies and Systems (IETS) a similar work regarding digitalisation in industry has begun and a first report[2] has been published. The main objective is to stimulate the adoption of digitalisation technologies for energy efficiency improvement and GHG emissions reduction in the energy-intensive process industries. In the Task discussions, experts agree that the analysis of large data sets will be key for competitiveness, productivity growth, and innovation and that its potential is only beginning to be exposed. However, the application of digitalisation, artificial intelligence and related technologies in the energy-intensive process sectors is relatively early stage compared to applications in other sectors such as banking, healthcare, manufacturing, insurance, web-based retail, etc. The Task work also resulted in proposals for two new Subtasks which now are implemented and running:

- Methods and Applications of Digital Twins
- Lessons Learned and Created Values by Digitalization

[2] Amazouz and Stuart. (2020), Digitalization, Artificial Intelligence and Related Technologies for Energy Efficiency and GHG Emissions Reduction in Industry - Subtask1: Needs and Interests Assessmenthttps://iea-industry.org/app/uploads/Task-XVIII-Subtask-1-Final-Report-20210915.pdf

A report[3] from 2016 describes the Swedish strengths and challenges regarding industrial digitalisation. One identified strength was the high Network Readiness Index – which aims to measure the degree of readiness of countries to exploit opportunities offered by information and communications technology (ICT) – in which Sweden was ranked 3rd in the world (ranked 2nd in the world as of 2021[4]). Sweden was overall estimated to have a strong ICT sector. One identified challenge was lack of competent working force. Examples of competences that were hard to recruit were programming, automation, and process control. An issue of concern was also the decreased interest for scientific subjects among students in schools. One suggested measure to promote digitalisation in Sweden was increased cooperation between industries, both in similar and different branches, as well as with academia. Increased cooperation can lead to more innovation, creativity, and development, as well as pilot projects and test beds. Another suggestion was financial support for small and medium enterprises (SME) since they usually do not have the resources to make big investment in research and developments.

There is a plethora of studies regarding industrial digitalisation, many involving interviews and enquiries. The conclusions are often that large industries are significantly more developed when it comes to digitalisation than smaller ones, and that challenges lie in a shortage of competence and resources as well as the concern of cybersecurity.

2 Method

2.1 Interviewed companies

The industries that have been interviewed in this study are either manufacturing industries or suppliers of digitalisation solutions and are presented in Table 1. Industries outside this area such as construction, real estate, or transport are not included. The interviewed manufacturing industries constitute a heterogeneous group with some companies being among the most energy-intensive in Sweden (using several TWh/year) while others are significantly smaller (in the range of a couple of GWh/year). The selected industries can, however, not be seen to cover the entire spectrum of industries in Sweden.

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[3] Roland Berger and VINNOVA (2016), Digitalisering av svensk industri – kartläggning av svenska styrkor och utmaningar, https://www.vinnova.se/publikationer/digitalisering-av-svensk-industri/

[4] Portulans Institute (2021), The Network Readiness Index 2021, https://networkreadinessindex.org/

A challenge when selecting companies to interview is to find employees that are suitable and willing to participate in an interview. A significant share of the interviewed companies has been selected since prior contact with them (in other projects) has facilitated communication. In some cases, the initial communication has gone through official channels such as general mailing addresses (e.g., info@...) or filling out contact forms.

Table 1. List of interviewed companies.

