PROSESS21

MAIN REPORT

Digitalization in the process industry
2025

Foreword

Prosess21 will provide strategic advice and recommendations on how Norway can best achieve minimal emissions from the process industry inside 2050, while at the same time facilitating sustainable transition, growth and value creation. The process industry is one piece of the government's initiative - Green Industry Boost. In February 2024, Prosess21 received a new mandate and a new steering group from the Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment.

Prosess21 has established various expert groups in areas of strategic importance for the process industry in Norway. This report deals with digitalization in the process industry. The purpose of the report is to describe how new technology and increased access to data, combined with new work processes, can contribute to increased value creation, restructuring and reduced greenhouse gas emissions from the process industry.

When Prosess21 published its main report in 2021, it was based on the work of various expert groups, including digitalization. However, the report on digitalization was never published. In 2024, the newly established steering group for Prosess21 decided to resume and update the knowledge base.

The work was initiated in the autumn of 2024 with a new expert group, consisting of members from the DigiPro Centre and external key people appointed by the Proses21 steering group. DigiPro is a national center with a focus on digitalization in the process industry and "twin transition". More than 40 participants from 23 member companies have contributed to renewing, updating and completing this report under the leadership of the centre's director (see Appendix 1 with an overview of participants). Among the contributors are employees inside the process industry, institutes, universities, technology companies and the policy support system.

Thank you to all the participants in the expert groups for their good contributions and good cooperation!

André Larsen

Chair of the Expert Group and DigiPro Centre

In this report, AI has been used for summarizing and minimizing text with quality assurance carried out by the Expert Group.

Content

Abbreviations

AAS	Asset Administration Shell
API	Application Programming Interface
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CRI	Commercial Readiness Index
CSR	Corporate Social Responsibility
DPP	Digital Product Passport
DT	Digital Transformation
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
EC	European Commission
EDIH	European Digital Innovation Hubs
EEA	European Environment Agency
EIC	European Innovation Council
EIE	European Innovation Ecosystems
EIT	European Institute of Innovation and Technology
ESPR	Eco-design for Sustainable Products Regulation
WE	European Union
FME	Centres for Environment-friendly Energy Research
R&D	Research and Development
GDPR	General Data Protection Regulation
IoT	Internet-of-Things
IPN	Innovation Project for the Industrial Sector
IT	Information Technology
TO	Artificial Intelligence
KPI	Key Performance Indicator
KS	Knowledge-building and Collaborative Projects
LLM	Large Language Model
ML	Machine learning
MPC	Model Predictive Control
MRI	Manufacturing Readiness Index
MTNC	Manufacturing Technology Norwegian Catapult Centre
MPT	Modular Type Package
OPC	Open Platform Communications
OT	Operational Technology
PID	Proportional, Integration, Derivation
PBC	Packaged Business Capabilities
PLC	Programmable Logical Controller
SFI	Centre for Research-based Innovation
SMB	Small and medium-sized businesses
TEF	Test and Experimentation Facilities
TUE	Technological Infrastructure
TRL	Technology Readiness Leve

Recommendations

The Norwegian process industry runs an activity of great national importance and social significance. The process industry contributes substantial export revenues with and is important for financing the Norwegian welfare society. The industry is particularly important for employment and other business development in rural areas. At the same time, the industry accounts for a large share of Norwegian CO^2 emissions that must be reduced towards 2030 and 2050.

The process industry must largely take responsibility for the development itself and take the necessary steps to ensure continued growth and profitability within the framework of stricter environmental and emission requirements. This includes taking advantage of the opportunities that lie in digitalization and the use of digital tools. However, due to the industry's great national economic importance, the formulation of strategies and relevant measures should take place in interaction with the authorities and the public policy apparatus.

The Norwegian process industry must not only focus on how data can be used to optimize operations, but also on how digitalization will transform the way they do business. The proposed recommendations below are succinctly formulated without further descriptions. Overall, the expert group highlights the following main points that are relevant to achieving the further effect of future digitalisation work:

Develop competence (culture building): Many of the players in the process industry have for many years invested in technologies, management systems, platform solutions, digitalisation, etc. Efforts should now be directed towards developing expertise that can absorb and adopt all the technologies and put them into productive work. Technology is globally available to everyone. This means that technology itself provides a short-term competitive advantage. In other words, technology development must, with other words, be followed up with competence and organisational development.

Create horizontal flow: In any business, the value-creating activities(s) and processes are horizontal. It also requires that the digital flow, the data, must follow the horizontal interaction between departments, functions and processes. The purpose is to be able to provide additional power for value creation. The horizontal flow will also involve the suppliers. Effective interaction in the flow requires standards to unleash the productive potential.

Closing the innovation gap: The process industry must continue its technology development. There is still a lot to be done inside digitalization and digital transformation. The potential that lies in, for example, the use of sensors, algorithms, machine learning or artificial intelligence is huge. Both with regard to increased competitiveness, efficiency, resource utilization and reduced footprint. The best at implementing new innovations are those who are also skilled at systematic and continuous improvement work.

The recommendations are mainly aimed at the industry itself, but also form the basis for how Norwegian authorities and policy actors can contribute to building a relevant framework for the further development of the process industry.

Integrate digitalization with your overall business strategy

- Consider digitalisation as central to the overall business strategy, and anchor initiatives that are realised in overarching goals. Set concrete levels of ambition for new values, increased profitability and reduced emissions, and use measurement parameters and benchmarks to track progress.
- Digital transformation can transform *your entire* business. Be prepared for changes in working methods and work processes, roles and tasks. New roles that are directly related to Digital Transformation (DT) need to be defined and supported.
- Engage the entire organization in the continuous improvement work.

Think digitalization for the entire business

- Create a plan for your entire business across functions, devices, and geographies.
- Prioritise the projects with the clearest effects on finances and sustainability
- Measure value added to the new solutions and use it as a basis for targeted training and change management.
- Facilitate scaling of solutions from day one, and be aware of various organizational, cultural, and technical obstacles and opportunities.

Prioritize growth and value creation

- Consider digitalisation as an opportunity for new value creation and increased profitability through improved marketing and sales processes, upselling and digital service innovation.
- Think smart production, efficiency and advanced analysis of product and customer data - for closer connector between production, suppliers and market.
- Document the value of the digital initiatives to inspire other parts of the organization and track the impact of the initiatives they are invested in.

Strengthen digital competence across the business

- Make a plan for competence development and continuing education of the employees at all levels – from top management to skilled workers and operators, including double trade certificates.
- Invest in IT talent and hire experts inside data science, data management, and IT security, but be aware that process knowledge must also be built in these talents.
- Build interdisciplinary teams that combine process expertise, digital competence, methodological expertise and other disciplines crucial to identify opportunities and develop effective, holistic solutions.
- Prepare your business for a fully digital production by leveraging digital technology to train your employees in deviation situations
- Be involved in the vocational education, competence building and research that takes place in schools, universities and university colleges as well as the research institutes.

Take control of your data and turn data sharing and AI into a competitive advantage

- Invest in a robust and structured data management system, data platform and IoT platform based on a common data model or different devices that are digitally connected.
- Ensure ownership of your own data and emphasize transparency and think about data sharing to create digital ecosystems, internally and externally.
- Use AI and digital technologies for better management, monitoring and control of production equipment and facilities.

Think collaboration across the board

- Look at technology providers as partners. Create alliances and partnerships with leading Norwegian and international players inside digitalization and digital technologies.
- Think ecosystems and consider value networks as well as value chains for how value is created by the business.
- Entering into closer collaboration with authorities, research communities and academia on education, subjects and R&D.
- Start early with clarifications about IPR with your partners to ensure a good collaboration.

Take the risk factors seriously - be ahead of the curve and be prepared

- Introduce risk management in the implementation of all digitalization projects.
- Application the digital roadmap for Cyber Security prepared by the Federation of Norwegian Industries.
- Have the ambition that all digitalisation initiatives will have a positive HSE effect.

Take the initiative for an R&D initiative on digital transformation and green transition

- Prioritise research topics that exploit national advantages and opportunities, remove barriers and with a high potential for gain.
- Prioritise ambitious collaborative projects with transformative effects on production and market.
- Seek triggering support for risk relief where there is a need both nationally and internationally.

Support supranational regulatory initiatives for digitalization

- Contribute to harmonisation, predictability and competitiveness by supporting European regulatory initiatives such as GDPR, the EU's AI Act and NIS2

- Contribute to closer cooperation between authorities, interest groups, industry players and suppliers on understanding and compliance with such regulations.

Further develop incentive schemes for digitalisation

- ... which stimulates investment in new digital infrastructure, replacement of old equipment and digitalisation of old facilities.
- ... for the continuation and conversion of pilot projects into commercial solutions with export potential.
- ... that motivate companies to invest in more strategic and targeted initiatives.

A clearer and more comprehensive system of policy instruments

- Closer integration between the various policy instrument actors to strengthen the policy instruments' ability to target entire value chains and entire development processes from early R&D to implementation.
- Establish greater clarity and a comprehensive industrial framework for how alternation between the various instruments and schemes of the policy instruments can contribute to closing the phases of the industry's various development processes.

Collaboration on standardization and best practices

- The process industry is served with collaborating on best practices and standardization in areas such as value chain integration and digital communication.
- Establish a broad national initiative for standardisation in these areas, with contributions from the process industry, key product and service providers, and the research communities.
- Public authorities should support this work through the policy support system.

Introduction

Prosess21 will provide strategic advice and recommendations on how Norway can best achieve a development towards minimal emissions from the process industry in 2050, and at the same time facilitate sustainable transition, growth and value creation. The process industry[is] part of the government's initiative - Green Industry Boost[1]. This industry must remain cost-effective despite rising and volatile energy prices and increasing trade conflicts. The products are often categorized as critical raw materials and the products must be delivered with a reduced environmental footprint. Prosess21 was initiated by the Solberg Government in 2018 and received a new mandate and steering group from the Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment

i n February 2024. [3]

The process industry has faced persistent and increasing global competition. The remaining industry is characterized by being energy-intensive, has a large export share to Europe and with competitors in Asia, Oceania and South America. Throughout Europe, electricity prices have increased, and in Norway, new power development has come to a halt. Overall, this challenges the industry's competitiveness and becomes a barrier to the green transition. Over the past 30 years, the process industry in Norway has made significant technology investments to reduce production costs and environmental emissions. These investments have been driven by increased competition from low-cost countries and increasingly stringent global and national environmental requirements. Many of the investments have focused on the development and implementation of various forms of smart technology (Industry 4.0) and further development of process technology. Norway is a country with high technology acceptance and is among the best in Europe in terms of maturity indices for digitalisation, which provides a solid basis for deriving greater gains from new digital technologies. Nevertheless, compared with our closest neighbours, Norwegian companies are the worst in the Nordic region at adopting new technological solutions[4], and we lack crucial expertise in automation and digital transformation.

On behalf of Prosess21, representatives from industrial companies, service and product suppliers, institutes, academia and policy instruments have produced this report on how new digital technology, increased access to data, strengthened expertise and new work processes can increase value creation, reduce emissions and strengthen the competitiveness of the Norwegian process industry. The report points to a number of challenges, opportunities and recommendations that are directed at the industry itself, expert communities in Norway and our authorities.

In order to succeed with both the green shift and increased export share, the competitiveness of existing and new value chains must be strengthened through the development and use of new technologies. However, it requires more than investments in technology, it also requires the industry to increase its own ability to innovate and continuously improve both products and processes. From previous studies[5,] we know that Norwegian industry has various advantages when implementing major restructuring. A flat organisational structure, operational management, a high degree of involvement and trust between the social partners are some examples of such advantages. Since the attempts at cooperation in the 70s, tripartite cooperation has been a foundation for the development of a competitive industry that has been able to adapt to changing conditions and framework conditions. The Norwegian model has proven to be robust, and is a good foundation to build on.

The government's role in supporting the needs of businesses has been important for the emergence of sustainable industries and industrial ventures. Education at all levels has contributed to a crucial recruitment basis for the industry. Furthermore, the Norwegian policy support system is well designed when it comes to supporting early-phase R&D and early-phase piloting of new technology. In the future, both the education sector and the policy support system must be prepared for changing needs. Newly graduated candidates face increasingly complex challenges, when domain knowledge and digitalization meet. Furthermore, the policy instruments will also need a mandate and the opportunity to support the implementation and scaling of climate technology that is to be validated on an industrial scale.

Over time, the Norwegian process industry has built up extensive expertise in close collaboration with research communities, educational institutions and suppliers. At the same time, a significant use of subcontractors has helped to create a competent and competitive supplier industry. Loosely interconnected networks of competence environments are crucial for the industry's future ability to innovate and develop. The value of such "ecosystems" lies in the

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a The process industry includes businesses that produce goods through chemical or physical transformation processes, such as metals, minerals, fertilizers, paper, plastics, and chemicals. Products from the process industry play an important role in the green shift, as they can help reduce emissions and increase resource efficiency in other sectors. Metals are used in wind turbines, solar panels, electric motors and batteries, among other things, which are necessary to promote renewable energy and electrification. Minerals are used to produce building materials such as cement, concrete, glass, and ceramics, which can be made more climate-friendly by reducing energy use and increasing the use of recycled materials. Mineral fertilizers are an important input factor for agriculture, which can help increase food production and food security in a sustainable way. Chemicals are used to make a variety of products and materials, such as medicine, paints, adhesives, cleaning agents, textiles, and pharmaceuticals, and can be made more environmentally friendly by using renewable raw materials, reducing hazardous substances, and increasing reuse. In Norway, the process industry has often been equated with the power-intensive industry.

the companies' ability to identify and utilise relevant solutions that have already been developed and combine them with internal resources. The industry's ability to introduce and scale solutions through ecosystems requires expertise and maturity to apply new digital solutions in existing processes.

Competition for skilled labour is increasing. Access to professional expertise will be crucial in the future for the industry's ability to both utilise and develop technology as an input factor for innovation and operational improvement. In order to attract competent employees, it is necessary for process industry companies to develop attractive workplaces with good conditions for development and learning. Digital transformation only succeeds when the basic professional competence is present, with the ability to work with technology, data, processes and organisation. This enables the use of digital solutions in both small incremental and large innovative improvements.

