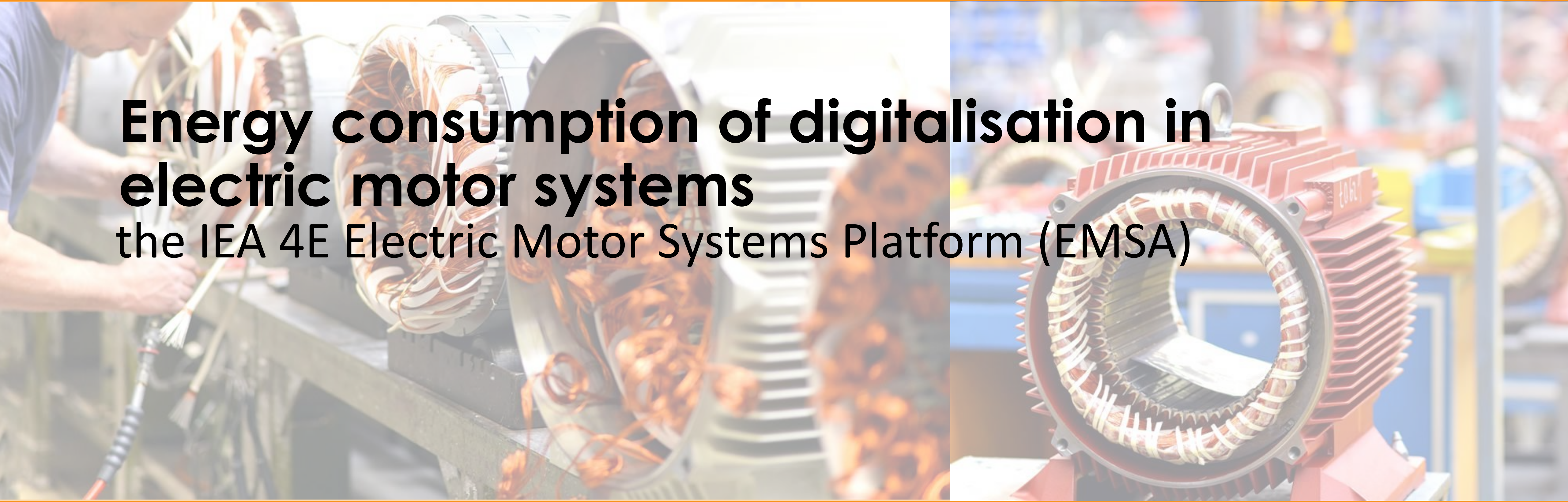
Energy Efficient End-use Equipment
International Energy Agency

Electric Motor Systems
EMSA

Energy consumption of digitalisation in electric motor systems

the IEA 4E Electric Motor Systems Platform (EMSA)



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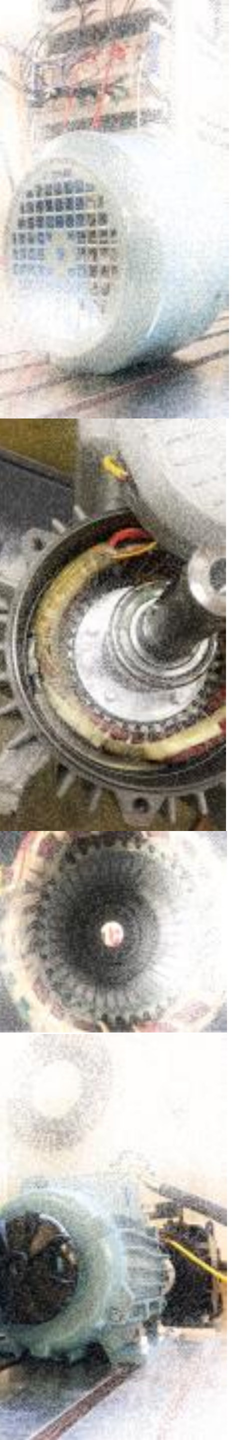

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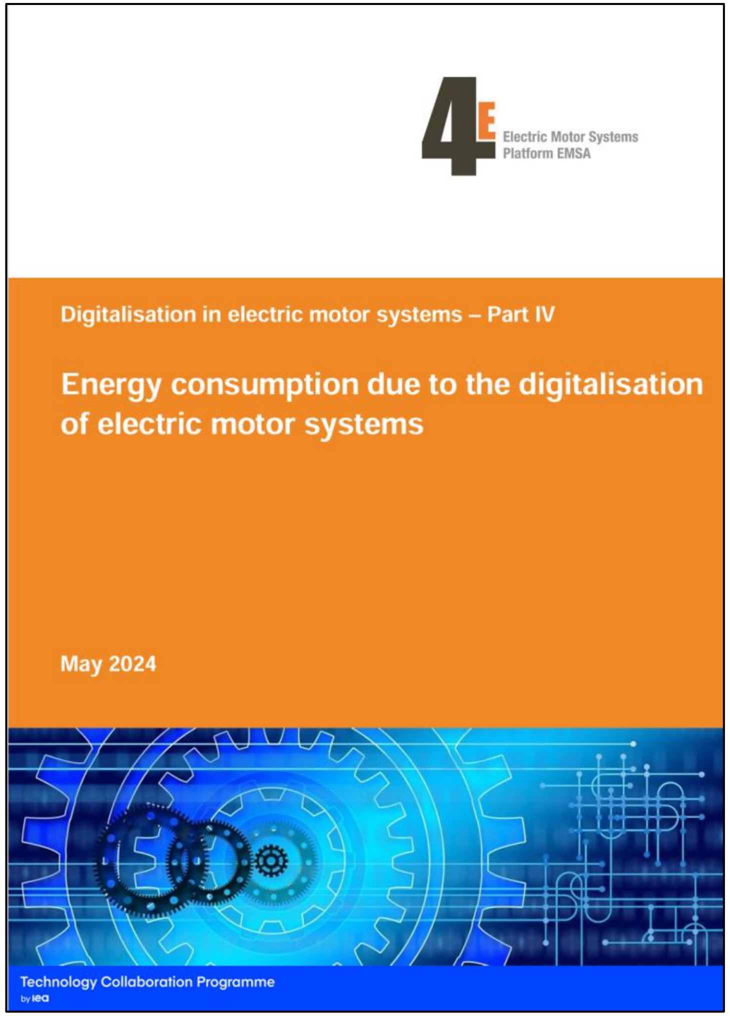
Electric Motor Systems
Platform EMSA