Company	Type of industry	Interviewed person
Inovyn	Chemical industry – Main products are polyvinyl chloride, caustic soda and hydrochloric acid	Ingemar Berg – Technical manager Nina Brinktell – Reliability engineer
Borealis	Chemical industry – Main products are olefins and polyethylene	Marcus Hedlund – Head of industrial digitalisation
SKF	Bearing and seal manufacturer	Patrik Dahlman – Director group manufacturing development
Södra Skogsägarna **Business area: Södra Cell**	Forestry cooperative	Daniella Johansson – Energy coordinator at site Mörrum
Södra Skogsägarna **Business area: Södra Cell**	Forestry cooperative	Sara Ingves – System engineer at site Mörrum
Sandvik **Business area: Materials Technology**	Engineering company that manufactures e.g., stainless steels and special alloys, metal-cutting, and furnace products	Susanne Lindqvist – Energy coordinator
Semper	Producer of infant formula and baby food	Conny Kvick – Technical manager at site Götene
Wernersson Ost	Company that works with cheese ripening and packaging	Johan Wärnbring – Vice CEO
ABB	Works with electrification, process automation, motors and drives, and robotics	Lena Delbom - Digital Lead
Sensenode	Supplier of digitalisation and energy services	Jonas Eriksson – CCO & Business developer
Siemens	A supplier of technologies in the areas of electrification, automation and digitalisation	Erik Lundén - Digital Enterprise Sales Specialist

2.2 Questions

All interviews have been conducted in the form of a dialogue where the interviewed person first has given examples of the digitalisation work the company has done, what they are currently doing, as well as describing the driving forces behind it. They were also asked about how ideas arise and how the ideas become reality. The second half of the interviews typically revolved around challenges and whether they can think of anything that would facilitate their digitalisation work. Although the questions were carried out in the form of a dialogue, the goal was to get into the questions presented in Table 2 and Table 3 (sent in advance to the companies). In general, the interviews lasted about 30 to 45 minutes.

Table 2. Questions for industrial users

Industrial users	
Base question: Have you tried to implement any form of digitalisation?	
If yes	**If no**
What was the main motivation for implementing digitalisation?	Are you interested in implementing digitalisation in your process? - If so, what are you interested in? What would you like to achieve? - If not, why not?
What have you tested / implemented?	Have you sought information about what opportunities there are? If so, where did you look?
What did the process of implementing a digitalisation measure look like (give an example): - Where did the idea come from? - How did you get started? - What challenges did you encounter?	Is there a need for more accessible information? In which areas?
For a given example, what improvements did you expect and what was the result? What effect has it had on production / energy efficiency? Is it possible to measure?	What obstacles and challenges do you see regarding digitization?
Have you evaluated the profitability? What was the result?	Do you see any risks with digitalisation? What are your thoughts on cybersecurity?
Did you get any added value from digitalisation? (i.e., something beyond the original purpose)	
Can you name some general challenges when it comes to digitalisation?	
Is there anything that would have made the work easier for you? For example, policy instruments, standardization, or more easily accessible information. Feel free to specify what would be useful.	
Do you see any risks with digitalisation? What are your thoughts on cybersecurity?	

Table 3. Questions for suppliers

Suppliers
What do you offer? What is the purpose? What are your selling points (is added value used as a selling point)?
What effect does your product have on energy use?
What does the process of implementation look like? - How do you receive the order (request from customer or selling effort)? - How do you implement your product? - Do you do any type of follow-up?
Can you name some challenges when it comes to digitalisation? - Competence? - Data-related? - Lack of knowledge about existing products? - Financial or legal?
Is there anything that would have made the work easier for you? For example, policy instruments, standardization, or more easily accessible information. Feel free to specify what would be useful.

3 Results

This section presents a compilation of the performed interviews. Since the answers differed significantly between companies, the results are divided into three sections: large companies, small companies, and suppliers. The words "large" and "small" companies are based on subjective assessments rather than any formal definition, see 2.1.

3.1 Large industries

3.1.1 Experiences and motivations

The large industries that have been interviewed in this project have been working with digitalisation for a long time. For example, they installed sensors on important equipment decades ago, and many parts of the business are today automated. In relation to Figure 1 presented earlier, most large industries have implemented technologies in the first two levels (from the left) and have ongoing projects regarding technologies in the third and fourth level, for example, AI, big data, drones or digital twins. Installing even more sensors, especially wireless transmitters, for more information about their processes and potential for optimization is continuous work.