In an era with digital transformation, different industries and companies will perceive and exploit the opportunities that digital technologies provide in different ways. Some will use cutting-edge technologies to deliver products, goods or services in completely new ways, while others will focus on further developing and optimising existing processes. This report provides an overview of what it takes to succeed with both approaches.

What is Digital Transformation?

Digital transformation is a strategic process in which organizations leverage digital technologies to improve their products, services, and internal operations. It involves changing business models, cultures, and customer experiences to be more competitive in a digital age. At the core of the transformation is innovation and streamlining through the use of data, cloud-based solutions, automation and artificial intelligence. This requires a holistic approach, where both technology, people and processes are adapted to achieve lasting value and growth.

Useful experiences in the introduction of digital technology

In the future, there are three important experiences in particular that must be built on:

Systems that enable seamless data exchange: Experience shows that projects that involve the use of new digital technology often suffer from a lack of budget funds for effective integration into existing organizations and infrastructure. The return on investment can often be delayed because the company does not have systems based on OPC (Open Platform Communications), which enable secure and efficient data exchange between different devices and systems from different vendors. This is essential for achieving seamless communication flow in industrial environments. The Norwegian context often differs from the international context, partly because of a strong ownership concept in projects. This can also help to brake the progress of the projects. Industry differences and factory-specific conditions must be taken into account. This sometimes requires tailor-made solutions for communication and data storage.

Digital transformation requires involvement and anchoring throughout the organisation: This applies to several areas of the organisation, such as in the communication between external researchers and the R&D department, between management and the project organisation, and between the project organisation and the operating operators. Involvement and anchoring are often lacking in projects that do not achieve the expected effect. Too little time is set aside in the final phase of projects, and the organization quickly shifts focus to the next project. This is particularly problematic if the project is not followed up by the company's management with clear expectations of results and process improvements, and if the end users are not sufficiently involved. This gap can be a bottleneck for future development in the industry.

Lack of standards: Companies inside aviation, automotive, healthcare, and oil and gas follow strict procedures and standards. However, such requirements are less common in the process industry. One of the biggest challenges for integration is data security, especially when software solutions are to be implemented in the plants' control systems. Another area concerns the use of sensors, which are often highly trusted and expected when it comes to accuracy and presentation in demanding environments. Redundancy, operation, and accuracy should be given more attention. There is a lot of experience to be gained from other industries. This is further elaborated in the report's section on "Standardisation" and the chapter on "Risks as a result of digitalisation in the process industry".

Digital maturity

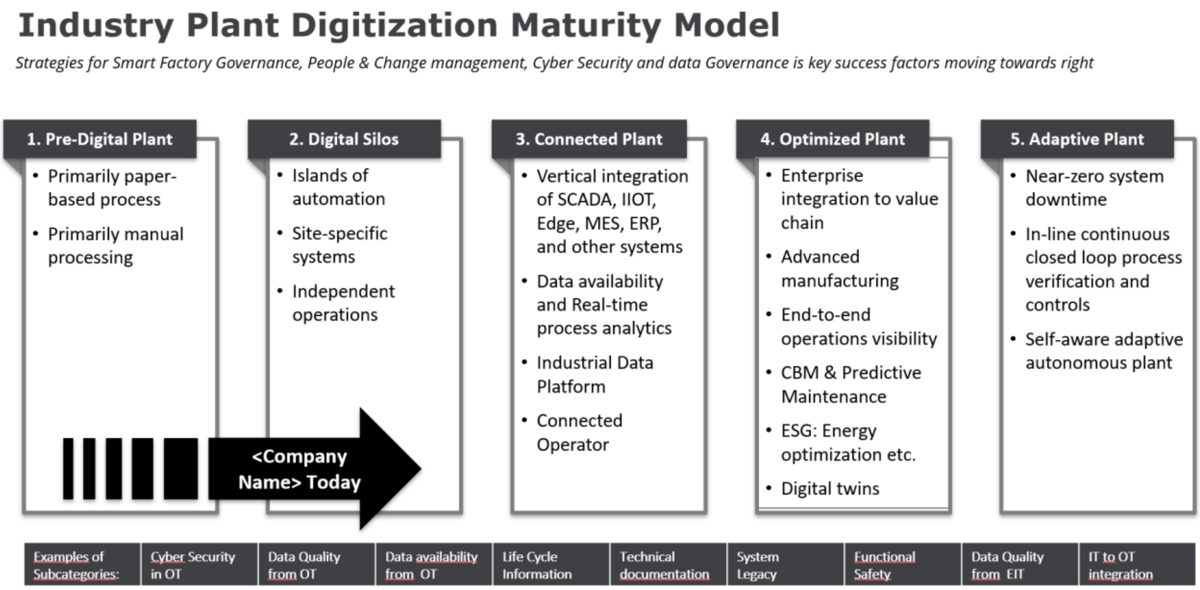
The industry in Norway is diverse, and there are large variations in digital maturity, both between the large industrial companies, between large and small companies, and among different subcontractors. To succeed with creating value from digitalization, it is important to have a realistic picture of how mature the company is inside three main categories: technology (T), processes (R) and people (M). Industrial companies may have high expectations of the effects of digitalisation, but in order to achieve these, there must be a plan for the holistic maturation of R-T-M. Experience shows:

- **Technology:** There is often a gap between operational technology (OT) and information technology (IT). The availability and quality of data, as well as cybersecurity, often turn out to be poorer than expected when good business opportunities are to be realized.

- **Processes:** Processes, workflows and methods are often outdated, difficult to relate to and not very accessible to support the work of the individual.

- **People:** Change is largely about engaging people and changing working methods and mindsets. Technically good projects often fail because they have not been able to engage the people who are affected by the changes.

A recommended technical maturity model for an industrial company might look like this:



Figur 1 Industry Plant Digitalization Maturity Mode – En modell for teknisk digital modenhet (ref. Deloitte Smart Factory presentation)

To succeed with digitalization, you need more than technical maturity. Business-driven strategies are required that enable the company to move in the right direction and at a fast enough pace to meet the challenges of the future. With increasing uncertainty and the pace of change, strategies must be dynamic and able to be changed and implemented quickly. This may entail, for example, new collaboration models, as few, if any, are able to do everything themselves with sufficient pace and cost-effectiveness.

Although many industrial companies have invested significantly in technology to automate all or part of their production, there is still great variation both between companies, internally between the factories in a company, and between different areas of each individual factory. Many Norwegian process industry companies still have a way to go before they have exploited the potential of increased automation and instrumentation of production, often referred to as "Industry 3.0". In addition, most companies have factory units with different systems, where several of the plants are old and often use supplier-dependent solutions in different parts of the value chain. This, combined with the fact that data is often stored in "silos", makes both integration and traceability difficult.

In recent years, great emphasis has been placed on establishing data platforms that break down the silos, free the data from the core systems and make it more easily accessible to larger parts of the organization. Hydro, Elkem, Yara and Equinor are examples of companies that have put significant focus on this area. However, the new digital technology is not always compatible with older equipment, and it is costly to upgrade and instrument older production equipment, even though the cost of sensors, actuators and communication has decreased in recent years.

For many companies, the initial investment is high before they can start reaping the benefits of digitalization. This makes it both difficult and demanding to realize the benefits that digitalization can provide for the entire company. It is no longer sustainable to work in silos; digital interaction must be facilitated throughout the production line. For example, Elkem has invested and standardised IT systems to cover various needs such as finance, purchasing, logistics, sales and production planning. This is to take full advantage of digitalization through seamless integration between the various systems that meet the needs of the entire production line.

Digital transformation in the EU

Critical need for digitalisation in Europe – message from the European Commission

The industry's largest market is the EU/EEA. Future development opportunities are affected both by regulatory frameworks and initiatives set in the process industry's most important market - the EU. The Draghi report*, "The Future of European Competitiveness"*[3], has identified three key areas for remaining competitive and sustaining sustainable growth:

1. **Closing the innovation gap with the US and China:** Europe needs to step up its efforts to promote technological and scientific innovation, improve the transition from innovation to commercialisation, remove barriers that prevent the growth of innovative companies, and work purposefully to close skills gaps.
2. **Develop a common plan for decarbonization:** Europe needs a coordinated plan to reduce energy costs, accelerate the transition to clean energy, and capitalize on industrial opportunities that come with the green transition. This includes supporting the development of clean technology and ensuring that European companies can compete on a level playing field internationally.
3. **Increase security and reduce dependence on China:** Europe must strengthen its economic security by diversifying its supply chains for critical raw materials and technology, as well as increasing investment in the defense industry and the aerospace sector. This also involves developing a common foreign policy for the economy that ensures access to necessary resources and protects strategic value chains.

In addition to providing a direct technological advantage, digitalisation with domain technology and knowledge can contribute to increased autonomy. Rising geopolitical tensions and aggressive industrial policies from China and the US are increasing uncertainty for imports of critical technology, such as semiconductors, and other inputs for industrial production. On the opportunity side, Norway is already an important supplier of critical raw materials to value chains that are under pressure.

Rising geopolitical tensions have led to challenges in technology trade with China, potentially affecting Europe's position in the technology sector. The EU is losing ground inside research and development (R&D) in some areas and is not able to create enough global innovative technology companies. While data demand and data volumes are increasing sharply in all sectors, the EU market for cloud services is largely dominated by US-based players. Data processing capacity is necessary, among other things, to train and develop AI models. Application of AI represents an opportunity for EU industry players to increase their competitiveness, but also poses a risk of losing leading positions if companies are unable to get a rapid effect from AI technology.

Non-European players are also leading the development of high-speed and high-capacity broadband networks with related equipment and software (including fixed, wireless and satellite/hybrid networks). Telecommunications equipment and software are essential for cyber resilience, the security of strategic infrastructure, and the protection of citizens' and businesses' data. In the case of quantum,6 cloud-7 and AI technologies,8 the drivers of innovation are weaker in the EU than in the US and China in three areas: (i) capital and finance, (ii) skills and human capital, and (iii) access to the global market.

In addition to the aforementioned areas where software is a key component, innovations inside hardware are also of paramount importance. For example, edge computing, which involves distributing computing tasks closer to the production sites and thus reducing data transport over long distances, is an alternative to connecting to the remote cloud. Here lie new opportunities in the digitalization market.

Regulatory developments in the EU

The digitalization of the process industry will be influenced by the rapid regulatory changes in the EU and the normative framework established by the European Commission. This includes, among other things*, the Data Governance Act, the General Data Protection Regulation* (GDPR) and the guidelines for trustworthy artificial intelligence, based on the EU *AI Act* (Artificial Intelligence Act). The room for manoeuvre and limitations provided by the regulations is something the industry must actively relate to, especially with regard to developments in artificial intelligence.

The EU's *AI Act* entered into force in 2024 as the first legally binding agreement highlighting the importance of human-centricity in AI systems to ensure alignment with European fundamental rights, regulations, and values, similar to the OECD Artificial Intelligence Principles *(OECD AI Principles).* As a result, the European AI Office[9] was established in May 2024, among other things, to follow up on the implementation of the AI Regulation.

Industrial companies should follow the development of digital platforms and ensure that they comply with regulations, especially with regard to the risk classification of AI systems under the AI Regulation and their impact on operational processes and the workforce. The principle of ethics by *design (Ethics by Design)* should be emphasized as a fundamental approach, where ethical considerations are identified and addressed proactively from the early stages of designing, developing, and operating digital processes and systems. This should be done in collaboration with different stakeholders to gather different perspectives and ensure that the design is in line with societal values and the needs of users.

In short, manufacturing companies must take a position on the following questions:

- What are the opportunities and limitations in handling ethical and regulatory principles related to AI and digital technologies within the framework of requirements set in the *Data Governance Act, AI Act* and GDPR?
- How can compliance with the aforementioned regulations be achieved for specific digital technologies in different types of process industry companies and in land-based industries in general?
- What are the implications of implementing digital processes in different operational industrial environments?

In late 2024, the European Commission established a new grant scheme called the "AI Innovation Package"[10] to support the development and scale-up of start-ups and SMEs with new, reliable AI products that comply with the AI Regulation. Norwegian process industries and their supplier ecosystem should connect with relevant players within this innovation package to benefit from this development. This will increase digitalization potential with the use of AI-compatible tools and products.

EU Competition Compass

On 29 January 2025, the European Commission published its document *"A Competitiveness Compass for the EU"*[11] (Competition compass, see Figure 2). The document builds on the recommendations of Mario Draghi and Enrico Letta and focuses on the main causes of inadequate growth and how the EU can strengthen competitiveness in Europe.

Figure 2 The EU Competition Compass [11]

The EU Competitiveness Compass contains around 40 flagship initiatives, including a *Clean Industrial Deal,* designed to promote sustainable industrial growth. The compass has three overarching objectives: to increase productivity in Europe by closing the innovation gap vis-à-vis the US and China, to establish a common roadmap for decarbonisation and competitiveness, and to strengthen Europe's economic security and strategic autonomy. These goals are to be achieved through a series of measures that promote innovation, reduce carbon emissions and increase the EU's independence from critical technologies and materials from third countries. Taken together, these initiatives will help ensure that Europe remains competitive in an increasingly complex global economy

The compass is built on three main pillars and so-called horizontal enablers. All pillars together form the basis for a new framework for innovation and decarbonisation of industry in the EU/EEA area, and this will have a significant impact on the Norwegian process industry.

The compass discusses a number of initiatives related to increased use, support and frameworks around digitalisation. We currently know little about the content of the various flagship initiatives, but based on the title, it may appear that the following announcements will be relevant to the digitalisation and innovation area.

- Start-up and Scale-up Strategy
- 28th regime
- European Innovation Act
- European Research Area Act
- AI Factories Initiative, Apply AI, AI in Science, and Data Union Strategies
- EU Cloud and AI Development Act
- EU Quantum Strategy and a Quantum Act
- Advanced Materials Act
- Digital Networks Act
- Omnibus simplification and definition of small mid-caps
- Revision of the Standardisation Regulation
- Union of Skills
- Quality jobs roadmap

The European Commission will publish a number of other initiatives and action plans during 2025. The purpose with these initiatives is to increase productivity through innovation, create a new dynamism in Europe's industrial crepi, and integrate decarbonisation policies with industrial, competition, economic and trade policies. These policy areas must be well integrated and act as a powerful driver of growth.