Digitalisation in electric motor systems – Part IV

Energy consumption due to the digitalisation of electric motor systems

May 2024

Technology Collaboration Programme
by iea

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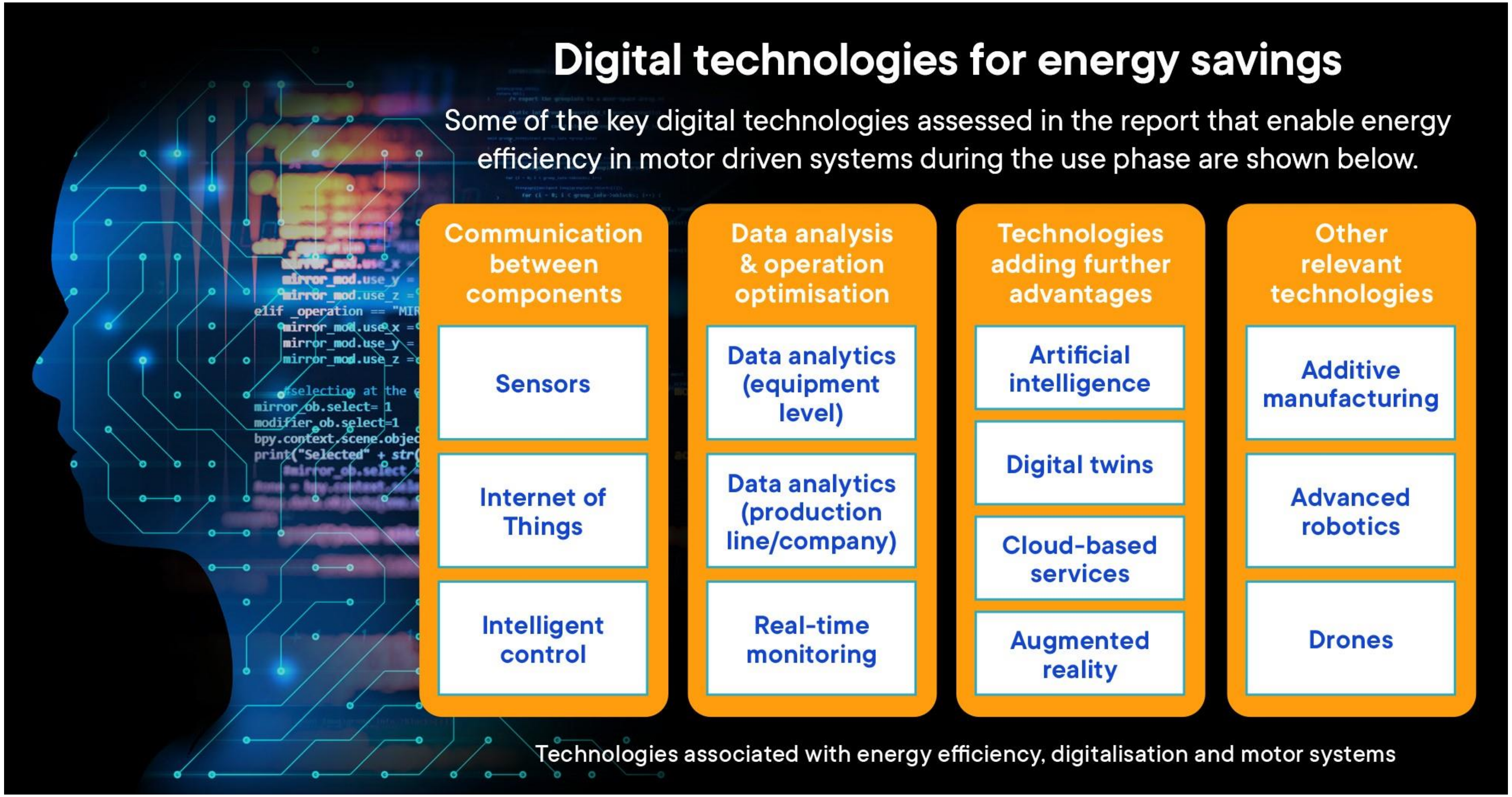
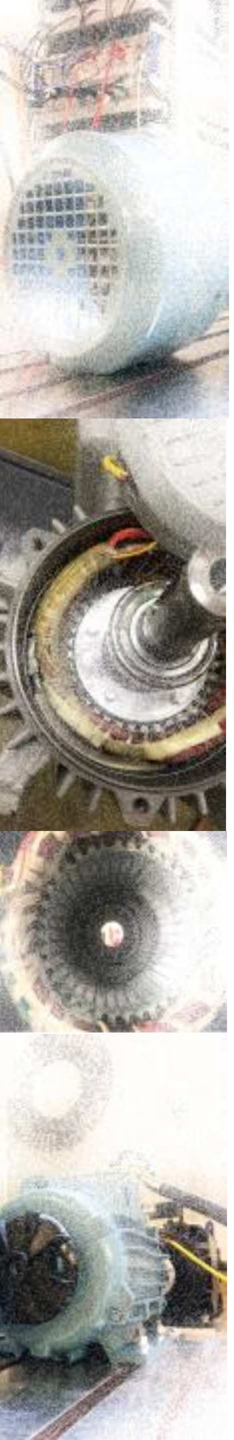
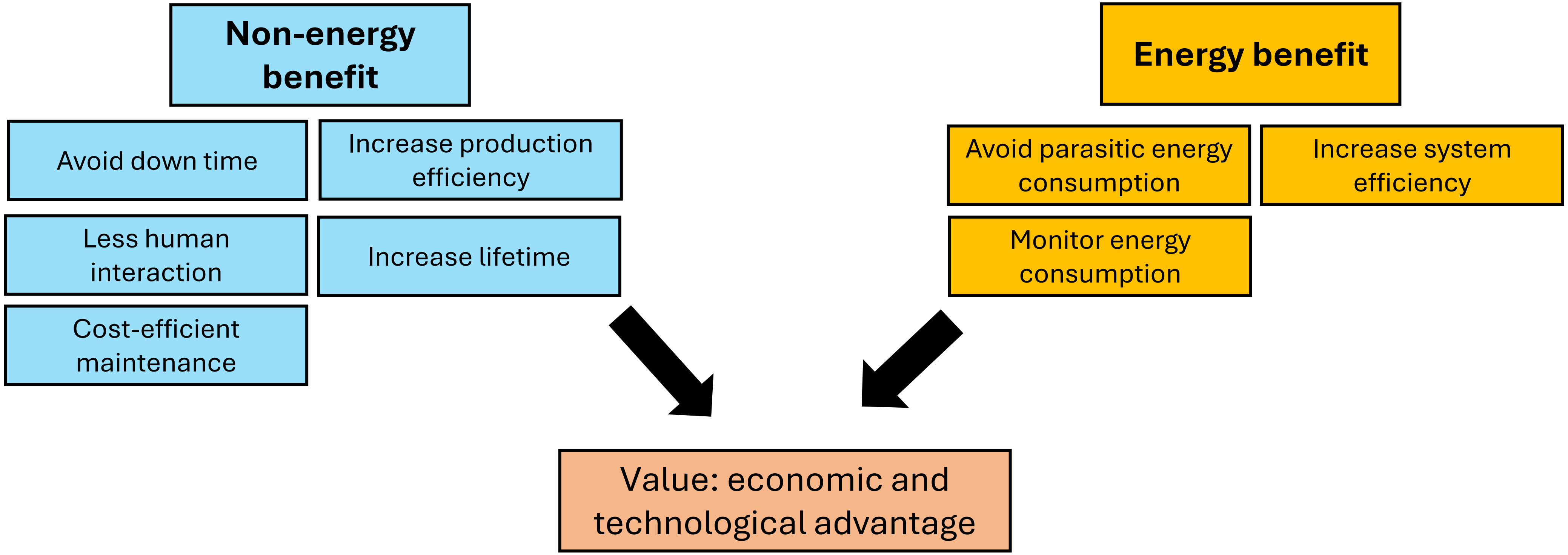
Digitalisation of electric motor systems