The motivation and drivers for digitalisation in large industries is generally based on:

- Production or energy efficiency
- Quality
- Safety and security. Digitalisation can lead to employees not having to interact as much with machinery and that the risk of human error interfering with the process is reduced.

Many of the large industries answer that energy efficiency is rarely the sole motivation for digitalisation but can be part of it. Profitability is what governs, which means that focus often lies on production or quality aspects. Profitability is stated to be valued in several different ways – payback period, internal rate of return, life cycle costs – but a general answer was that initiatives with a repayment period of about 2–3 years are significantly more probable to receive resources for implementation. If a digitalisation measure that increases energy efficiency can achieve such a high level of profitability, it thus has a good chance of being implemented. The industries that have been interviewed also have ambitions for a green transition, where energy efficiency and digitalisation are facilitating factors.

3.1.2 Idea and implementation

Digitalisation initiatives can originate from several different sources. One of the industries mentions that operation personnel often identify a need or an opportunity for digitalisation in their daily work. They point this out to the production management, which results in a preliminary project. Digitalisation ideas can also arise within systems for evaluating accidents and incidents. Several large industries emphasize that they are part of an international corporate group where there is a central working group (or person) for digitalisation and that ideas often come from there, or at information meetings/workshops within the organisation. Suppliers also get in touch frequently regarding ideas, services, and products. Collaboration with universities can also lead to digitalisation ideas, often in the form of an initial master thesis work.

When a decision has been made to move forward with an idea, the companies typically gather suppliers and open for discussions and site visits and start taking in offers. One of the industries emphasizes that it is better to use suppliers than to try to build something internal of your own because the suppliers have worked with the idea / service / product for a long time and many of the initial faults, mistakes and bugs are thus avoided. Another interviewed industry – which is a large international company – has gone the other way and acquired an IT company that now works internally with digitalisation projects, and they develop their solutions themselves.

3.1.3 Challenges

Below are the challenges that have been mentioned in the interviews.

Data. Machine learning algorithms need data to practice on. Even if there is a large amount of data in large industries, the processes are typically operated in a continuous and stable way, which gives a narrow picture of what conditions the industry may face. Human expertise about a process and its behaviour is typically based on years of experience and discussions, something that is difficult to replace with an algorithm that trains on large amounts of similar data. Algorithms may also fail in judging whether a measurement value is unreasonable (for example a faulty meter) or just unusual. It is not uncommon for other solutions, such as statistical analysis and rigorous modelling, to perform better than advanced forms of AI and machine learning.

The amount of data that arises from sensors and measurements can be a challenge. No industry has mentioned issues regarding data storage specifically even if one industry mentions that due to images being taken every day (globally) their daily accumulation of data volume is in the order of terabytes. However, creating value from the large volumes of data can be troublesome.

Competence. All large industries agree that lack of competence is one of the major challenges today. Many different skills are required when it comes to digitalisation, both in terms of software and hardware skills. Engineers in IT, machinery and automation are needed to make digitalisation solution work as intended as well as understanding it. Although several companies estimate that there is not a shortage of software engineers, there are few software engineers that have the required understanding of the actual equipment or process. Another issue that, historically, many large industries have had complete control and understanding of all their equipment, both hardware and software, while with new digital technologies there are several 'black boxes' which increase the demand for external competence.

Resources and change. There is usually a high level of activity at industrial sites and employees have routines and working habits. Implementing a digitalisation solution, e.g., an optimized and automated process control or predictive maintenance, requires many initial internal and external meetings, discussions, and decisions. Although large companies tend to have more resources for process development than small companies it may still be challenging to find time for the right personnel give their input and for the management to come to a decision.

Once the digitalisation solution is implemented it can also require the employees to adapt quickly to new routines.