European digital tools

The European Commission has increasingly developed initiatives aimed at supporting the development of industry in order to strengthen its competitiveness, both at European, national and regional level. This is expected to increase in scope with the start of a new commission, parliament and council from 2024-2029.

The Digital Europe Programme[12] (2021-2027) is the EU's initiative for digital transformation in business and the public sector.[13] Increased use of digital technologies is intended to strengthen the competitiveness of the business sector, improve public services, and contribute to solving global challenges inside climate, environment, health and safety. The programme will also contribute to the EU becoming more technologically independent from other countries and regions. In 2024, Norway joined the EU's programme[14] through a separate strategy. Digital Europe encompasses six important areas for Norway: high-performance computing and supercomputers, cloud technology, data and artificial intelligence, digital security, advanced digital competence, the use of digital technologies and semiconductors (microchips).

A key initiative of the Digital Europe programme is the establishment of a network of 200 European Digital Innovation Hubs (EDIHs). These innovation hubs will contribute to skills development and help small and medium-sized enterprises to take advantage with the opportunities offered by digitalisation and new technology, both nationally and within the EU programmes. Norwegian companies, clusters and other research and innovation actors can participate in EDIH[b]. This commitment and these initiatives take us in the right direction, while the efforts in Europe inside the industry are diverse and create opportunities at several levels.

The Draghi Report[2] points out that despite many initiatives and initiatives, the efforts are not sufficient. The report highlights a lack of focus and clear priorities as the main challenges. Although the EU has a strong economic

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[b] Norway participates in two EDIHs, respectively Nemonoor[15] and

Oceanopolis[16] power, the resources are spread over many instruments, which leads to a lack of coordination and efforts in critical areas.

The report points to the following relevant challenges that are also relevant to the process industry:

- **Investment in technology and infrastructure:** Draghi emphasizes the need for significant investments in new technology and infrastructure to promote digitalization. This involves upgrading existing systems and integrating advanced technologies such as AI and IoT to increase productivity and efficiency. Europe must take decisive action to close the innovation gap with the US and China, especially inside enabling technologies.
- **Skilled labor:** A main focus is to attract and retain highly skilled labor. The report suggests that Europe needs to develop a robust education system and continuous training programmes to ensure that its workforce has the necessary digital skills.
- **Supportive industrial policies:** The Draghi Report calls for coordinated industrial policies that support innovation and digital transformation. This includes creating favorable regulatory frameworks and providing financial incentives for companies to invest in digital technology.
- **Collaboration and ecosystems:** Collaboration between industry, academia and government is crucial. The report highlights the importance of creating ecosystems where different stakeholders can work together to drive innovation and share best practices. Europe has many talented researchers and entrepreneurs, but struggles with commercializing innovation.
- **Cybersecurity:** Ensuring Heavy Duty cybersecurity measures is essential for the successful digitalization of industries. The report emphasizes the need for strong cybersecurity frameworks to protect digital infrastructure and data.

The points from the Draghi report form a broad foundation for digital transformation in industrial companies, with the main goal of increasing competitiveness and contributing to decarbonization.

The status of digitalization in the process industry

In this chapter, we aim to document some of the most important ongoing digitalization activities inside the process industry. This includes a review of systems, tools, and methods that help improve efficiency, reduce costs, increase competitiveness, and reduce greenhouse gas emissions. The goal is to provide a comprehensive understanding of how far the process industry has come inside digitalization.

Value creation potential of digitalization

Companies that over time are leaders inside their industry are characterized by at least one of three characteristics: i) a better cost position than their competitors, ii) differentiation through strong brand names or specialized products and services, and iii) unique commercial positions that make it costly for customers to switch to alternative suppliers, control over unique raw material sources, or ownership of patented products and/or production processes.

Many companies in the Norwegian process industry are competitive as a result of access to affordable, renewable energy, a culture of continuous improvement, and the ability to specialize products or services. Going forward, the process industry must be prepared for extensive changes in its value chains. This includes everything from access and price of input goods such as electricity and raw materials, to new requirements for traceability and reduced emissions of greenhouse gases, which in turn affect production costs directly and indirectly. In addition, the market will demand new products and services, and there will be increasing demands for the carbon intensity of the products.

Several analyses show the benefits that industrial companies can achieve through digitalisation. An analysis from McKinsey & Company concludes with that manufacturing companies can improve EBITDA with 8-13% by systematically digitizing marketing and sales, product development, R&D, manufacturing, logistics, purchasing and internal processes.[17] Similar gains should be expected in the Norwegian process industry.

In addition to value creation in companies, digitalisation of the process industry will also create ripple effects and value creation in associated supplier industries, universities, research institutes and the ecosystem in general.[18–20] There is also reason to sash that companies that have a comprehensive and marketed digitalisation strategy can benefit in a labour market where there is competition to attract candidates with the right skills. The most important benefits of digitalization in the process industry are:

- **Lower costs and capital expenditures, and higher production margins**
  - Increased capacity utilisation and production in existing facilities.
  - Reduced consumption of input factors such as raw materials and energy, as a result of increased yields.
  - Extended service life and reduced maintenance costs on equipment and facilities.
  - Streamlined logistics.
  - Better understanding of capital needs and optimized allocation.
  - Automated routine tasks, such as inside reporting and documentation.

- **Reduced greenhouse gas emissions and less waste**
  - Energy and resource efficiency in production processes
  - Better balance of supply and demand
  - Reuse of materials through circular economy

- **Increased safety for employees**
  - Automatic safety systems with increased use of sensors
  - Identification of hazardous conditions using advanced imaging

- **Increased sales and higher sales margins**
  - Interaction with customers on product specifications, quality and deliveries on digital platforms
  - Combined deliveries of product and services, such as digital tools for product quality, optimized adaptation and use of the products
  - Application of digital tools for sales forecasting and product pricing

- **In development projects, increased quality and safety and reduced costs**
  - Application of digital 3D models enriched with information through design, construction and operation
  - Optimization of production processes before construction through digital simulations

- Shorter path from idea to handover of product using digital tools for documentation, planning and project management.

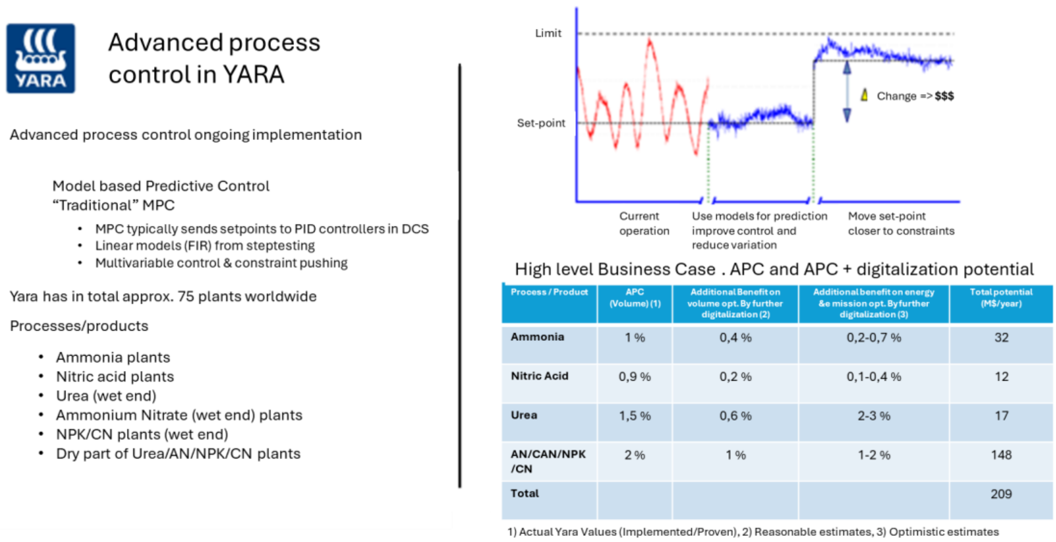
- **Improved transparency throughout the value chain**
  - Application of the Digital Product Passport (DPP) for more secure and accessible information about the origin and footprint of the products

Streamlining production

The Norwegian process industry has a long tradition of automating its production facilities. As early as the 1960s, when industrial control systems consisted of analogue electronics and relay control, leading Norwegian industrial companies carried out extensive automation projects. Norsk Hydro (now Hydro and Yara) was an early adopter with automating the production processes in its factories (see Figure 3).

Over the past 30 years, the process industry in Norway has made significant technology investments to reduce production costs and environmental emissions. These investments have been driven by increased competition from low-cost countries and increasingly stringent global and national environmental requirements. Many of the investments have focused on the development and implementation of various forms of smart technology and process technology.

The technology for the efficient operation of process industry plants is becoming increasingly advanced. From starting with simple sequence control, single-loop PID controllers and on to Model Predictive Control (MPC) in the 1990s, the Norwegian process industry collaborates with leading research institutes on the development of advanced process optimization that combines instrumentation, data capture, machine learning and communication with the operator.



Process / Product	APC (Volume) (1)	Additional Benefit on volume opt. By further digitalization (2)	Additional benefit on energy &e mission opt. By further digitalization (3)	Total potential (M$/year)
Ammonia	1 %	0,4 %	0,2-0,7 %	32
Nitric Acid	0,9 %	0,2 %	0,1-0,4 %	12
Urea	1,5 %	0,6 %	2-3 %	17
AN/CAN/NPK /CN	2 %	1 %	1-2 %	148
Total				209

1) Actual Yara Values (Implemented/Proven), 2) Reasonable estimates, 3) Optimistic estimates

Figure 3 Example of advanced process control at Yara

Over the past ten years, there has been a major focus on extracting more value-creating information from existing process data. This has been made possible by ever-lower costs for storage capacity and computing power. The efficiency potentials from this information have already been exploited by most people, using centralized and virtualized server systems. More demanding tasks now remain to extract additional valuable information, which is based on data quality, contextualization and availability of data.

To further streamline, data must be linked throughout the process, which requires both physical and digital traceability. This often involves both physical and procedural changes in production management, while at the same time establishing digital traceability between the systems. The digital transformation therefore entails changes to how daily tasks are solved throughout the organization to a greater extent than before. When introducing new solutions, it is important to focus on anchoring, involvement and associated change management throughout the process. Here, agile work methodology can play a role in keeping users involved in planning, implementation, and compliance. If the organization is unable to adapt to handle more advanced and complex systems, there is a risk that these systems will have a limited lifespan, and that the organization will fall back to the old, simpler, but less efficient systems. It is important to ensure that the effort put into developing and maintaining more complex systems yields a return that exceeds the effort.

Several process industry companies are now working with digital solutions to ensure access to up-to-date and real-time information during the execution of practical tasks through handheld devices. In addition to supporting individual operators, today's information and communication solutions make it possible to compile information from several complex and linked production sections into one common system. DataOps platforms (methodology for simplifying the data architecture) play a role in the compilation and contextualization of production and maintenance data, and provide the opportunity to establish AI models in the same tool. At Elkem Carbon in Kristiansand, digitalisation has been moved out into the production team and contributes to operator involvement, increased yields, removal of bottlenecks and reuse of scrap production. This results in more efficient production and better resource utilisation. Figure 4 shows Elkem's Smart Furnace to reduce energy consumption in silicon metal production using machine learning and digital twin.

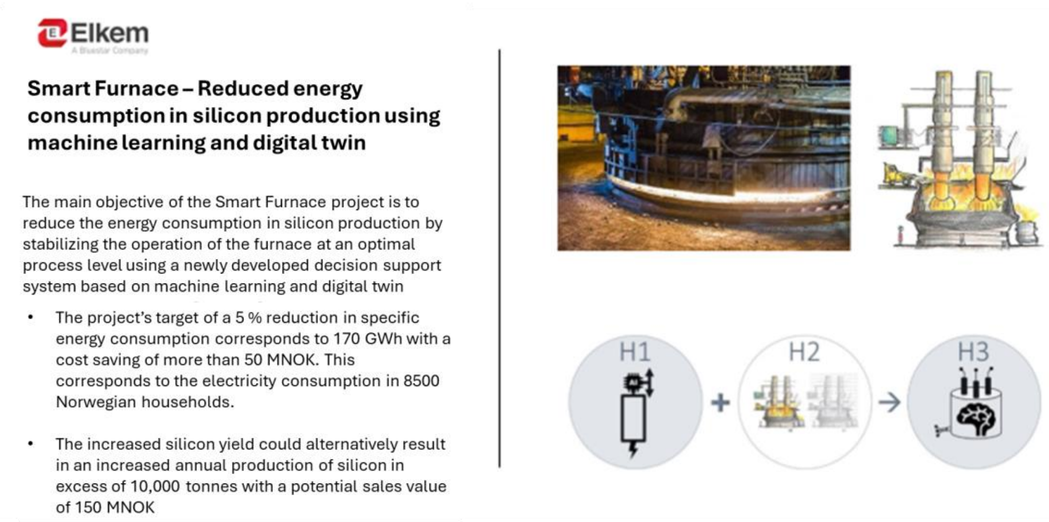


Figure 4 The Smart Furnace project in Elkem

Borregaard achieved significant efficiency gains by bringing together several factories and production units under a common control and management system, see Figure 5. Such success stories are becoming increasingly common, as companies realize that the adoption of digital solutions must be seen in the context with changes in work processes and therefore implemented in close dialogue with the employees who will use the technology. The alternative, with costs for the acquisition and maintenance of individual control systems, is often perceived as high in relation to the direct gain gained from such investments.