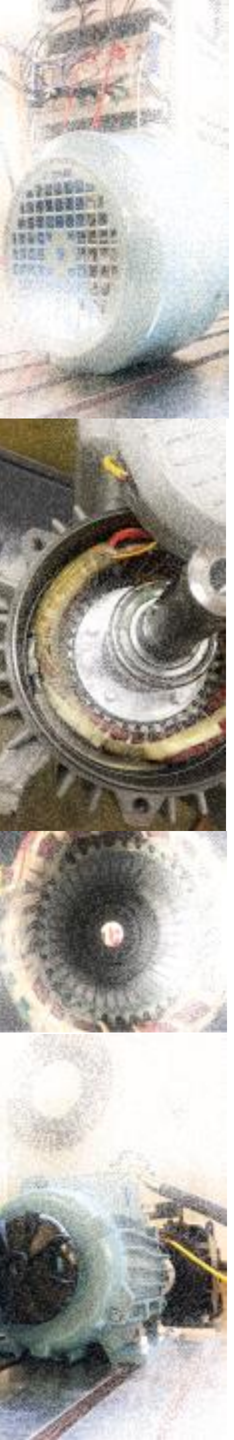


Source: Classification of digitalisation technologies for electric motor driven systems, EMSA, 2022

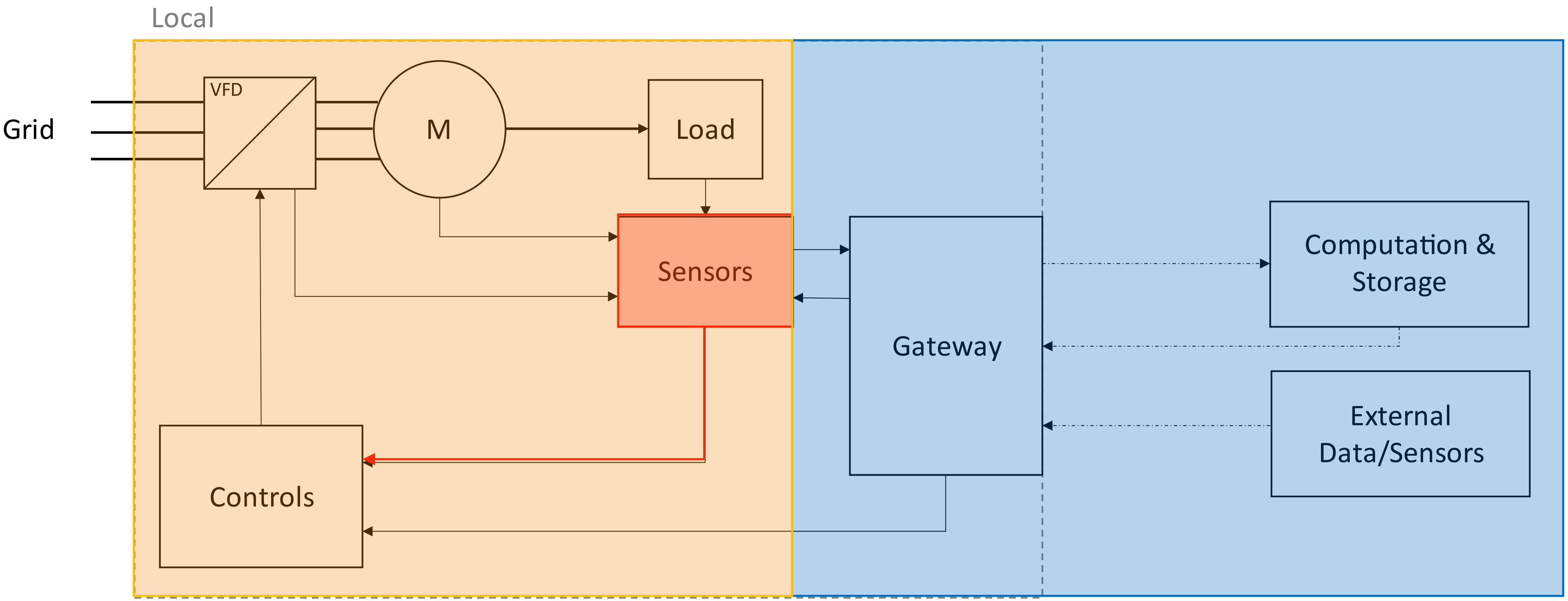
Benefits of digitalisation



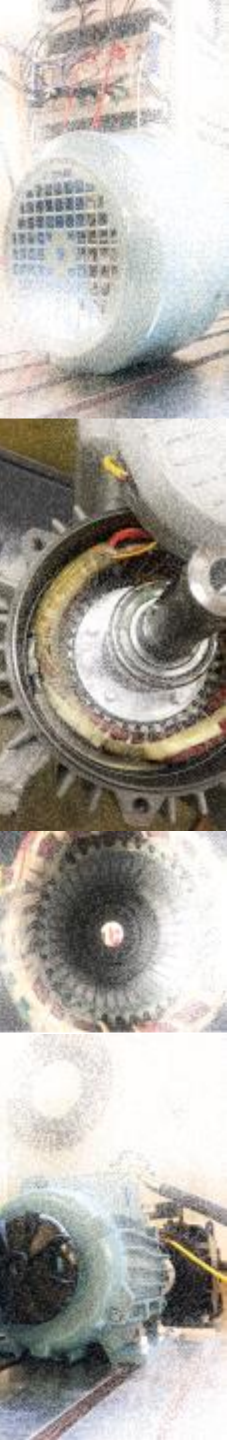




Generalised structure of digital motor systems



1. **Sensor**: includes all subcomponents that facilitate a sensor signal including its local data transmission
2. **Internal**: the energy required to process and store data locally
3. **External**: the group of power consumers enabling the facilitation of all external data communication and delocalized storage processes (gateway, network transmission and delocalized storage)
4. **Other**: residual energy that is not assignable to 1-3 (e.g. embodied energy from device manufacturing, prevented technician mobility).