Cybersecurity. All industries state that cybersecurity is a risk and challenge for the implementation of digitalisation. The most severe risk in case of a cyber-attack is access to control systems. If an external part could control processes at the site it could lead to significant damage, both in terms of physical damage on equipment and employees (e.g., in case a high-temperature or high-pressure systems is out of control) and in terms of economic damage. Attacks on logistic information and interruptions of the information flow can also have a major disruptive impact on the company. For this reason, the wireless transmitters that many industries are now installing should never be directly linked to the control systems. Another cyber-security risk is the risk of confidential data being leaked, such as recipes for products or specific knowledge about solutions. The concern of leaked data is prominent since digitalisation measures often include cloud-based data storage, which means that companies have less control of who has access to it. Data leakage does not have to be a result of a cyber-attack but could instead be unintentional sharing since several actors (suppliers, consultants, customers) might have access to it.

Integration of new and old software and hardware. Existing equipment at industrial sites might be decades old, and it is not always straightforward to integrate them with new digital technologies.

Which idea is the best? There is a plethora of ideas and possibilities when it comes to digitalisation, but it is difficult to estimate which ideas should be invested in and how different ideas might interact.

3.1.4 Suggestions on how authorities could support digitalisation

When asked how authorities can facilitate digitalisation efforts in industry, several large companies find it hard to come up with suggestions. A common answer from the largest companies is that they know best what solutions and possibilities exist on the market and that they don't believe that, for example, national energy agencies can help them in any significant way. Some suggestions that have come up are however:

Good examples. Sharing good examples of digitalisation solutions is an effective way to engage and motivate companies to evaluate if that solution could be implemented in their own process.

Digital meetings/webinars about digitalisation where experts present and discuss technologies or concepts. An example that was mentioned in an interview was the webinars held by Energikontor Väst[5] on different subjects. These are not focused on digitalisation, but their format could be an inspiration if webinars on digitalisation would be implemented.

Early information about guidelines, regulations, and policies. One industry drew a parallel to when a certain chemical compound was not allowed to be used. Information about the restriction reached them late and caused a major upset in the production planning. If authorities could help with informing about such regulations in an early stage, it would be appreciated. In terms of digitalisation, it is however difficult to determine exactly what such restrictions or guidelines would be.

Advisors on digitalisation. An unbiased and competent advisor on the National Energy Agency could be useful if, for example, energy coordinators want to know more about how to proceed with digitalisation technologies and what is important to keep in mind. Not all large companies have a digitalisation group or an IT division that is involved in the production process.

3.2 Small industries

3.2.1 Experience and motivation

It is worth mentioning that the responses for the smaller industries are heterogeneous, but they tend to have accomplished significantly less than the large industries when it comes to digitalisation. If they are looking into digitalisation concepts, it usually involves installing more sensors in their process or modernizing their economic/business system (e.g. generating automated reports on sales and volumes or available spare parts).

When it comes to motivating a digitalisation implementation, profitability is naturally key amongst the smaller industries as well (a payback period of 1-2 years was mentioned as “easy to implement”). In one interview it was stated that there exists a scepticism towards if it really could be profitable to simply install more meters. However, the industries believe that digitalisation will gradually happen but that it simply takes time.

3.2.2 Challenges

Resources and competence. The largest challenge for smaller industries is resources (people, time, and money). Compared to large industries they have significantly fewer employees and suitable competences for implementing new

[5] Regional energy agency in the west of Sweden (there are 16 of these in Sweden).

digitalisation technologies, and the few employees that would be suitable to be involved in digitalisation efforts usually have a lot to do. Simply put, small industries use relatively more of their resources for the daily operation rather than developing and optimizing their process compared to large industries. Gathering resources to implement a digitalisation measure is therefore difficult.

What's the point? It's not always clear what the benefits of digitalisation will be. For example, measuring electricity consumption or temperature levels on selected machines or systems will not bring in additional revenue or reduce expenditures if those machines/systems already operate at optimised performance. And if the measurements show that a machine is over- or under-dimensioned it will lead to more work and more investments (in time and money) if the issue should be addressed. Although there is a value in knowing how, for example, a cooling system is performing, it's not clear that that knowledge is desirable enough to invest, especially since the available resources are scarce. Furthermore, other aspects, such as carbon emissions, tend to have higher priority than energy efficiency and it can therefore be hard to convince management to invest in digitalisation for energy efficiency compared to installing solar cells or buying eco-labelled electricity.