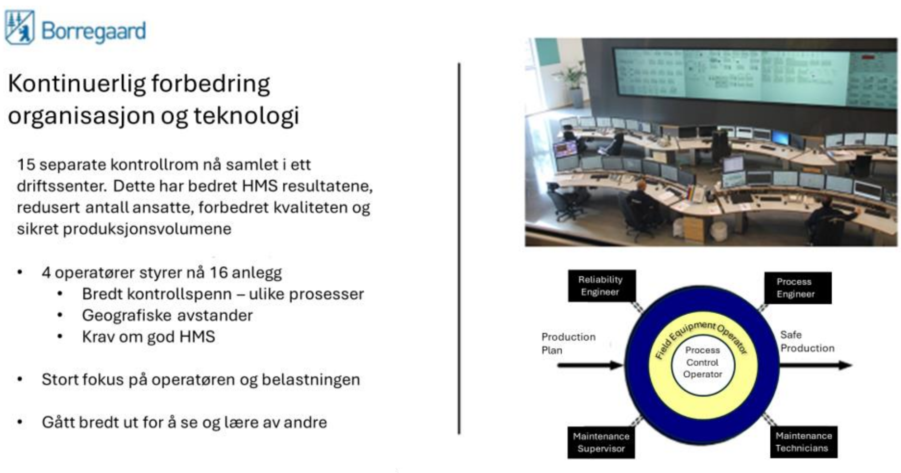


Figure 5 Control and management system at Borregaard

Some experiences from "Industry 4.0" projects

Over the past 5-8 years, a number of major digitalization projects have been initiated and implemented in the Norwegian process industry. Many of these projects have addressed demanding technological challenges in collaboration with R&D actors. Although not all the projects achieved defined and ambitious goals, the work has contributed to an important competence boost inside digitalisation for both companies and suppliers. Such projects have helped to increase the understanding of the challenges that need to be addressed in order to achieve further digital transformation.

In metal production and ferroalloys, there are challenges related to very high temperatures and harsh environments, which lead to a lack of sensors and access to real-time data. When using advanced sensors, challenges have also been encountered, as these often cannot withstand or are unable to measure stably in the demanding environments where the process takes place. [21–23] In some processes, the sensor equipment is exposed to very challenging conditions, such as high temperatures, corrosive environment, dust, or all three at once. Protection measures for electronics and probes in the harsh environments can lead to reduced signal strength, requiring a trade-off between lifetime and signal strength. Degrading the sensor systems over time and maintenance requirements are also a major challenge.

In other projects, inadequate development of digital infrastructure has limited development. In some cases, this has resulted in ad hoc solutions, where data solutions have been partly developed as one piece of the project, and the potential for digital transformation has therefore been less realized.

Many have faced challenges in implementing complex advanced process control models due to inadequate monitoring of the process. As a result, digital twins have been developed, where measured values are defined based on simulations, also called *soft sensing.* A significant challenge with soft sensing in complex industrial processes is the presence of a multitude of variables. This can result in too many degrees of freedom to be able to estimate the desired parameters. AI, combined with neural networks, has also been tested, but the estimates have so far often not been good enough for practical use.

Experience dictates: use custom-built sensors for demanding environments, facilitate advanced process control to train AI models, build digital twins based on domain knowledge and solid mathematical models where everything is integrated into a common digital platform and AI is used for analysis and optimization of the process.

Individual projects in enterprise vs. digital transformation

The manufacturing companies have developed many good examples of digitalisation in the Norwegian process industry. These examples have often represented important challenges for companies, been handled by dedicated teams, and resulted in successful solutions. It is not uncommon to experiment in individual projects down to the factory or business area. A complete restructuring through digital transformation places completely different demands on strategy, crepi, organizational understanding and project planning.

A major challenge for the process industry is to scale and implement successful solutions across units and factories in the company. This makes it difficult to realise the full potential of the digitalisation projects and achieve transformative effects for the entire company. This is paradoxical, as digital solutions usually have very low copying costs. Once the software is developed, the cost of creating a copy is virtually zero.

The challenge with scaling can have several reasons. Often, factories have different IT and automation systems, so a solution that works in one place may be less suitable in another place or require significant adaptations. Both physical equipment and processes can vary between departments/factories. Other times, the equipment is the same, but different organizational models or work processes mean that the organization is not able to utilize the digital solution as well. A third factor is the 'Not Invented Here' effect, which means that people tend to be more willing to adopt solutions and change their way of working if the proposal comes from themselves or someone they have a close relationship with, than if the proposal comes from a more peripheral person or organization. In addition, infrastructure and internal culture may necessitate adjustments and adaptations with digital solutions.

Regardless of the reasons for the challenge with scaling, it is a clear management responsibility to facilitate successful solutions to scale across the company. This also means making sure that the organization is set up to handle the maintenance of the systems, and that the systems are developed and scaled in a way that makes the maintenance as efficient as possible.

Marketing, sales and product/service development

Digitalization has become a key factor in sales and marketing. With the rise of AI technology and customer-centric portals, the way customers are reached, engaged, and served is changing. The customer's expectations of tailored follow-up and availability challenge the industry to invest in tools that provide increased value and strengthen the customer relationship. AI technology provides the opportunity to analyze large amounts of customer data and use the insights to offer tailored solutions.

Many industries have put considerable effort into digitizing their customer relationships. Service industries such as banks, insurance companies and tourism have undergone extensive structural changes and have partly functioned as precursors inside digitalisation. In this process, they have developed new sales channels and product portfolios, while internal case management has been streamlined through automation of manual work operations.

In 2023, total B2C European *e-commerce* revenue saw a modest growth of only 3%, increasing from € 864 billion to € 887 billion. The next few years will be crucial for achieving a stronger and more unified single market in the EU and unlocking the untapped potential of cross-border trade. On October 24, 2019,

The process industry has also begun to digitalise its customer relationships, but compared with service industries, the restructuring has been far less extensive. The process industry in China and Southeast Asia has led the way in the use of *e-commerce solutions.* An example is Alibaba. with, which mediates the sale of a number of products from the Chinese process industry. Some Western process industry companies, such as BASF, have also chosen to take advantage of this opportunity. While there are some examples of *"Innovators"* and *"Early Adopters"* in the Western process industry, it still lags behind its competitors in China and Southeast Asia. Dow Corning's e-commerce platform *"Xiameter"* is one of the few examples in the West of a process industry that established digital sales channels at an early stage.

More and more of today's customers expect to be able to handle large parts of the buying journey themselves with the help of intuitive customer portals that provide full control over the buying process, product information and support. These platforms simplify the customer journey and provide businesses with new opportunities to build loyalty.

A previous survey conducted by Bain & Company on behalf of Prosess21 (2020) mapped how Norwegian companies relate to digitalization compared with the global process industry. It showed that Norwegian process industry companies have lower investments in product and customer experiences compared with investments in operations and the supply chain. Fortunately, this is about to change. Nevertheless, Norwegian process industry companies are still significantly more focused on the digitalisation of the production system than on the digitalisation of marketing, sales, services and customer relations.

Among the traditional Norwegian process industry companies, Yara has come a long way in implementing a digital initiative to transform business operations and rethink how products can be combined with digital services to meet customer needs. A key tool in this initiative is Atfarm[25], which is shown in Figure
6. This is a platform that analyzes plant growth, soil health, and weather conditions to help farmers with optimize nutrient use and increase yields. Through such digital solutions, Yara secures a stronger market position, while building closer relationships with customers by offering innovative and efficient tools for agriculture.

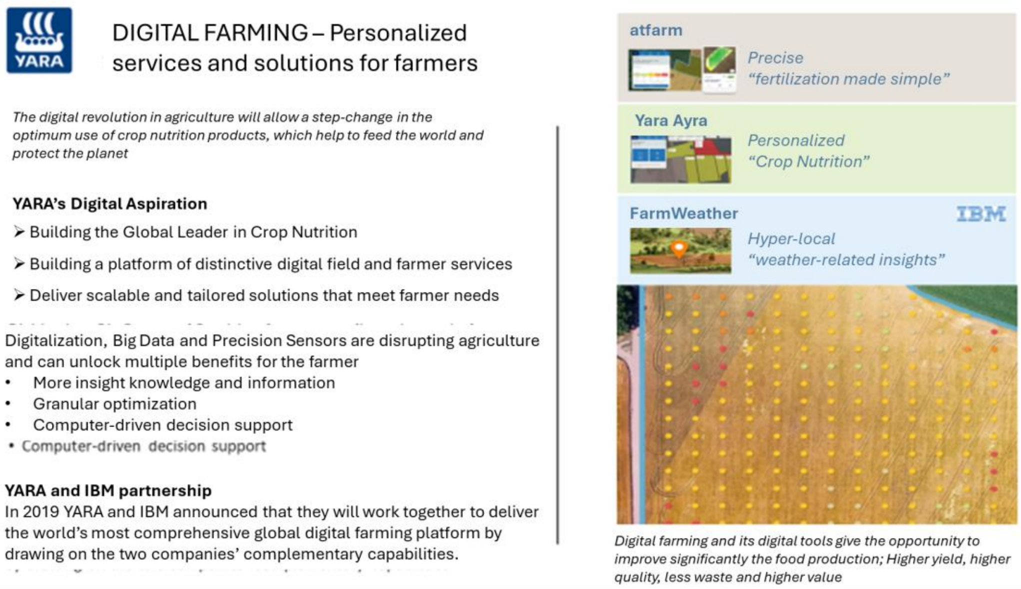


Figure 6 Digital solutions for the farmer, provided by Yara.

Another example is Jotun, a process industry company with downstream activities aimed at companies and end users, has developed the solution *'Color Eye'.* This solution enables customers to take with a colour sample, scan the colour and mix a corresponding paint colour.

Borregaard combines traditional and digital sales channels to reach out to potential customers and help them find sustainable solutions with their challenges.[26] A good example of this is the Scope 3 calculator for bioethanol, where customers can calculate how much they can reduce their Scope 3 emissions by choosing Borregaard's products. Borregaard also actively uses challenges that their potential customers may have in the headlines of their websites. This both strengthens visibility in search engines and makes it easier for AI solutions to find relevant content.

Elkem recognizes digitalization as a key factor in improving sales and marketing, and has implemented several measures to meet customers' increasing expectations for tailored follow-up and availability. A common CRM system is implemented to gather all customer information in a central database. This system facilitates collaboration and provides better insights across roles, ensuring that all relevant information is easily accessible and can be used to build stronger relationships with customers. In addition, the system forms the basis for a new customer portal, where customers get an overview of transactions and product information. In the long term, the portal will also contribute to upselling and cross-selling. All customer visits to Elkem are reported directly in the CRM system, which provides significant insight into the customer's needs. A newly developed AI solution called *CXinsight* analyzes this data and assists in tailoring solutions for customers. *CXinsight* is one of many "bots" that are part of Elkem's *AI Accelerator Platform,* a secure and internally developed platform that enables rapid adaptation of AI solutions to Elkem's different needs.

The process industry in Norway is recommended to increase its focus on activities that strengthen customer loyalty and keep with the emergence of non-traditional sales channels. By taking active positions, companies can avoid the customer base disappearing as a result of changing buying patterns. AI-based solutions and the establishment of customer portals can be used to improve the customer experience, ensure relevant communication and build stronger relationships. For example, AI can be used to offer hyper-personalization, proactive support, and effective automation, improving customer satisfaction. Customer portals provide customers with 24/7 access to information and services, strengthening relationships and increasing customer satisfaction. At the same time, companies must adapt to changes in customer expectations, which are constantly increasing with the advance of digitalization. Through these measures, the industry can strengthen its competitiveness and secure a leading position in the digital landscape.

The emergence of non-traditional sales channels, both open marketplaces such as Alibaba. with and more industry-specific marketplaces, represent new competitors for the established Western process industry. In recent years, there has been an increase in copies of products from Norwegian process industry companies; In some cases, there are counterfeit products with identical product names.

Reduction of greenhouse gases

If you look at the 35 largest point emissions in the process industry, the emissions add up to 9.9 million tonnes of CO equivalents, which accounts for 21% of Norwegian emissions. Compared with other global industrial players that produce the same products, the process industry in Norway has minimal emissions from the consumption of electrical power used in production. As a result, Norway has a low carbon intensity in manufactured products due to the high share of renewables in the power mix.

Reducing CO^2 emissions on a large scale is challenging because carbon is either included as a chemical raw material in processes (such as in the production of Aluminium and ferroalloys) or is a natural by-product of the process (as in cement production). Achieving significant reductions in CO^2 emissions from these industries requires major, groundbreaking changes in process engineering. Below are some exciting zero-emission projects that are already underway. Climate measures in various industrial processes are also described in the expert group report for new process technology. [On October 27, 2019,]

In 2023, net domestic energy supply was 317 TWh (including offshore power production), of which electricity consumption was 127 TWh inside. This is especially true for "deep decarbonisation", where carbon is currently used as a production raw material. In such processes, the energy in the carbon is used very efficiently, while alternative reduction methods often require far greater electricity consumption.

Environmentally friendly production therefore requires holistic thinking: both production processes, techniques for electrification, the energy market and carbon capture methods must be developed in tandem to achieve real emission cuts. This underlines the importance of technology development and R&D strategies across sectors. Digitalisation and the use of digital tools will be central, but must be combined with new technologies that require research and development. If the industry's emission ambitions are set lower than what is possible to achieve through technology and digitalisation, there is a risk that national industry will lose framework conditions, which can lead to deindustrialisation. This would then lead to carbon leakage, as the global centre of production would shift to regions with weaker emission requirements.