Five cases

1. **IoT sensor** in air ventilation system in server facilities **to detect clogged filters**
   Source: IoT solutions provider PRiOT AG, Switzerland

2. Predictive maintenance and **vibration diagnostics via smart sensor**
   Source: motor service company Küffer Elektro-Technik AG, Switzerland

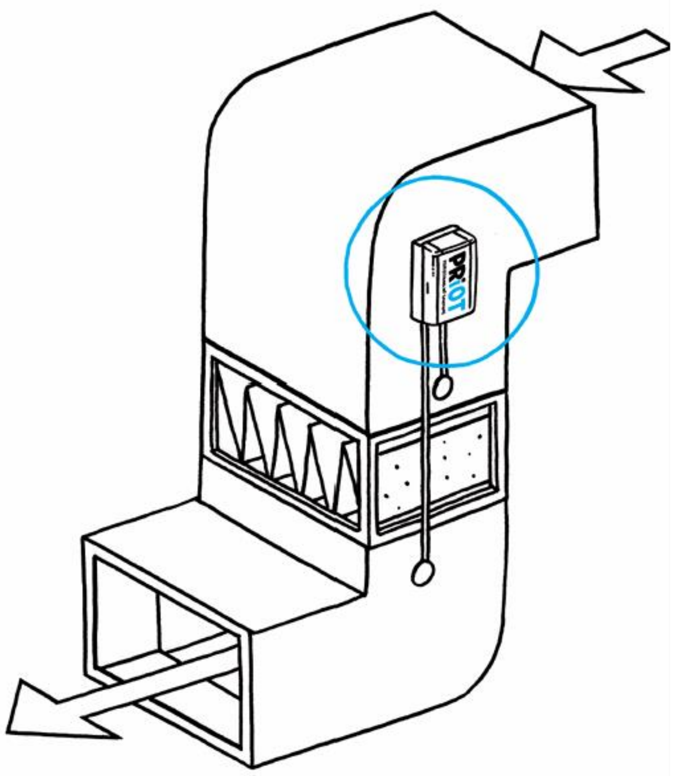
3. Intelligent control of water treatment facility pump system, applying **electrical signature analysis**
   Source: water supply and sewerage company Yorkshire Water, United Kingdom

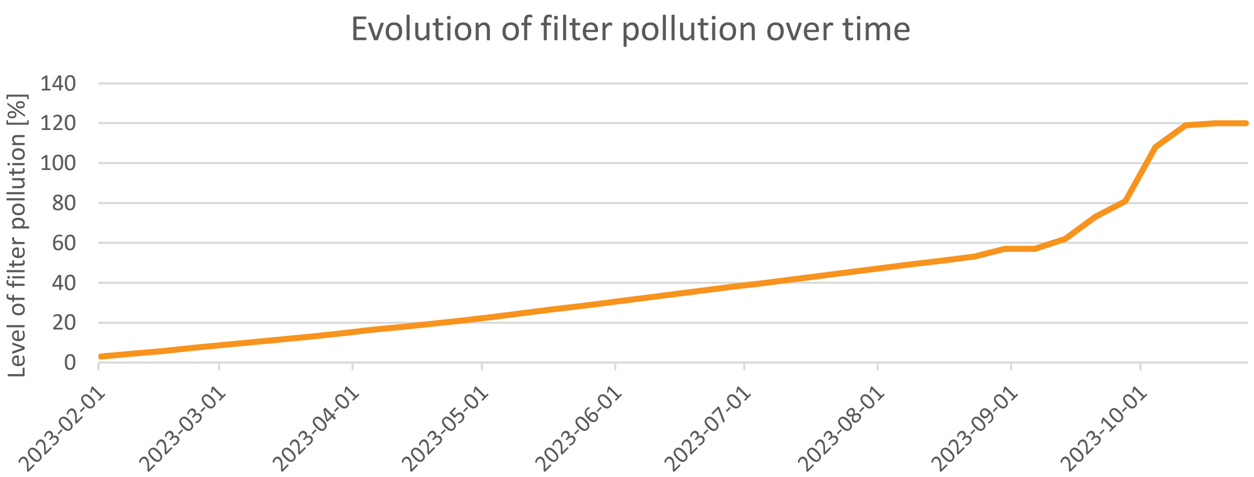
4. Large scale field trial, using **electrical signature analysis** as in Case 3
   Source: project ERGO. Solutions provider: Samotics, the Netherlands

5. **Intelligent control** of an air compressor system
   Source: Hamilton Bonaduz, Switzerland, producing medical devices and laboratory equipment.
   Solutions provider: KAESER Kompressoren

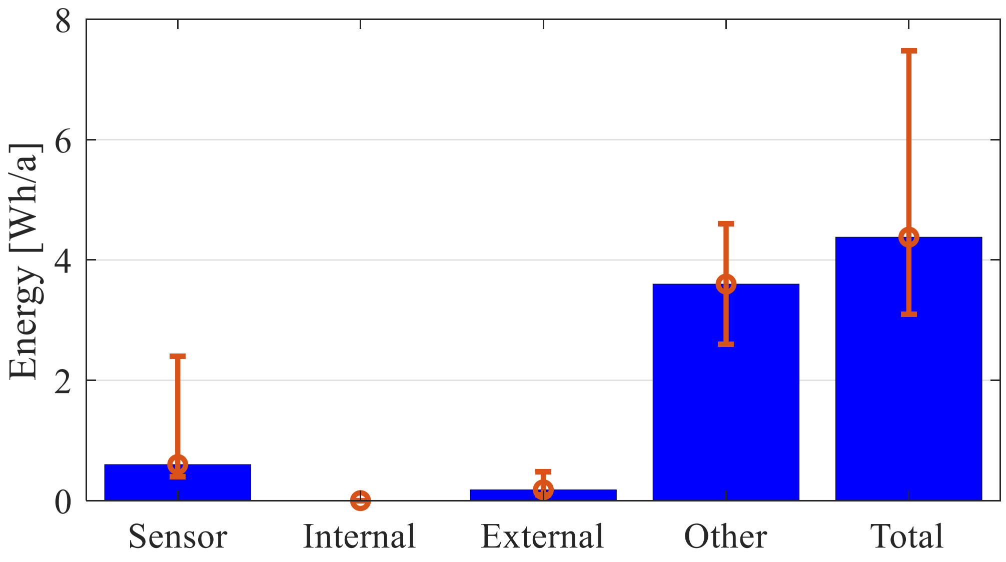
Case #1: IoT sensor to detect clogged filters (1/2)

- Sensor module can detect clogged air filters via differential pressure sensing
- Power drawn by the motor is increased by a factor of 2.5 when the filter is clogged
- In an example, after 9 months of operation, the filter was clogged. Without the sensor, the filter change would have happened at the next manual inspection, 3 months later. Instead, it could be exchanged promptly.
  This way**, 20.4% of electric energy could be saved**.





Case #1: IoT sensor to detect clogged filters (2/2)



Case 1	Energy [kWh/a]	Share of total energy [%]
Annual consumption	**6’510**	**100.0%**
Gross saving potential	**1’329**	**20.4%**
Digitalisation energy expenditure	**0.0044**	**0.0%**
Net energy benefit due to digitalisation	**1’329**	**20.4%**

1. Sensor: **negligible**, compared to overall energy consumption. It consists of the module consumption obtained from the average battery current.
2. Internal: **no internal energy** is consumed, as there is no further internal hardware to facilitate the system.
3. External energy: arises from the **data transmission and cloud storage** given by the data volume and current impact of end-to-end network consumption. [1] This is quite **low due to low data transmission rate**.
4. **Other**: **embodied energy from battery manufacturing**. This can be up to two magnitudes higher compared to the battery capacity [2], but may still be **insignificant in view of the motor system energy consumption**.