3.2.3 Suggestions on how authorities could support digitalisation

Help in finding the right competences for specific processes. A recurring challenge – not specifically related to digitalisation – is to find consultants and external help that have knowledge about the specific processes and equipment at industrial sites. A suggestion from the interviews was a competence matrix that would facilitate choosing the most suitable support/supplier.

Information measures. Smaller industries are less aware of the possibilities and details regarding digitalisation. To learn more, authorities could provide an information platform/website where digitalisation technologies are described along with reminders on things to keep in mind when implementing them. Today, one of the interviewed smaller companies report that they use search engines or work-related social platforms (such as LinkedIn) for finding information. Although there is nothing wrong with finding information in such ways, an unbiased website with the purpose to facilitate digitalisation efforts would provide a good complement.

Monetary support. Since finding available resources is such a crucial challenge for smaller industries, monetary support could help. If the cost for installing a monitoring system or installing more sensors would be subsidized it would likely increase the willingness to invest in digitalisation technologies.

3.3 Suppliers

The interviewed suppliers provide digitalisation solutions in many different forms, for example installing sensors, predictive maintenance, digital twins, and other software development. When asked about their sale arguments for digitalisation the answers depended on the technology offered. The goal of digital twins and predictive maintenance is generally to achieve an efficient and continuous process with as few upsets as possible, which often indirectly benefits energy efficiency. For installing more sensors and getting a better understanding of the process, energy efficiency can be a more prominent sale argument although words like sustainability, circular economy and resource efficiency are more often used.

Getting orders from large industries is usually a result of having an established and continuous contact with them. However, smaller industries are starting to contact suppliers about digitalisation at a higher rate than before, likely because the technologies are becoming more mature, and the cost of digitalisation solutions are coming down. One common way for suppliers to market themselves is through fairs and events which can initiate discussions from both small and large industries.

3.3.1 Challenges

Organisational. When digitalisation in any form is to be implemented, the IT section of the customer company usually needs to be involved. However, it is not uncommon that IT sections are focused on fixing daily issues not related to the industrial equipment or processes, e.g., trying to fix computer problems. This weak connection between the IT part of a company and the actual production process can significantly hinder and delay digitalisation as one group may not use the same taxonomy as another group, which may also differ from the supplier, and many meetings and clarifications are often required. Furthermore, digitalisation is mentioned to change the hierarchy/structure of a company since data is in focus rather than individuals. A result of this shift in focus is that some employees become less or more important for the company than earlier, which is mentioned to be positive since it democratizes the company, but it can also cause a stir in the organisation.

Resources and competence. Resources are often limited on both the supplier and customer side and implementation processes can drag out for several months longer than anticipated. When the supplier is working in a new process/branch it takes even more time to understand the issues and possibilities on how to implement digital technologies. Knowledge on the supplier side regarding specific industrial process and equipment is important when implementing digital technologies, while on the customer side it is important that they understand what they can expect from the technology.

Standards. The lack of standards was mentioned to have been a significant problem in the past when trying to connect different machines and systems to each other since they use different protocols. However, standardization has been improving over the last couple of years and is less of a problem now. The open-source standard OPC UA[6] was mentioned to have facilitated communication and integration of systems significantly.

3.3.2 Suggestions on how authorities could support digitalisation

The challenges that the interviewed suppliers mention are in some ways already being addressed. In one interview it was mentioned that VINNOVA[7] and the Swedish Energy Agency has helped with raising awareness and knowledge about digital technologies, and that there already exist funding opportunities for implementation (especially for new and innovative ideas). The suppliers find it hard to answer what the authorities can do to address some of the main challenges, such as time-consuming processes and lack of competence. Many projects are innovative, large, and complex and there is no silver bullet on how to accelerate the implementation. However, the Swedish Energy Agency could help with strengthening the connection between digitalisation and energy efficiency, by e.g., promoting the energy benefits from digitalisation (which is what this EMSA-task aims to do). A standard for calculating energy KPIs was also mentioned as an idea on how the energy agency can support digitalisation. No concrete examples were however given.