Digital solutions and automation can help reduce greenhouse gas emissions by optimizing the production process or raw material composition, reducing emissions. Stable production provides more efficient use of energy and raw materials, resulting in lower direct and indirect emissions. Targeted instrumentation and information systems make it possible to monitor greenhouse gas emissions and take corrective action in the event of deviations. Better access to data provides new insights into processes and enables the use of advanced data analytics and artificial intelligence. [28.29]

Process industry companies face a complex challenge when they have to keep track of their overall climate accounts, regardless of the size of the company. The total greenhouse gas emissions include direct emissions from production, indirect emissions from the production of purchased electrical power, as well as other indirect emissions from the production of raw materials, logistics, travel, waste management, with more. To document their total greenhouse gas emissions over time, several Norwegian process industry companies have adopted digital solutions. *Emisoft* is an example of a Norwegian-developed tool that can be used to follow up the company's climate accounts, and this tool has been used by Equinor for a long period of time. [On October 30, 2019,]

The extent of accidents and injuries can be reduced by replacing dangerous operations with machines or robots. This can also contribute to a healthier working environment by reducing or eliminating exposure to harmful substances. For example, various AI techniques can be used for early warning of gas emissions or other conditions that may pose a fire or explosion risk. [On October 31, 2019,]

Groundbreaking projects

In cutting-edge projects inside the process industry, modeling and the use of simulations are essential to reduce development costs and ensure faster progress. By simulating different scenarios and processes, it is possible to identify and solve potential challenges before they arise during pilot trials. This allows for a more cost-effective development process and increases efficiency in expensive and time-consuming physical tests. When the projects are scaled up to industrial pilots, modeling and simulations provide valuable insights that contribute to further optimization and a smooth transition to larger scale.

Hydro has made significant progress towards a sustainable process with its innovative HalZero technology, see Figure 7. This groundbreaking process eliminates CO_2 emissions and instead releases oxygen. This is achieved through a radical change in the core process, where the feedstock is chlorinated before electrolysis, and the CO_2 emissions are reused in the process to form a closed loop. With successful tests and modelling in Porsgrunn, Hydro is well on its way to reaching an important milestone for small-scale production Aluminium with its new process inside 2025. Advanced testing and development of new digital models will form the basis for scaling up to larger industrial volumes inside 2030. [32]

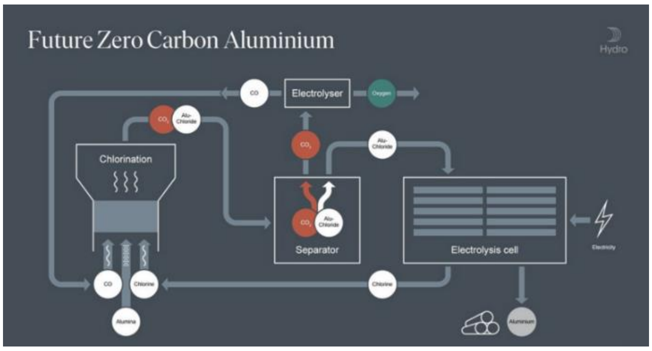
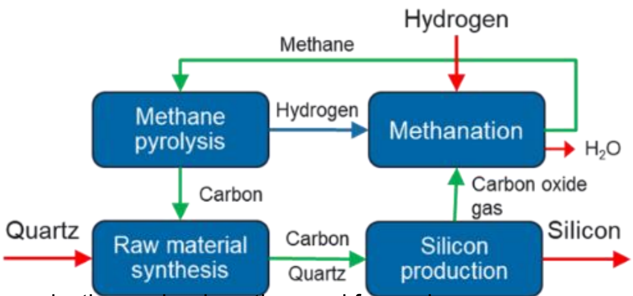


Figure 7 - HalZero – zero-emission electrolysis from Hydro | Illustrated by Hydro

Elkem is developing a new process for silicon in the groundbreaking Sicalo project, ref. Figure 8. The project involves capturing the carbon oxides emitted from the silicon furnace and converting them to solid carbon using low-carbon hydrogen, which is then reused as a reducing agent in the production process. This will be able to eliminate all direct CO^2 emissions from production and reduce the need for coal or biocarbon as a reducing agent. Elkem aims to



the Figure 8 - Sicalo process developed by Elkem establish an industrial pilot with continuous production before 2030. To succeed with the project, digital analysis, modelling and the use of advanced sensory technology in combination with process data are essential. [33]

Many industries are experimenting with alternative raw materials to carbon. After initial investigations with the ferroalloy industry, SINTEF has initiated the HyPla project. The project aims to use hydrogen gas, which is converted to plasma in an electric arc and thus make metal from mining ore. An observation probe with an industrial camera makes it possible to observe what is happening in the reactor directly, which is important for process development. The HyPla reactor is equipped with an industry-standard control system (PLC) connected to the postgreSQL time series database in the SINTEF cloud, which enables real-time observation and historical analysis. The project, which is funded by SINTEF, has yielded promising results at a scaled-down prototype level, The technology will make it possible to use hydrogen as a raw material in the production of ferroalloys, which is not possible without the use of plasma. However, a lot of research remains before a full-scale pilot can be produced. [34]

Figure 9 - SINTEF's HyPla project uses hydrogen plasma as a replacement for coal in metal production, Photo: Sintef

Competence and organisational development

Digitalization is not only about implementing technology, but also about changing the culture and how the organization works. Broad employee involvement is necessary, and an organisational culture with flat crepi promotes trust and participation. Increased competence in digital areas, especially inside data-driven decision-making and new technologies such as machine learning and digital twins, is essential. [5]

Companies must invest in both training and recruitment of specialists inside digital technologies, as well as building good relationships with technology suppliers and professional communities that have complementary expertise and experience. Environmental and climate requirements create new market opportunities, and it is necessary to adapt to the paradigm shift towards sustainable production. Here, solutions should be sought that are combined with the development of new digital systems to achieve cost-effective solutions - "Twin transition".

Companies today develop and implement digital solutions inside sales, marketing, administration, logistics as well as production-oriented processes with predictive maintenance, smart digital systems and the use of digital twins and AI to optimize the individual process. with Like the oil industry, a need for standardisation will emerge here, which is a prerequisite for subcontractors to deliver cost-effective products that work across different industrial companies and their digital systems. The process industry is now on the verge of entering the next phase of leveraging its investment in digital infrastructure and moving to digital transformation. This will be discussed in more detail in the next chapter.

Digitalisation in focus towards 2030

The process industry, like other industries, is likely to undergo significant digital changes with the next five years. Increased opportunities for the collection of large amounts of data, integration of 5G, migration of services to the cloud, as well as the use of advanced analytics and artificial intelligence, provide great opportunities both inside production and sales. Digital transformation can be crucial for the effective implementation of new technology across the entire organization. This can involve everything from automating production processes to developing new business models based on data analytics and artificial intelligence (AI).

Traceability requirements will increase in the future, not only for quality assurance, but also to meet stricter regulatory requirements and consumer expectations for sustainability. Digital solutions such as *blockchain* (Digital Product Passport) and advanced IoT platforms can provide holistic and uninterrupted traceability throughout the value chain, from raw material supply to final product. This provides opportunities for more insight and understanding of processes that lead to efficient and responsible operations.

In January 2021, A.SPIRE, with the European process industry and leading research environments, updated the *P4Planet 2050 Roadmap.*[35] The roadmap identifies important technological barriers to realising the ambitions of a zero-emission society inside 2050, and deals with, among other things, digitalisation. In the same way as Prosess21, A.SPIRE has chosen to focus its digitalization work on the period up to 2030.[36] A.SPIRE emphasises that the digitalisation of the process industry will cover the entire value chain, including R&D, operations, purchasing, logistics and customer relations. Digitalisation will make production facilities more energy and resource efficient and more flexible, contribute to significant reductions in greenhouse gas emissions, and set the course towards a climate-neutral economy. The process industry will become more competitive, while conditions inside health, safety and the environment will be further improved.

The Norwegian process industry still has large unrealised gains as a result of digitalisation of production processes. New technology is constantly being developed, and in order to maintain competitiveness, it will be important for the process industry to be proactive with the use of relevant digital technologies.

In production and operations, the following technologies are expected to contribute to increased effects:

- **New sensors,** preferably based on sound, image or video, for use in demanding environments.
- ***Edge* AI:** Sensors with built-in microcontroller for AI analysis that only send data upon change and after local processing.
- **5G** with energy harvested from the environment (vibration, heat differences and/or sunlight)
- **Compile data** from a large number of sources, both structured and unstructured data.
- **Advanced analysis methods,** including artificial intelligence.
- **Digital twins** with the use of AI for optimization of the entire production line.
- **3D visualization** and other forms of human-machine interaction

The Norwegian process industry should combine efforts to maintain a leading position inside advanced process control, as well as actively seek out relevant examples and draw inspiration from other industries.

Figure 10 describes the TAPI project, which is an example of an R&D project that combines new sensory science with advanced methods for modelling, estimation and control. The purpose with the project was to develop the next generation of digital tools for optimal operation and maintenance of complex industrial processes. The project focused on knowledge building and it has created an important basis for the development of future digital products and methods. One example is the use of AI to analyse the exhaust gases of a process where deviations were detected that could be related to errors in the process that would otherwise not have been detected.

Experience from research projects involving digitalization of the production process shows that one must implement gradual improvements of the process and equipment at the same time as working with major changes. Working with simpler forms of digitalization can trigger value potential relatively quickly and lay the foundation for more advanced management of the process. This can lead to a maturation of the operating environment with working digitally, and thus lay the foundation for further advances in digitalization of the production process. Working with advanced digital models without first having taken the basic steps to digitize the process has often proven to mean that you do not reach the goal with implementing the more advanced models.

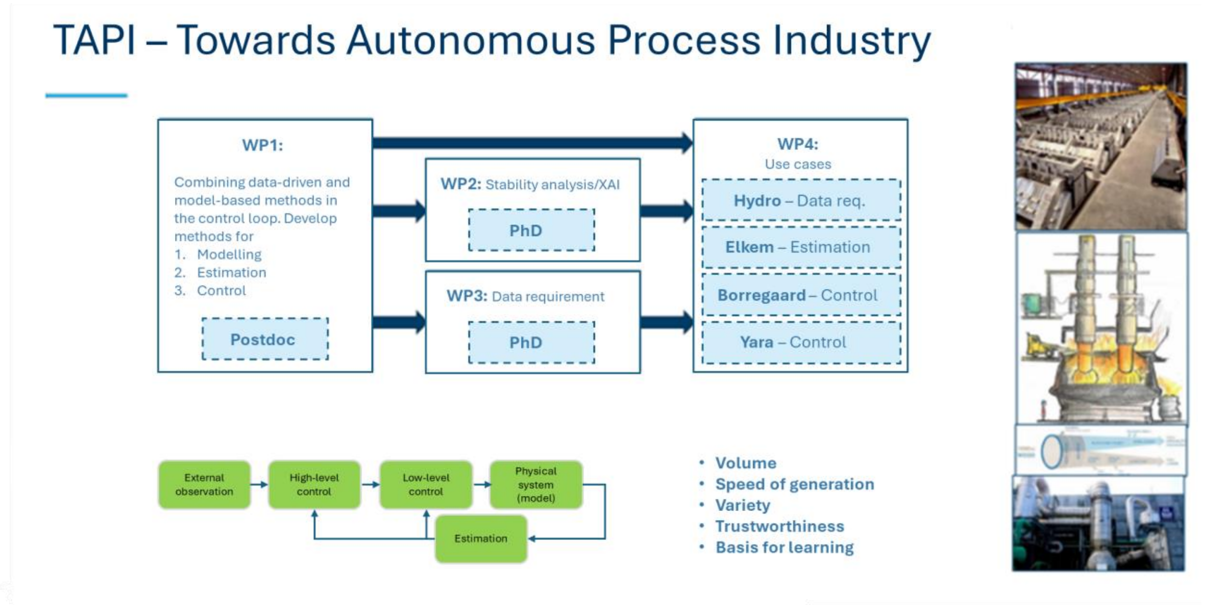


Figure 10 The TAPI project

The integration of AI with digital platforms can fundamentally transform supply chains by providing advanced insights and optimization. This combination provides real-time insights into the raw materials' journey, enables accurate tracking of materials' origin, and ensures that products meet quality and sustainability standards. Resource efficiency is improved by identifying inefficient processes and suggesting improvements, reducing waste and increasing efficiency. AI can also monitor data to identify and respond to supply chain risks, taking action before problems escalate.

In the article *"What is supply chain optimization",* IBM describes the use of new technology for value chain optimization. Here*, blockchain,* AI and IoT are combined for supply chain optimization.[37] The French *SETRAGe* has conducted studies for *"Increase of transport capacity"* with the use of AI, digital twin and predictive transport analysis (see Figure 13). These are good examples to inspire Norwegian process industry companies.

Standardization

All modern industrial companies benefit from digitalization to achieve increased competitiveness. Such innovation should often be regarded as the intellectual property of companies. In many situations, however, the companies benefit with cooperating. Digital Norway[38], DigiPro[39], NFEA[40] and the RINVE network[41] are examples of collaboration arenas where the industry shares insights and participates in mutual learning in digital topics. Collaboration can provide access to a wider range of resources, both technological and human, than are available in individual companies. Industry standards and best practices developed collaboratively can help raise the bar for the entire industry, make participants more Heavy Duty against global competitors, and make it easier for suppliers to deliver relevant offers.

Best practices for value chain integration and vertical interoperability

In today's factories and industrial groups, cyber-physical networks are used – digital components in a layered infrastructure from the production floor to the cloud, exchanging information in complex patterns. These are networks with considerable complexity. At a concept level, however, we can place the data flows into two main categories: Data that follows a value chain, and operational data that flows between the layers of a digital architecture. The figure illustrates this.

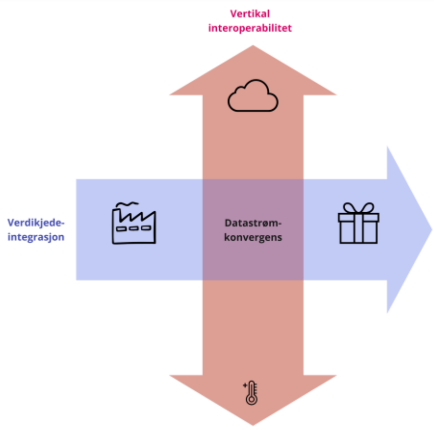


Figure 11 - Conceptual communication Architecture (Figure: Bouvet)

Value chain integration in a digital context means that all relevant information – through all maturity levels – is made structured and available in real time across actors and systems, so that the use of resources required to handle the information can be reduced, increased the quality and resolution of the information and drive continuous improvement throughout the life cycle. There are two main categories of value chain integration:

- Digital lifecycle information on production equipment and facilities from concept to design, construction/installation, operation and decommissioning
- Data on goods produced in a value chain: The raw materials involved, the production processes, quality, product name, product ID, carbon footprint and other characteristics

Building appropriate models and transfer formats for value chain integration is extremely demanding. The value chain includes many different actors, from internal and external suppliers to end users and customers, with their own systems, data formats and processes. Some parts of the value chain may be highly digitalised, while others are still based on manual processes or older technology. Defining models that are suitable for all players in the value chain requires compromises between general standards and specific needs. The choice of migration formats must balance ease of use, security, scalability, and performance. Different data structures and formats can make it challenging to integrate systems seamlessly. Intermediate layers or interfaces must often be established that can "translate" between systems and formats, which can be technically complex and costly.