[1] Kemna R: et al., ICT Impact Study Final Report , 2020
[2] Ramsey, H., Life Cycle Analysis of AA Alkaline Batteries, 17th Global Conference on Sustainable Manufacturing, 2020

Case #2: smart sensor (1/2)

- In this showcased demonstration, a smart sensor is affixed to the motor to identify potential issues (e.g. bearing failure)
- Sensor transmits data wirelessly
- Powered via cable to avoid the need for a battery

Demonstration setup Küffer Elektro-Technik AG, Switzerland

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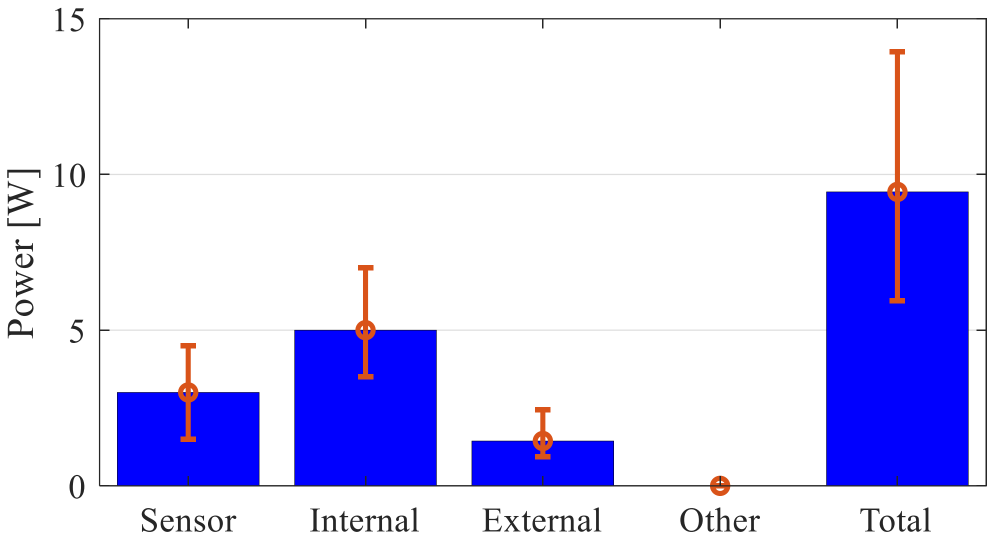
Case #2: smart sensor (2/2)



	Commercial Sensor 1 [1]	Commercial Sensor 2 [2]	Sensor Case 1 (IoT sensor)
Battery Energy [Wh]	9.36	2.85	6
Battery life (worst case) [a] (maximum) [a]	2 5	2 5 or 15*	2 10
Annual energy consumption [Wh/a] (based on worst case lifespan)	4.68	1.43	3
Gateway included	no	no	partially

[1] Siemens SITRANS digital solutions, https://cache.industry.siemens.com/dl/files/158/109804158/att_1085480/v1/sitrans_ms200_cc220_scmiq__fi01_en.pdf, accessed 11/2023
[2] ABB Motion Services, ABB Ability Smart Sensors, https://new.abb.com/service/motion/data-and-advisory-services/condition-monitoring-for-rotating-equipment, Accessed 11/2023

- Cabled (vibration) **sensor** power rating: 3 W
- Internal **gateway hardware structure** average power: roughly 5 W. The idle power of the module is roughly 3 W.
- External impact of **data transmission and storage** is given by the data transmission rate and specific network energy impact, which amounts to an equivalent of 1.5 W at the given sampling rate and data volume.
- **Total digital power assignable to the smart sensor system: 9.5 W**
- Sensitivity analysis for motor size, data transmission rate, operating hours in the report

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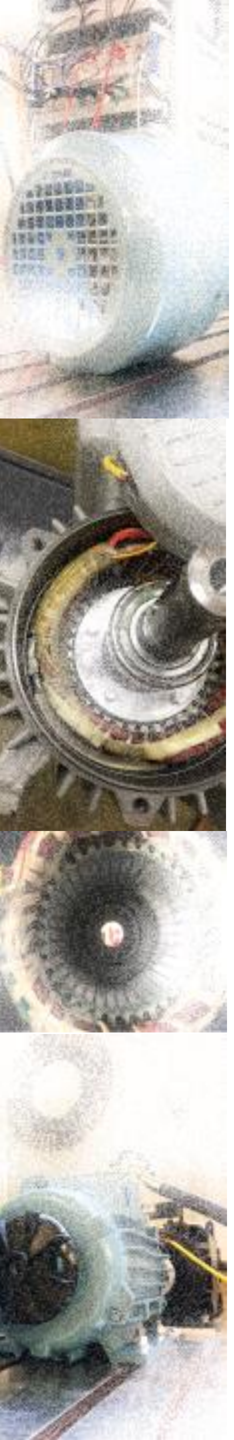
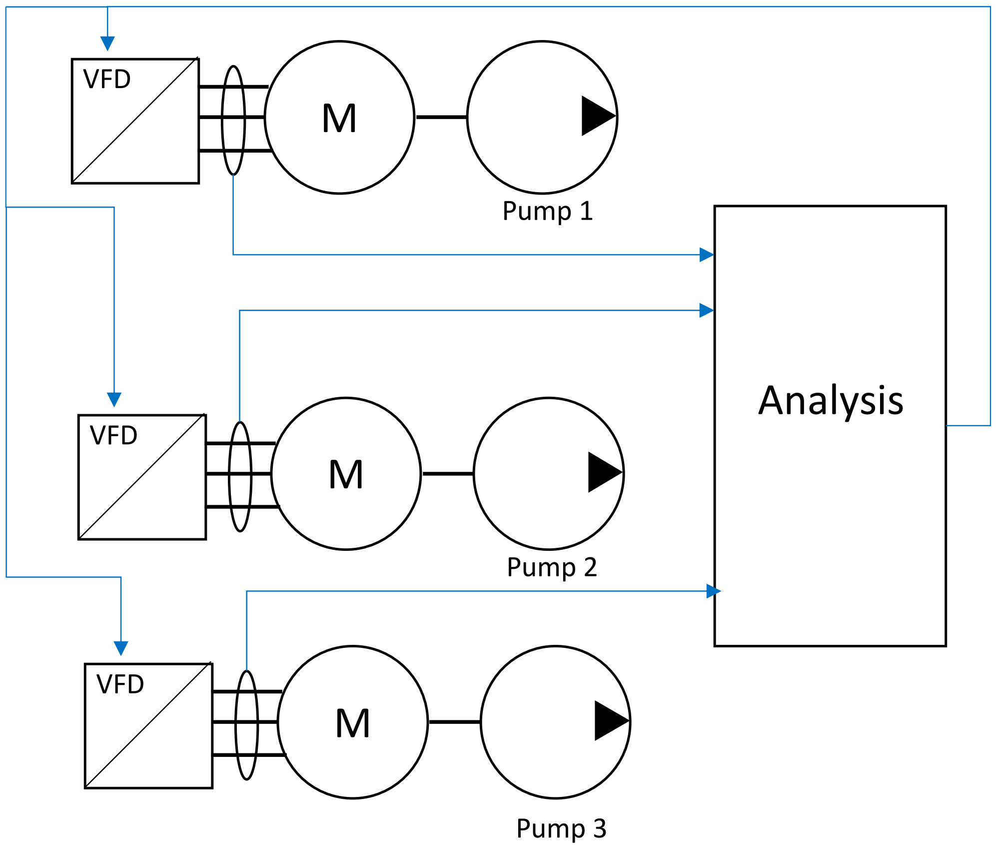
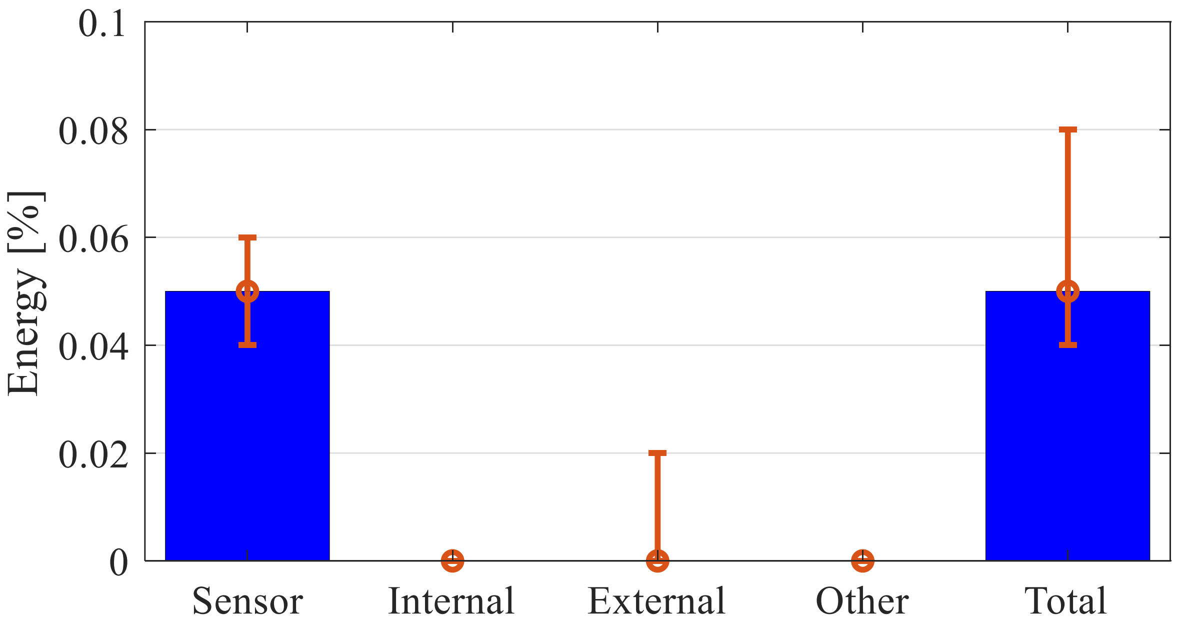
Case #3: electrical signal analysis (1/2)