4 Ideas on how authorities can facilitate digitalisation

The performed interviews confirm what several others have described regarding challenges in industrial digitalisation as well as the differences between large and small companies. The focus of this chapter is focused on what authorities can do to facilitate digitalisation, taking the inputs from the interviews into account. It is likely that authorities can make more difference by directing efforts to facilitate digitalisation in those industries that have less profound experience with digitalisation technologies and have not yet installed many sensors or data collection systems (most often small industries). Due to the energy perspective of the project, the focus will specifically be on what the national energy agency can do.

[6] Open Platform Communication Unified Architecture
[7] Sweden's innovation agency

4.1 Information measures

Information measures are the most straightforward type of measures that the national energy agency can provide. A website or platform focused on digitalisation technologies and its connection to energy- and resource efficiency should be the first measure to implement. It could for example be part of the energy agency's guide for energy efficient companies[8] (there are in general many parallels between the work for energy efficiency and the work for digitalisation). The goal of the platform should be to provide an overview of different technologies as well as details on how to implement them. A conclusion from the interviews is that the target group is industries that have not yet implemented any significant digitalisation, the information platform does not need to describe the implementation of more advanced technologies in detail, such as digital twins or deep learning, but should focus on the more mature technologies such as data collection and predictive maintenance. The platform should also provide real-life pedagogical examples in the form of case studies (a suggestion from several companies), as well as a quickstarter guide for digitalisation (which is also being developed in the current EMSA-task).

There are a lot of abbreviations, acronyms and words in the digitalisation community that can be overwhelming for newcomers, even for basic sensor technology and data collection. Some examples: SCADA, DCS, RFID, M2M communication, PLC, edge/fog/cloud computing, data diodes, and OT. Clear definitions and examples of these should be provided by the platform. Information on available "self-check" tools[9] or models to assess how ready an industry is to take advantage of digitalisation technologies should also be provided.

A similar and recommended measure that has been suggested in the interviews is to have a digitalisation advisor/division at the energy agency that can provide information and advice regarding digitalisation. Such an advisor could be compared to the municipal energy and climate advisors that exist in Sweden which SME (among others) can contact free of charge to receive unbiased service regarding energy. There are also regional digital coordinators as well as the authority DIGG[10] that aim at coordinating the digital development in Sweden. The purpose of the digitalisation advisor at the national energy agency would be to answer questions and provide detailed information regarding digitalisation

[8] Energimyndigheten, Guide för Energieffektiva Företag, https://www.energimyndigheten.se/guide-for-energieffektiva-foretag/
[9] An example of a self-check tool is the Industry 4.0 Readiness self-check developed by the IMPULS Foundation of the German Engineering Federation, https://www.industrie40-readiness.de/?lang=en
[10] Swedish authority for digital management

technologies specifically for the industry, and the connection to energy efficiency. Some examples were mentioned in the interviews. If the energy coordinator at a company would like to know more about how to proceed with predictive maintenance and what one needs to think of (what to measure, standards, transmitters etc). Another example could be the manager of an SME who wants to modernize their production process by installing sensors and a data collection system. The advisor could then recommend how the company should organize itself before starting to implement basic digital technologies.

Another type of information measure is to provide information on new guidelines or legislation about e.g., standards, data sharing and cyber security. The energy agency has a newsletter which could include such information, although it is questionable whether the energy agency should be responsible for it (the regional digital coordinators would probably be a better fit for spreading such information).

Finally, it was also mentioned that building a network regarding digitalisation for energy efficiency could be an efficient way to spread information. The Swedish Energy Agency already has experience of establishing networks for energy efficiency, for example the network EENet[11].