For decades, the Norwegian oil and gas industry has invested considerable resources in the development and adoption of standards and best practices for value chain integration, particularly for digital lifecycle information. Examples of this are NORSOK[42], READI JIP[43], POSC Caesar Association[44] and OSDU[45].

For land-based, goods-producing industries, the Reference Architecture Model for Industry 4.0[46] offers the most complete set of standards for value chain integration. RAMI 4.0 is a multidimensional reference model that structures digitalization in industry by connecting products, processes, and information throughout the life cycle across hierarchy levels and IT layers.

For data on goods produced in the value chain, the situation is similar. DPP[47] is a concept designed to promote traceability, sustainability and circularity in various industries, especially in the process industry. Although there is no exact date for when DPP will become mandatory in the Norwegian process industry, it is likely that the requirements will enter into force with the EU's implementation, which is expected to take place successively between 2026 and 2030.

The Norwegian process industry faces major challenges when adopting standards for value chain integration. Adequate best practices or standards optimized for the process industry have not yet been developed. Moreover, the available standards are extremely complex and partially overlapping. This makes the work with identifying and implementing an appropriate selection of standards very resource-intensive and unsuitable for handling in each of the companies.

Vertical interoperability is about the communication of data between the physical world, with sensors and production equipment, and digital components in higher layers of the digital architecture: control systems, professional systems for production and maintenance, optimization solutions, data platforms, external specialist systems, and more.

The Norwegian process industry has traditionally been characterized by closed, supplier-specific automation solutions, where production equipment and operational systems (OT) are rarely integrated effectively with business applications in the IT layer. A lack of Heavy Duty information structures and clear semantic models means that data is often presented in disparate formats, which in turn creates fragmentation, increases costs and makes collaboration across departments and facilities difficult. The need for seamless facilitation of data in appropriate syntactic models and semantic contexts is becoming increasingly urgent, especially when the goal is to improve maintenance, optimize production processes, and strengthen competitiveness.

The introduction of recognised standards such as ISA-95[48], Namur Open Architecture (NOA)[49] and OPC UA[50] lays a solid foundation for structuring information across hierarchical levels and ensuring that different systems can communicate and interpret data in a consistent manner. By establishing common terminology and data hierarchies, time-consuming reformatting and manual intermediaries are avoided. This makes it easier to leverage data in real-time analytics, maintenance programs, and integrated ERP solutions. Semantic interoperability means that information about, for example, production volume, quality and raw material consumption can be stored and interpreted in the same architecture, so that different actors gain relevant insight without having to deal with a confusing myriad of proprietary formats.

In the same way as for value chain integration, this field is also very demanding to handle for the companies individually. By collaborating on best practices for protocols, transmission formats, security requirements and other relevant topics, industrial companies will achieve major efficiency benefits and enable supplier companies to exploit economies of scale.

Data stream convergence occurs when a digital model of a physical object is enriched with data from both data streams. For example, a supplier of a pump system can hand over technical data to an industrial company in an agreed digital format. With such *a value chain integration,* the company has a static digital model of the pump system. It can be enriched continuously with condition data from sensors mounted on the equipment – pressure, temperature, current draw and so on. With this *vertical interoperability*, the model becomes a digital twin with static and dynamic properties, which can create value inside production optimization and maintenance.

Collaboration on standardization and best practices

The Norwegian process industry faces great opportunities in optimizing value chain integration and vertical interoperability, but the lack of standardization hinders effective implementation.

A broad national initiative for standardisation in these areas could provide a common direction for how the process industry can move from proprietary solutions to open, secure platforms, so that future integration architectures become more cost-effective and less risky. By bringing together industrial actors, authorities, suppliers and research communities in a common forum, it is possible to exchange experiences, develop guidance documents and best practices – based on available standards. There is probably no need for new standards, but rather clear advice on choice and use. There is also a need for contract templates and other documents that industrial companies can use with the supplier industry, for example to set requirements for the delivery of plant and product information in structured, digital form. A broad industry standardisation initiative can help reduce barriers.

Standards and open interfaces

Application of open and standardized machine-to-machine interfaces (APIs) allows for the interaction and exchange of data without being limited by proprietary solutions. This enables seamless integration where you can build on the existing digital systems.

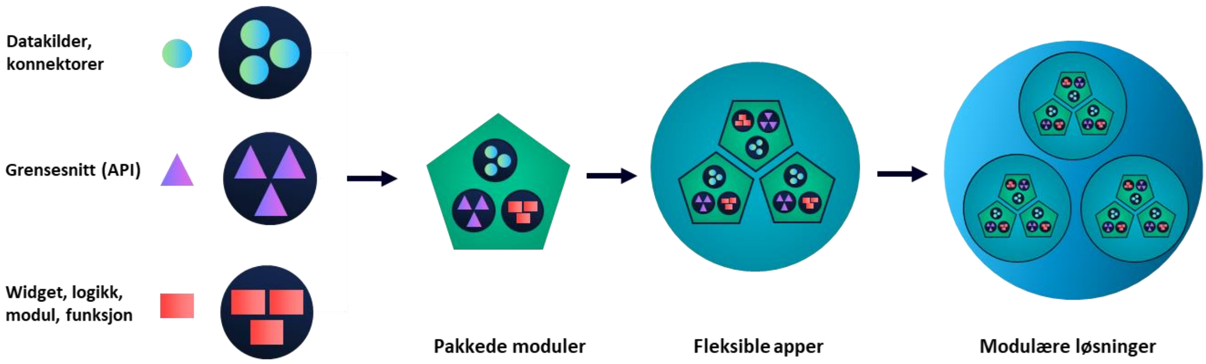


Figure 12 - Digital Foldable Building Blocks (Figure: Siemens).

By using modular "building blocks" and taking advantage of best practices and industry standards, the Norwegian process industry can more quickly establish flexible and future-oriented concepts for digitalization and innovation. These modular building blocks, often referred to as packaged *business capabilities (PBCs)* on the IT side and MTPs *(modular type packages)* on the operational side, make functionality easier to integrate and promote autonomy and flexibility.

When different components and systems are compatible, innovation can be introduced without major changes. This allows for faster and more cost-effective adoption of new technology, more secure data management and a dynamic infrastructure that better meets tomorrow's demands and opportunities. Open standards promote innovation by facilitating collaboration and sharing of best practices across sectors and actors.

Digitalization in a value chain perspective

For industrial companies, it is natural to prioritise digitalisation measures inside production-related core processes. But it is also important to think about digitalisation in a larger perspective: Between departments in a manufacturing company, and between business areas in a group. Even large industrial groups are included as players in global value chains. The interfaces with suppliers, partners and customers often represent great opportunities for digitalisation: What opportunities do we have to facilitate for our raw material suppliers to be able to work more efficiently with us? How can we collaborate better with partners on common goals? What do we know about the products we make that our customers could benefit from?

The complexity and potential with value chain optimization increases as the perspective expands. The more links in the value chain you include with in the optimization work, the more variables and dependencies you have to handle. At the same time, this opens up a greater scope of opportunity, because measures that lead to improvements at one step in the value chain can create ripple effects further up or downstream. In this way, expanded collaboration and data flow can lead to benefits that are not visible if you only look at one link insulated. But it is precisely this increased complexity that means that such projects require good coordination, a common understanding of goals and technical solutions that can handle large amounts of data and different systems. Some value chain challenges should be solved in collaboration between industrial enterprises, or in interaction with political authorities.

How can digitalisation streamline trade between suppliers and the industrial company? By sharing forecasts and planned production in real-time, raw material suppliers can adapt to fluctuating demand, reduce delays, and ensure smooth flow of goods. Data exchange of tracking data can be further digitized, as can the document flow between customer and supplier. Digital tracking of raw materials allows for better quality control, better sustainability management, and easier identification of bottlenecks.

Suppliers of industrial infrastructure, buildings, production materials and other capital equipment can be more closely linked to the industrial companies' value chain, for example by delivering more information in formats that can be reused analytically, for example in digital twins, without the need to recreate information in unstructured form.

In a similar way, industrial companies can explore opportunities for increased digitalization in the interface with their customers. This can involve optimizing sales processes and improving customer engagement, as well as advanced analysis of order and customer data. This can form the basis for new business models, reduce sales costs, provide better market understanding, insight into competitors, faster adaptation to changing market needs, specialized and tailored products, better customer follow-up and increased customer satisfaction.

In particular, digital service innovation with an emphasis on upselling is an area where many industries, industries and industries see great growth opportunities.[51,52] What value-creating digital services can industrial companies offer their customers? For example, Yara has had success with additional sales through *Digital Farming* services combined with standard physical products (fertilizers). Another example is how DOW achieved great success by changing the business model for one of its most important products and selling this through a pure *eCommerce solution.* This was done based on customer analysis and the development of a dedicated business model optimized to satisfy the needs of the customer segment.[53]

Digitalisation can also contribute to better market understanding and competitive conditions and therefore faster development of specialised products. Growth in the process industry requires both top-line growth (revenue/sales) and bottom-line growth (profit/profitability). It is important to consider how the green shift may affect top-line growth.

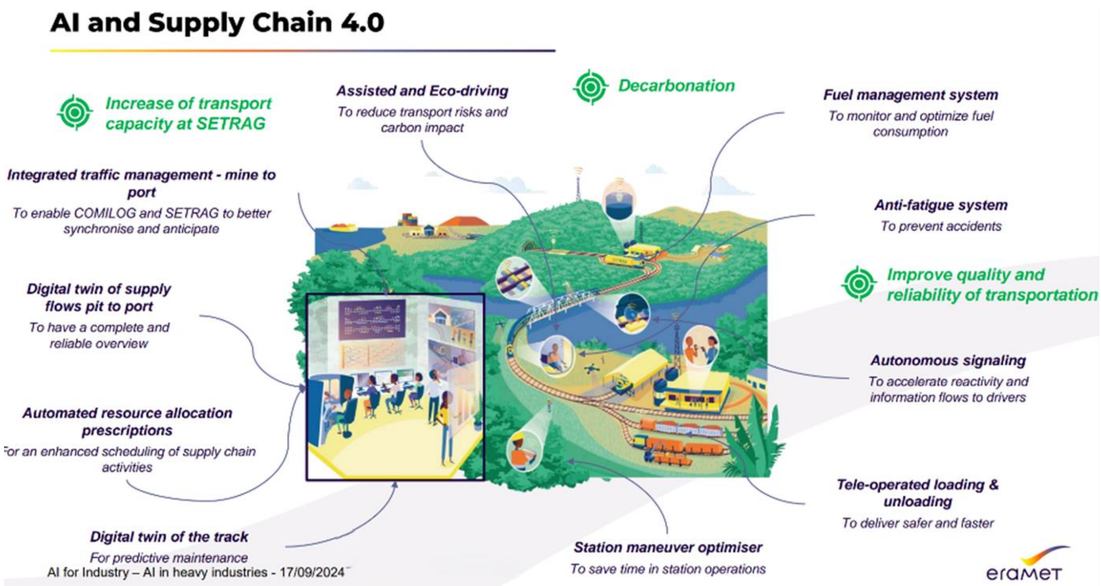


Figure 13 AI in logistics and supply chains (Eramet)

Figure 13 shows some of the areas where AI can be useful outside the production process. Digital solutions for traceability and documentation of material flows will be necessary for the circular economy to have a major impact, for example through increased recycling and efficient exchange of side streams between companies. A digital twin of the supply streams provides a holistic view of the entire supply chain, from mine to port. This enables better planning, monitoring, and optimization of all links in the chain, leading to a more efficient and reliable supply chain. By using AI technology, businesses can ensure that their supply flows are seamless and well-coordinated, improving both efficiency and reliability.

Elements of the digitalization process

Digital Infrastructure and Data Management

Digital21[54] emphasises that digital infrastructure and management of digital data resources are crucial for strengthening the business sector's ability to utilise and develop digital knowledge and technology. This requires strategies that maximize value creation through efficient infrastructure and sound resource management. A robust data infrastructure that bridges the gap between traditional IT and OT data sources is essential for digitalization. Modern software systems enable data exchange through Application Programming Interfaces (APIs), and considerable work and innovation is underway in this field internationally, which Norwegian companies should follow closely.

Norway is still facing investments in the fifth generation mobile network (5G). 5G has also been launched for industrial purposes in sectors such as logistics, transportation, energy, healthcare, and media production. It is important to highlight the new business opportunities and the need for expertise to exploit the potential of this infrastructure, especially inside the process industry. Private, geographically limited 5G networks can provide major benefits for the process industry.

In Europe, the European Commission has defined the frequency range from 3.4 to 3.8 GHz, known as the 3.6 GHz band, as the primary pioneer band for 5G in the EU countries. European industry is already developing industrial solutions for private 5G networks in this band. Technology developments must be followed closely, as the Norwegian process industry is dependent on international suppliers for solutions inside instrumentation and automation.

Strategic data sharing

The report from the expert group on data sharing in the business sector highlights how strategic data sharing can strengthen Norwegian industry's competitiveness, both internally and in value chains.[55] The major players, *the asset owners,* must lead the way in these changes. Optimal management of data can provide significant value creation and innovation, including standardization across suppliers. Data alone has value, but it is only through improved decision-making that the full value is realized.

The most important technologies that can benefit from this are big data analytics and artificial intelligence, which in the process industry can streamline decision-making processes, provide precise predictions, improve customer insights and, as a result, increase the pace of innovation. This strategic approach to ownership and sharing of data can give Norwegian companies a significant competitive advantage and create a more dynamic and innovative industrial sector.