- Sewage pump system has been equipped with electrical sensors.
- **Voltage and current sensors** allow observing the **load and rotational speed of the pumps**.
- Offline optimisation algorithm subsequently adapts the set-points and target speeds at which the different pumps are operated at, so the **pumps can be operated closer to their best efficiency point**.
- Continuous monitoring
- **5.7% of energy saved**, without any hardware measure, **solely because of control adaptation**.



Case #3: electrical signal analysis (2/2)

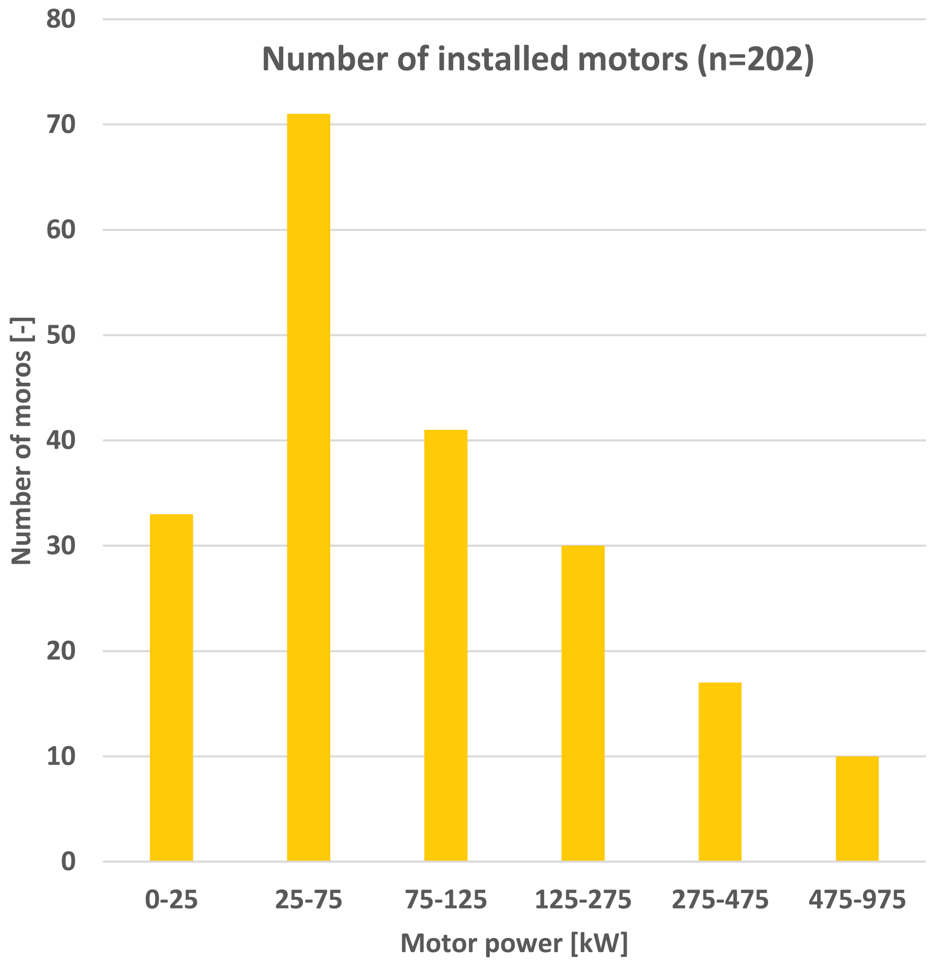


Case 3	Energy [MWh/a]	Share of total energy [%]
Annual consumption	1'060	100.0%
Gross saving potential	60.4	5.7%
Digitalisation energy expenditure	0.5	0.05%
Net energy benefit due to digitalisation	59.9	5.7%

- **Sensor** and computer system consumption based on power rating (120 W)
- Total **relative consumption is below 0.1%** for any scenario, where additional energy for cloud storage/communication is factored in.