4.2 Training and educational measures

Lack of competence has been mentioned repeatedly during the interviews as a challenge and obstacle for the digitalisation of industry. When asked regarding what type of competence that is missing, several industries responded with "everything", but in particular they emphasize competence on how to combine IT and automation with existing processes and machines. Existing education at universities can be adjusted to involve more industrial digitalisation, but to address the more short-term need of competence in a company, training of staff is a possible way to go. However, there already exist several initiatives that aims to train personnel and to kick-start digitalisation. Some examples:

- The workshop series Kickstart Digitalisering by Tillväxtverket[12] which aims to help SMEs in taking the first steps in digitalisation
- The learning portal kompetens.nu which offers many free-of-charge short courses regarding industrial digitalisation technologies (e.g., there is a course named Connectivity, 5G and Cloud Communication)

[11] Nätverk för Energieffektivisering (Network for energy efficiency) - https://www.energikontorensverige.se/cases/natverkande-kring-energieffektivisering-ger-resultat/ (only in Swedish)
[12] Swedish Agency for Economic and Regional Growth

- Produktion 2030 which is a strategic innovation program supported by VINNOVA and FORMAS[13] as well as the Swedish Energy Agency.

These initiatives and the organizations behind them have been working with digitalisation for several years, and especially Tillväxtverket has focused on SMEs. The Swedish Energy Agency also supply support and organise initiatives for SMEs[14], but with regards to energy. Any new training programs regarding industrial digitalisation and energy should learn from these experiences and good communication between the responsible organisations should be established. The Swedish Energy Agency could be the owner of such a program if digitalisation for energy efficiency is a core subject.

Apart from the technical competence of the staff, the organisational competence and the motivation of the management are important factors. There will not be any investment in digitalisation unless the management approves, and it is also key that there is a structure or a strategy on how the company will work with digitalisation in the future. Although training of management for implementing digitalisation is a process that seems more suitable to be owned by another authority than the energy agency (since it is not by itself energy-related), there are parallels to how the energy agency has worked with organisational change regarding energy efficiency[15].

Also, on a European level there are projects working on establishing methodologies on how SMEs can work with energy efficiency. An example is the project GEAR@SME[16] which aims to encourage and disseminate energy efficiency efforts in SMEs, through a shared approach that involves 'trusted partners'. The methodologies and the tools developed for energy efficiency in such projects targeting SMEs are relevant for digitalisation as well since there are many overlapping aspects, such as organisational challenges and lack of resources.

Another method for increasing the awareness and competence, mentioned in the interviews, is to have webinars where invited experts discuss certain technologies. If a digitalisation platform is set-up like described in the previous section, such webinars should be launched through that platform.

[13] A Swedish government research council
[14] See for example http://www.energimyndigheten.se/smf (only in Swedish)
[15] See for example https://www.energimyndigheten.se/guide-for-energieffektiva-foretag/organisation-och-ledning/satt-upp-en-organisation/ (only in Swedish)
[16] https://www.gearatsme.eu/

4.3 Economic measures

As already mentioned, there are many parallels between working with increased energy efficiency and working with increased digitalisation. When it comes to energy efficiency, the Swedish Energy Agency is the authority that large companies report their energy audits to. In these audits, a company's energy usage is mapped and analysed which results in suggestions for energy efficiency improvements. During the period 2018-2020 there was also a program called Energisteget that could give economic support for implementing identified measures that did not fulfil the company's own investment criteria (e.g., too long pay-back time).

Similar to the energy audits and Energisteget, it was suggested in one interview, that the Swedish Energy Agency could push for 'digitalisation audits' where companies' readiness level for digital technologies are established and which results in company-specific strategies for digitalisation. Measures to implement should be identified. Since it is generally difficult to estimate the economic benefits of digitalisation, the concept of giving support for measures regarding certain economic criteria (like in Energisteget) seems questionable. However, if the company can show that they are working on digitalisation – for example by having an assigned employee/group that aims to move the digitalisation work forward – the company could get monetary support (or tax reductions).