Artificial intelligence and process knowledge

Succeeding with the use of artificial intelligence (AI) will be crucial for realizing the value potential from digitalization. In general applications of AI, there is continuous innovation led by large communities in the US, China and the UK. It is important that Norwegian companies can make use of the results from these internationally leading environments. At the same time, Norway can position itself as an international leader inside the development and use of AI for management, optimisation and monitoring of advanced processes.

The key lies in combining Norway's leading domain expertise inside the process industry with digital expertise. Norway is a world leader in modelling advanced production processes in the process industry. Solutions based on mathematical models and data-driven methods such as machine learning can give the Norwegian process industry a competitive advantage. Norwegian communities can benefit from decades with experience in the use of physics-based models to describe industrial facilities. The combination of such models with AI enables valuable user experiences and can form the basis for building internationally leading supplier companies.

Another important question is how digitalisation can maximise capacity utilisation in process plants. Large costs are associated with possible equipment failures and production stoppages, quality variations, lack of capacity utilisation and dividends. There is great potential here in predictive maintenance and production utilization by combining sensor data from production and process plants with AI techniques. This can, for example, provide advance warnings of critical equipment in need of inspection or repair, and AI-controlled condition monitoring can predict major production disruptions.

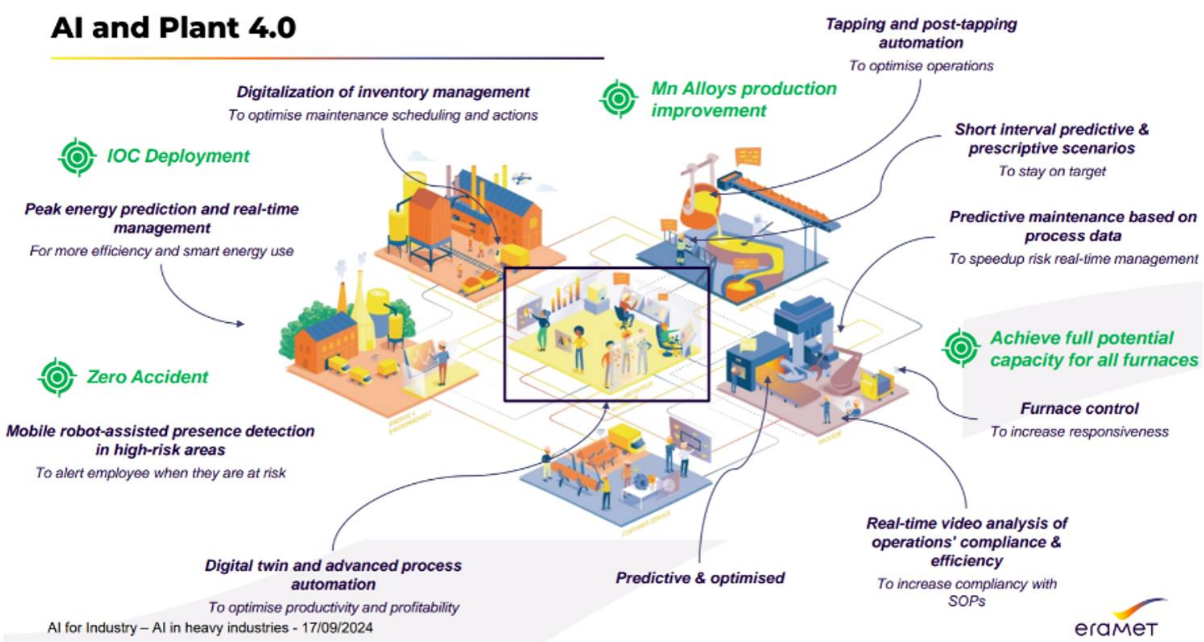


Figure 14 Ways in which AI can be utilised in operations (Eramet).

AI can analyze large amounts of data to provide insight into operational patterns and optimize resource allocation. It can also coordinate between different departments and ensure access to correct and up-to-date information. AI creates opportunities for efficiency, cost reduction, and improved decision-making processes, giving companies a competitive advantage in the market. Figure 14 shows some of the areas where AI can be useful.

Collaboration and innovation culture

Norwegian industrial companies' ability and willingness to cooperate are often highlighted as a competitive advantage. The trust that exists between companies makes it more legitimate to share knowledge, technology and data across industries and sectors. This is important for driving change and innovation, and helps to create win-win situations for the partners, which in turn provides increased value creation. International actors are often impressed by Norway's ability to cooperate.

Carrying out digitalisation projects often requires access to technology and expertise that the company itself does not possess, such as inside data security and advanced analytics. The solution is often to establish cooperation with other suppliers and knowledge companies. Academically and technologically, there are many common challenges across industries and sectors, and there is a lot to learn from each other by exploiting the so-called triple-helix model between industry, R&D and academia.

Norwegian industrial companies have an organisational culture characterised by shorter distances between operators, middle managers and management. This provides greater influence for the individual employee, which can promote a better innovation culture internally. A culture where it is allowed to try and fail, and where all employees have the opportunity to improve their own work situation, is one of Norwegian industry's greatest competitive advantages. In the process industry, there are many examples where companies share knowledge and experience in R&D projects, FME/SFI initiatives and in various clusters.

Research and Development

In order for the Norwegian process industry to speed up and succeed with digitalisation, a joint investment in research and innovation is crucial. Digitalisation requires new expertise and the introduction of new types of digital technologies, which differ from previous methods. The process industry has peculiarities that create specific challenges for realizing the digitalization gains compared with other industries.

Prosess21's mandate is to both increase the value creation potential and reduce greenhouse gas emissions. This must be reflected in the initiative, where digital transformation is seen as a driver for the green transition of the Norwegian process industry. The focus should therefore be on specific topics where technological and organisational challenges have been identified that hinder digitalisation and digital transformation.

The initiative is primarily intended to give the process industry access to new technology and knowledge that can be used in digitalisation. Secondarily, it will develop lasting partnerships and alliances between the actors, which can create strong ecosystems and fruitful value networks. This includes building expertise in the research communities and strengthening the supplier industry's innovation capacity.

The research should be carried out in close collaboration between process industry companies, supplier companies and the research and competence communities, with an emphasis on openness and sharing of knowledge and results. This is important in order to optimise the socio-economic effects of the investments.

It is also important to be well informed about the various parts of the policy support system and to familiarise oneself with the various support schemes that exist for public funding, both nationally and internationally. Norwegian R&D institutes have been good at obtaining a large part of the R&D funding in the EU relative to how much Norway contributes financially. In order for innovative solutions to also have an effect in the Norwegian process industry, it is important that companies also contribute to EU projects.

Examples of Norwegian industrial lighthouse projects

GreenBox aims to develop the green digital factories of the future and lay the foundation for upgrades and new establishments in the Norwegian process industry. With ambitions to reduce CO^2 emissions with 35% inside 2030 and reach net zero inside 2050, robust instrumentation, improved process models and automatic sampling and analysis are essential. Vianode's factory at Herøya and Elkem's pilot in Kristiansand serve as test arenas for new technology, while Hydro, Future Materials and the Eyde cluster spread the technology further. Norwegian technology suppliers, with NORCE and SINTEF, are developing new products and solutions to keep Norway at the front globally. [56]

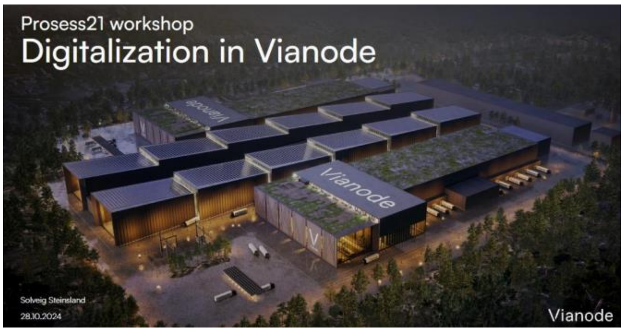


Figure 15 Illustration of Vianode's future gigafactory

Borregaard has systematically worked with digital transformation to strengthen its position as one of the world's most advanced biorefineries. The company has adopted advanced automation solutions and established a centralized operations center for monitoring and controlling integrated processes. By using sensor technology and machine learning, they have increased uptime, reduced maintenance costs, and extended the life of equipment. Borregaard leverages data and technology to improve sustainability and meet regulatory requirements. Security and digital competence are also key focus areas, with continuous training and collaboration with external suppliers.

Figure 16 Borregaard

In sales and marketing, Borregaard utilizes data and technology to create business value. By combining behavioural data with data from internal systems and external data sources in Borregaard's centralised data platform, increased insight and development of predictive models has been facilitated. These models identify market movements and other factors that influence strategic decisions. Automation, integrations with third-party platforms, and seamless sharing of insights have contributed to new customers, higher marketing ROI, and improved data quality. This enables Borregaard to streamline workflows, increase production volume and strengthen competitiveness.

An important success factor for Borregaard is to strengthen the employees' digital skills. Through broad participation in digitalization initiatives and a culture of continuous learning and improvement, the company has built both internal expertise and achieved lasting results. At the same time, strategic collaborations with external suppliers provide access to cutting-edge expertise. To ensure a holistic perspective, Borregaard has established a portfolio board for digital initiatives and introduced processes for prioritization based on business value.

Boliden's Green Zinc Odda 4.0 project aims to develop the world's most environmentally friendly and technologically advanced zinc plant. The project combines an expansion of the factory in Odda with a comprehensive modernization using digital technologies to increase productivity and reduce environmental impact. A scalable digital platform integrates infrastructure, information architecture, and a digital ecosystem of software, providing better control and management of production. The platform facilitates data-driven decision support using real-time data, which contributes to more stable and efficient operations as well as reduced energy consumption. Strategic partnerships with suppliers ensure expertise and

Figure 17 Digitalisation with new and old infrastructure at Boliden Odda

Technological solutions adapted to the factory's needs. The new information architecture is flexible and scalable, making it easier to adapt to future requirements and technology. Through digitalization and increased capacity, Green Zinc Odda 4.0 builds a solid foundation for further technological development with the organization's capabilities.

National and international perspectives

The national digitalisation strategy[57] aims to make Norway the world's most digitalised country by inside 2030. The reality is that Norwegian companies are increasingly learning from their competitors instead of leading. In the report *"The Digital State of the Kingdom 2019-2024"*[58] from Digdir, it is also mentioned that Norway has an ambition to be a world leader in digitalisation, and it is also emphasised that it is important for Norway to join the digitalisation train from the EU. This is probably even more important for the process industry, where you experience global competition, that there is pressure on margins and where competitors are becoming more numerous and better. In accordance with the National Digitalisation Strategy, the Government has ambitions and willingness to invest in ICT education and development inside AI technology. It is also emphasised that one must have a strong research environment inside ICT in order to keep with international developments. This investment is a prerequisite for being able to succeed with digitalization in Norway.

Statistics Norway (SSB) has analysed the proportion of companies with more than 10 employees that use artificial intelligence (AI). The survey shows that the use of AI has doubled over the past year, from 12% in 2023 to 24% in 2024. The increase is mainly due to the increased use of generative AI, such as *ChatGPT, Bing Chat,* and *Microsoft Copilot.* Generative AI has become more accessible and user-friendly, making it easier for companies to implement the technology in their processes. Tools like ChatGPT and Microsoft Copilot help businesses with everything from customer service to internal communication and data analysis. This development has led to increased efficiency and innovation in many sectors, and strengthens the

[59] competitiveness.

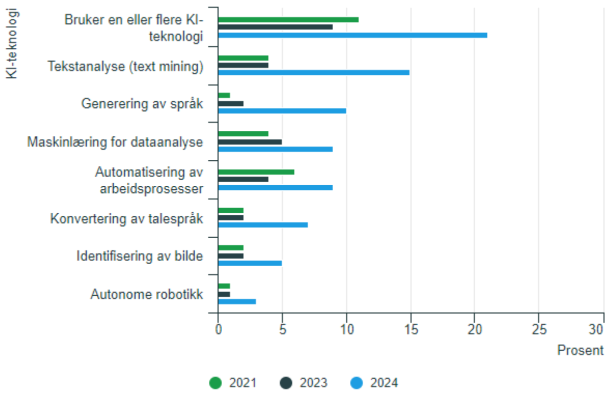


Figure 18 Application of ICT in the business sector, Statistics Norway. [54]

The European Commission's report 2024 *State of the Digital Decade package*[60] provides a status of member states' progress inside digitalization, as well as the development of new laws and regulations that will accelerate interaction and facilitation of digital transformation. The report is a wake-up call that encourages members to increase their efforts inside digitalisation with a focus on harmonising digital policies and investments.

The starting gun has been fired for the digital industrial journey

The great growth inside AI is only the beginning of a digital upheaval inside industry and society. Application of AI in interaction with digital twins, product passports and robotics is expected to provide great opportunities for the industry. To succeed with this, we must collaborate and have the willingness to invest in new technology.

AI is used in many activities inside areas such as administration, logistics, marketing, traceability, process optimization, cost efficiency and environmental considerations. In the past, these tasks were carried out separately and independently of each other, but now we see that some are taking the lead in implementing digital twins with the application of AI technology for entire factories. This enables a digital transformation where the total impact of the technology is fully exploited. This development is in its initial phase, but is expected to become an important method and process in the years leading up to 2030.

More and more companies are now implementing digital platforms that communicate across all processes. Going forward, research projects will benefit greatly from the established infrastructure, which enables efficient testing of new concepts and digital solutions. New technology can then be connected to the platform and at the same time benefit from data from operational processes. This will provide a significantly faster path from research to implementation of new digital technology. Our industrial lighthouse companies open the door to the future of digitalization and we must harvest from their experiences and share our knowledge to lead digitalization forward and into 2030.