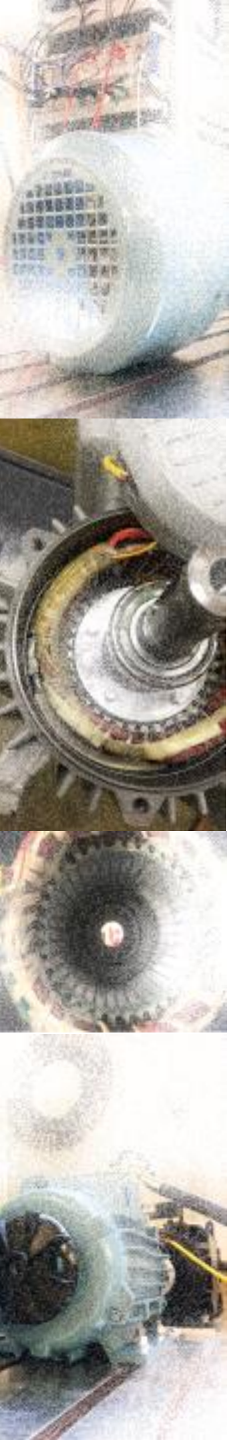
Case #4: field trial - electrical signal analysis (1/2)

- To analyse the energy saving effect in more detail, data from a bigger study is presented
- A field trial project with 1’007 assets (mainly pumps) within water and chemical companies
- Digital setup as presented in Case #3
- A selection of 202* motor systems has been monitored and assessed for energy savings potential, including analyses on efficiency benchmarks, operating points and best efficiency points
- 142 were already equipped with a VSD before the optimisation (‘optimised assets’), 60 were not (‘non-optimised assets’)



*Selection based on the data availability of the motor (rated efficiency from nameplate or datasheet) and the driven application (datasheet with pump curve) at the end user.

VSD: Variable Speed Drive

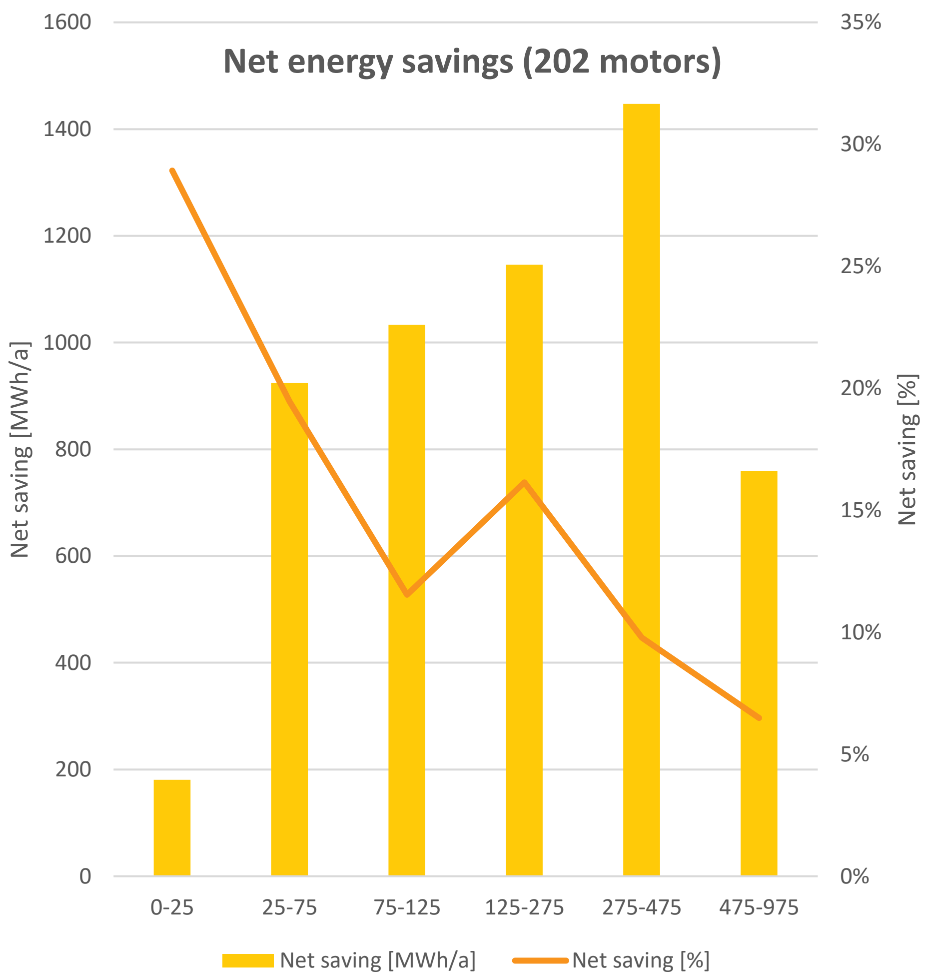


Case #4: field trial - electrical signal analysis (2/2)

- Energy consumption from digital installation assumed to be the same as in Case #3 (equal set-up)
- Relative savings between 6% - 29%, average: 11.4% [1]
- Illustration of potential savings range for a small sample (202 pump systems)
- Larger systems deliver larger absolute energy savings (kWh)
- Pump systems without a VSD before:
  - Highest net saving: 46%
  - Average net saving: 24%.
- Pump systems with a VSD before:
  - Average net saving: 9%

[1] ERGO project - Energy reduction through condition based maintenance, 2023, Institute for Sustainable Process Technology, Netherlands

VSD: Variable Speed Drive



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Case #5: intelligent control (1/2)

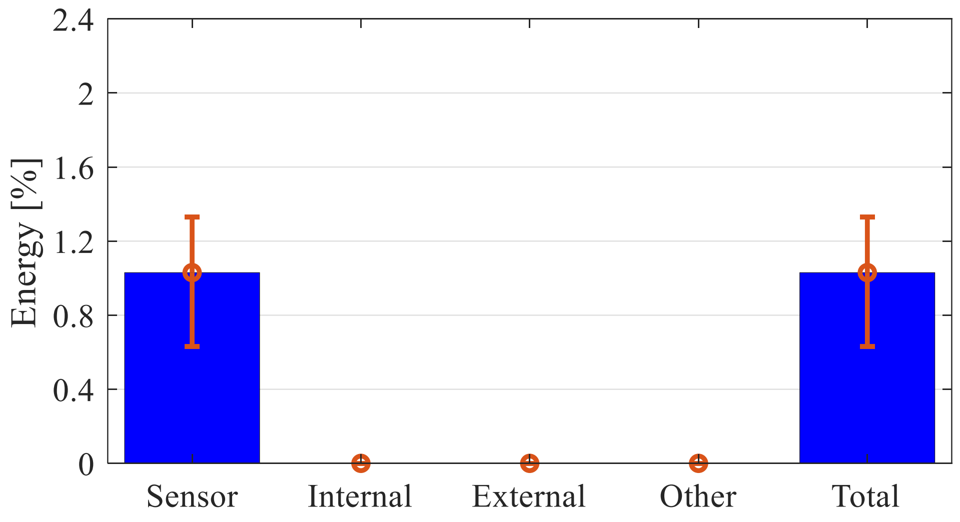
- An air compressor system has been equipped with an intelligent control system
- Control system evaluates pressure and humidity sensor feedback for an adaptive compressor control
- Hardware upgrade: three compressors were retrofitted of which two are equipped with a VSD
- Compressed air baseload is produced through compressors without VSD, remaining variable compressed air produced with compressors with a VSD
- Energy saving: 16%, due to:
  - *running the compressed air system at the lowest possible total system pressure (5%)*
  - ***optimised control (6%)****
  - hardware retrofit (5%)

considered as a quantifiable direct consequence of the digital solution

VSD: Variable Speed Drive

The new compressed air system with Achim Sax, Director Facilities Hamilton Services AG (photograph: Pascal Kienast)

Case #5: intelligent control (2/2)

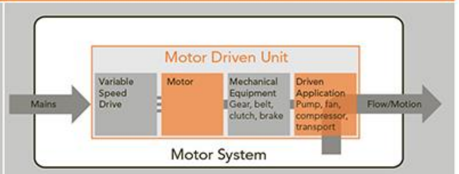


Case 5	Energy [MWh/a]	Share of total energy [%]
Annual consumption	488	100.0%
Gross saving potential	78	16.0%
Digitalisation energy expenditure	5	1.0%
Net energy benefit due to digitalisation	29	6.0%
Net energy benefit total	73	15.0%

- **Sensor**: arises from the overall consumption of the intelligent control system consisting of sensor modules and computer system
- As the control system operates in a closed loop, there is no additional energy consumption that can be directly assigned to the system

Overview

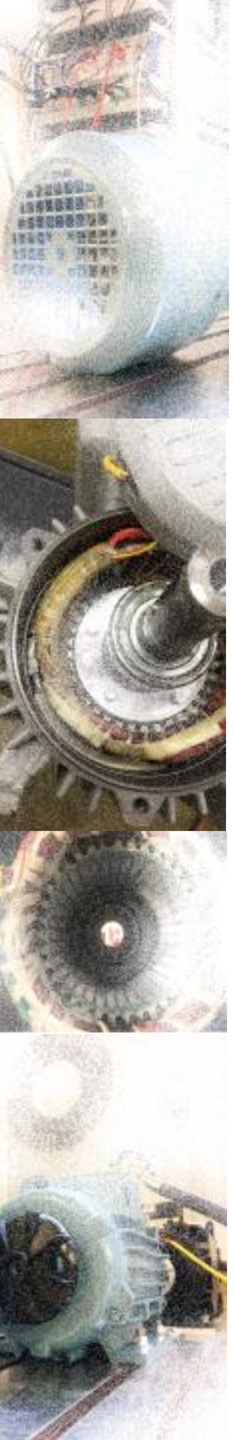
Case studies of digitalisation of Electric Motor Driven Systems (EMDS)



Case	Digital aspects	Before	After	Net savings	Role of digitalisation	Power equipment	Controls: VSD	Controls: Control, sensor, gateway	Motor	Transmission	Application (PFCO)	Piping, other	Heat exchanger, other
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 setpoints (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

- **Net savings** (excluding digital energy consumption): **5.7% to 20.4%**
- **Energy expenditure to facilitate digitalisation never exceeded 1%**
- **Digital energy consumption in motor systems is low and may be neglected in many cases of this study**
- **Consumption** attributable to the digitalisation of motor systems stems **from a variety of sources**
- **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
- **Battery life in smart sensors:** more common to work with small and compressed data sets that leave a **marginal impact**
- **Sensors and local data communication or storage devices** typically show a **low energy consumption**
- **Infrastructure necessary to facilitate digitalisation** of motor systems **may already be in place** to a large extent, **or is not required** (e.g. data handling for smart sensors)

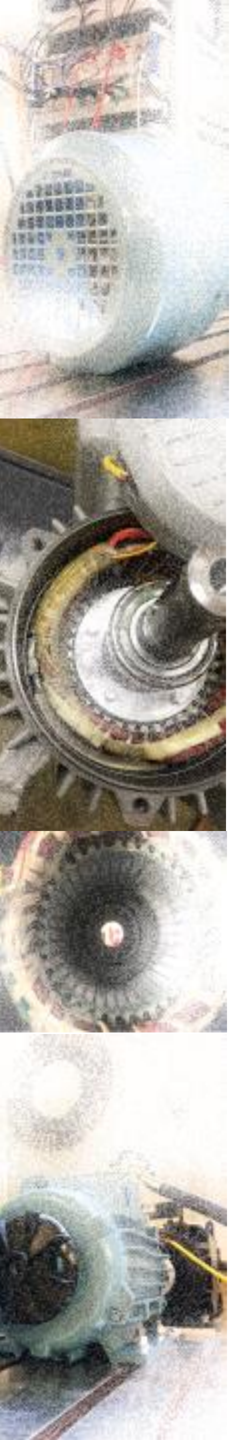


Conclusions: proposed classification

Classification of digitalised motor systems	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, analytics	Error detection, optimisation	Energy savings, emission reduction
Assignable cases from this study	Case 1 Case 2	Case 2 Case 3 Case 4	Case 5

Energy savings achieved through the digitalisation of motor systems far outweigh the additional energy consumption resulting from the digitalisation process.

- **Different typical energy consumption** which correlates with the computational complexity
- **Baseline values chosen arbitrarily** considering the cases
- **Benefit** of digitalisation is constrained to **what type of measures are classified as digitalisation** and **what is** regarded as **the baseline**
- In the cases studied, the **savings potential depends on** whether
  - the **motor system** is **already optimised** to some level
  - **measures** can **contribute to** an **optimised system operation**

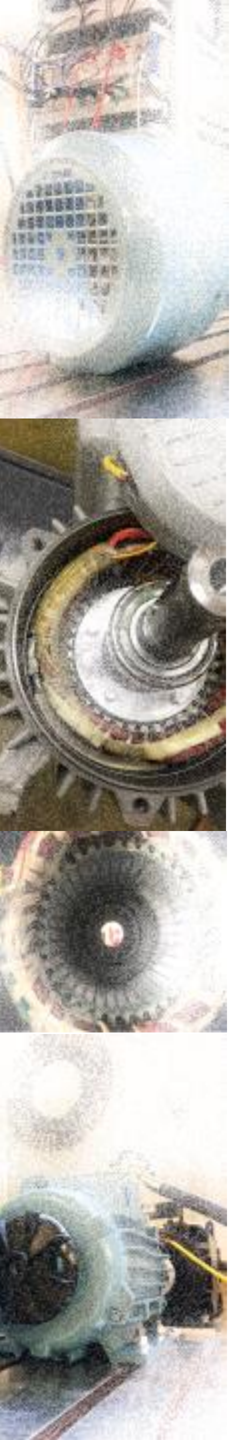


Outlook

- The sample size with five cases is not representative which is a limiting factor for aggregated conclusions.

- Collection of further cases would be helpful to be able to draw statistically relevant conclusions and get more detailed answers on the following:

1. What type of digitalisation solution suits best certain motor system setups?
2. To what extent does digitalisation unlock additional energy savings?
3. What is the savings potential in certain sectors (energy-intensive, non-energy intensive)?
4. What is the cost-effectiveness of digitalisation and the size of programmes required for its large-scale application?



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