> "The business community and the public sector must stand together to speed up the digitalisation of Norway. It is about leadership and unity around common goals, and it is about willingness to adapt and ability. But it is also about how Norway can best facilitate achieving results through good framework conditions and investment in knowledge, research, technology and infrastructure."
> \- NHO, *Politikknotat KI*[61]

Technology for digital transformation

The wave of digitalization in the last 5-8 years has led to the emergence of new technologies that have gradually been adopted. These technologies have evolved significantly during this period and will play an even more important role in the further development of today's and tomorrow's process industries. In this chapter, we discuss the most important technologies for implementing a digital transformation.

IoT and advanced sensors

Sensors and measuring instruments form the foundation of any digital crepi. All digital solutions rely on sensor data from the process. To build long-term trust, the data must be of consistently high quality. Smart data, with reliable sensors and intelligent pre-processing, is essential for machines, people and systems to be able to perceive reality accurately in real time. This leads to more accurate processes, better decisions, and benefits for both efficient operations and resource use.

The need for improved process control and the development of digital twins is constantly maturing. Norwegian process and industrial companies are already equipped with a wide range of sensors, from simple load cells that measure fill levels in silos, to temperature meters in process tanks and advanced gas analyzers that monitor environmental emissions. Nevertheless, there is an increasing need to add new measurement points. This can include measurements in harsh environments where heat, dust, mechanical stress, or aggressive chemicals reduce sensor life, or signals from measurement points where it is not possible to route cables for practical or safety reasons. In some cases, significant customization and modification of the sensors is required, making it challenging to find suppliers willing to adapt. There are several *trends* going on today that will be important to meet these needs:

- The emergence of new technologies for mass markets has been significant. Photonics is one example, where advanced lasers, holographic sensors, optical spectrometers and quantum detectors have been introduced in the last decade. The miniaturization of bolometer technology has led to a new generation of thermographic cameras that are well suited for demanding environments. Through the use of new materials, structures and nanotechnology, sensors are now being produced with extreme performance, including increased sensitivity, stability and time resolution.
- *Edge analytics:* Ten years ago, it was common to predict massive data stores in the "cloud," but now the trend is towards analyzing and filtering data at or near the physical sensor. Edge analytics has many benefits, including lower energy consumption, reduced need for digital infrastructure, and easier IT security. This approach is particularly well-suited for turning large amounts of data into a few key figures. A good example is the use of sound and vibration data for condition monitoring of machines.

- IoT – *"Internet of Things":* This trend has evolved from the use of batteries and wireless methods (Bluetooth, LoRa, WiFi, 5G) for the mass market. An IoT provider can offer a wide variety of sensors in "sugar cube format," such as thermometers, vibration sensors, surveillance cameras, and power meters. The sensors are usually wireless and can therefore be mounted in places where power and data cabling is challenging. They report to a common point (gateway), either directly or via the company's WiFi network. IoT can be integrated into PLC systems, making it well-suited for scaling and retrofitting.

Digital twins

A digital twin is a virtual representation of a physical product, a production process, or a performance, enabling seamless integration of all process stages. The technology is used to predict behavior, optimize performance, and validate complex products. There are different perceptions of what the definition of "digital twin" covers. Here, we will consider it as a mathematical (numerical) model that meets the following criteria:

- The model is a digital representation of a physical system.
- The digital model is continuously updated with actual measurement data from the physical system.
- The model calculates variables that are not directly measurable and/or provides estimates of future behavior of the system.
- It provides real-time or near-real-time estimates, with faster time updates than typical time constants for the system it describes.

In the process industry, digital twins can be used for process control and preventive maintenance, among other things. Some companies are already using simple variants of digital twins as decision support for operators and process engineers. In the long term, digital twins will certainly be developed that are directly connected to the control system. In condition-based maintenance, digital twins are used to analyze operational data and condition measurements (vibration, temperature, engine loads, etc.) to estimate the remaining service life, which can be used for preventive maintenance planning.

Most digital twins are tailored to fit a specific physical system, making mass deployment challenging due to the different processes with few identical devices. Most digital twins used today often represent only a small part of the total physical system. This is due to the high complexity of large, complex production facilities.

Asset Administration Shells (AAS)

Asset Administration Shells (AAS) are digital platforms for storing and distributing information related to assets and equipment. The concept functions as a platform that gathers information from production (production drawings, user manuals), operation (operational data) and maintenance (modifications and service). A strength of AAS is that it can receive information from several actors (manufacturer, user and maintenance/workshop) and make the information available to the same actors as needed.

Variants of AAS are in use in the process industry, especially inside equipment maintenance with frequent service and replacement frequency. There is rarely a connector to operational data, and data is primarily shared internally within the company. The products that the process industry makes rarely participate in their customers' AAS systems due to the composition of the products they supply, which are often bulk goods or metal units.

Industrial Artificial Intelligence

Breakthroughs inside machine learning and artificial intelligence (AI) have led to highly efficient data processing with impressive results in many areas. AI can be regarded as a digital tool for processing and analysing large amounts of data. What is unique with this technology is how efficiently AI can extract insights and patterns without the details of the mathematical algorithms being programmed in advance. Thus, AI can uncover patterns that would have been difficult to detect with traditional algorithms, patterns that no human can describe in detail, and patterns we did not even know existed. In some applications, AI systems have achieved performance levels that exceed human capabilities, such as inside image recognition.

Pattern recognition and signal analysis are core competencies of AI, enabling applications inside predictive maintenance, anomaly detection (identifying unusual patterns or anomalies in data), and process optimization. Advanced models such as Transformers, Large Language Models (LLMs), and other basic models power many of the newer AI applications. This is especially true for generative AI – a collective term for AI that produces text, images, speech and the like. Multimodal models use data from multiple source types (e.g., text, images, and audio) to provide more comprehensive and accurate analysis. AI agents reason using foundational models and perform tasks autonomously by making decisions and interacting with users or other systems. These technologies provide new opportunities to increase automation and efficiency by processing high-level data (processed and possibly analysed data). There is obviously a great potential for extracting greater value creation from the industry through AI.

One can envisage a future where the process industry leverages AI to increase productivity, reduce costs, and improve product quality. AI can optimize operations and decision-making processes by supporting engineers and operators both in long-term planning and in real-time analysis of data, predicting outcomes and recommending adjustments on an ongoing basis. If the process industry succeeds with introducing AI in a good way, it can "ride the wave" of technological progress and increase value creation. Furthermore, this can contribute to improved resource use, reduce emissions and lay the foundation for completely new, greener technologies and processes.

Industrial AI is still in its infancy, and the full scope is not yet understood. A global survey from June 2024 shows that while only 17% of AI decision-makers have fully implemented the first AI plans, over 90% of them are discovering new uses along the way.[62] This indicates that a major and broad upheaval may be developing, also for the process industry. One point of concern is that European investments in AI are significantly behind the US.[63] Furthermore, it is interesting to note that the time it takes to utilise generative AI varies between business functions. Faster adoption is reported in support functions such as marketing, HR and IT, while projects that use AI directly in production require more time.

While the potential for AI is huge, there are several barriers that can hinder adoption, including technical, organizational, and cultural challenges. A significant challenge is the lack of qualified personnel who can develop, implement and maintain AI systems. Legal issues, such as intellectual property rights (IPR) and regulatory compliance, can also complicate AI implementation. Additionally, safeguarding data security and privacy is crucial, as AI systems can be used on sensitive or proprietary information. Overcoming these challenges is essential to be able to fully utilize AI.

The Research Council of Norway has announced funding for Artificial Intelligence Research Centres[64]. Applicants can receive support over a period of five years, with a total of NOK 850 million available for the selected centres. Allocation of research funding is expected before the summer of 2025. Hydro, Elkem and Vianode have joined as partners in one of these AI centre initiatives. Such an investment in AI centre will be central to the industry's implementation of AI technology and important for the development of artificial intelligence for the process industry in Norway.

The National Digitalisation Strategy describes that "Norway shall be the most digitalised country in the world". This requires the industry to exploit the opportunities and potential of artificial intelligence (AI), data and data-driven innovation. There is a strong focus on closing the gap between basic research and innovation, especially inside the operationalisation of AI. *Artificial Intelligence for Decisions* (AID) refers to the use of artificial intelligence to support and improve decision-making processes. This involves using advanced technologies such as machine learning, data analytics, and predictive modeling to analyze large amounts of data, identify patterns, and provide insights that can help decision-makers with make informed choices.

One of the biggest barriers to AI adoption in the process industry is a lack of understanding of risks, leading to insufficient verification, validation, and assurance of AI systems. Technological barriers include limitations in AI methods for decision-making in risky environments, integration of knowledge and decision-making processes, as well as resources and costs for implementation. In addition to technical challenges, human and organizational barriers play a critical role. Lack of trust, limited certification frameworks, resource-intensive development, weak governance, and a lack of AI expertise often hinder implementation. To ensure the correct use and desired effect of AI for decision-making, there is a need to address both technical and non-technical challenges. This requires a combination of basic research, operationalization of research, case studies, as well as competence and organizational development.

For industrial companies in the process industry, AID will play a central role in building AI competence among both current employees and future workforce, especially through direct collaboration between academia and industry on specific applications defined by the industry. These applications are characterized by sequential decision-making processes in systems with high complexity and high-risk outcomes. Risk-based maintenance is a typical example, encompassing challenges with collecting and processing data efficiently, determining the condition of physical assets, assessing the likelihood and consequences of failures, and identifying the best actions to take with limited resources and under uncertainty.

What is the difference between artificial intelligence and machine learning?

Artificial intelligence (AI) is a broad branch of data science that focuses on developing systems that can perform tasks that normally require human intelligence, such as problem-solving, decision-making, and language understanding. Machine learning is a subcategory of AI that is specifically about developing algorithms that allow machines to learn from data and improve performance over time without being explicitly programmed. While AI can include rule-based systems and other technology, machine learning relies on pattern recognition and statistical modelling to make predictions or make decisions. In short, AI is the overarching goal of creating intelligent systems, while machine learning is a method of achieving this through learning from data.

Data platforms

Digital platforms provide the infrastructure and foundation for digital transformation in the process industry. By connecting OT (operational technology) with IT (information technology) and establishing a digital infrastructure that integrates operational and analytical environments, data-driven insights and decision support are enabled that can reduce costs, increase productivity, and reduce process variations. Data platforms make data available in a structured, scalable, and value-adding way. By harmonizing and democratizing access to and use of data across systems, you can create new valuable insights into production processes.

Modern data platforms are distributed and can be flexibly assembled as needed, for example using industrial systems and building blocks with open, standardized interfaces. Digital platforms can be deployed and run close to the process, at *the edge,* in a data center, in the cloud, or distributed across physical infrastructure, depending on needs and requirements.

Operational functionality is the value-adding part of the data platform and includes data access, business logic, as well as applications and systems for decision support. This may involve guided or automated decisions that influence or optimize the production process.

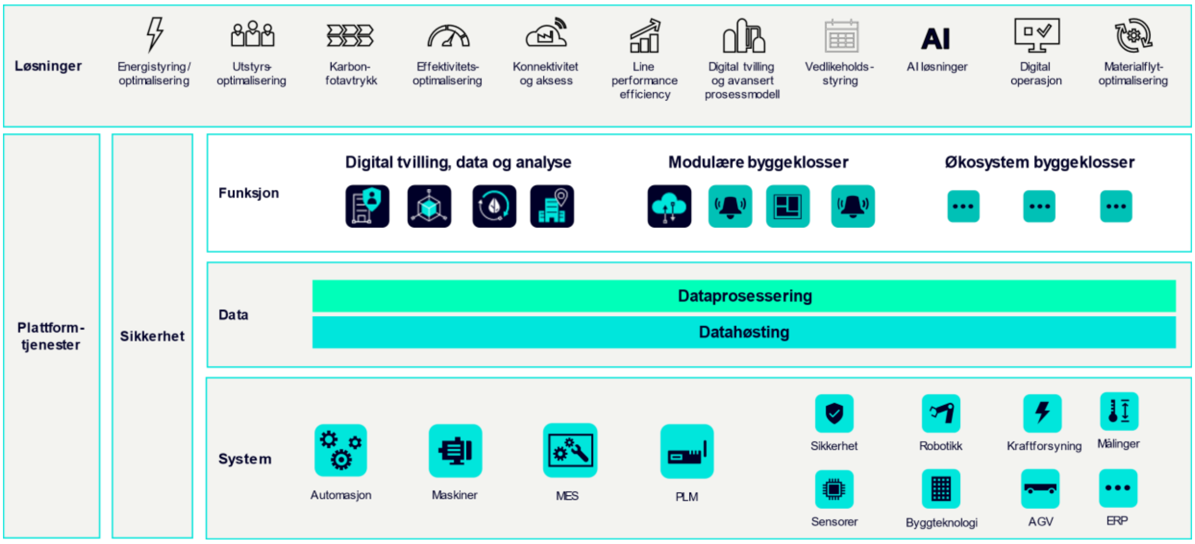


Figure 19 Conceptual structure of digital platform (Ref: Siemens)

Characteristics of a digital platform:

- **Industrial cybersecurity:** Digital platforms must meet IEC62443 and ISO27001 security standards to protect industrial systems.
- **Modular and interoperable systems:** Application of OT and IT technology that ensures cybersecurity and other important requirements, such as open and well-documented APIs (Application Programming Interface).
- **Data Citizens concepts:** Tools that enable non-experts, such as IT personnel or data analysts, to use data. This is becoming easier with the increasing use of generative AI.
- **Data Science Lab:** Advanced data analysis with access to complex tools that require deeper programming skills.
- **Vertical and horizontal integration:** Data must be available throughout the value chain and linked to different operations.
- **Secure data handling:** Adjustment, guidelines and procedures for how data should be managed in the organization.
- **Optimized data infrastructure:** Customization of where data is processed and stored (on-premises, hybrid, or cloud) based on each use case.

A data platform can be conceptually divided into the following functional components, layers, or building blocks that can be assembled and established both at *the edge* and in the cloud, depending on needs:

- **Data sources and operational systems:** OT systems, IoT systems, sensors, equipment, utilities, and external data sources. These should be integrated into the digital platform as much as possible, possibly using data federation (data management) to avoid duplicate data and incoherent data flows.
- **Data harvesting layers:** Layers where data is stored as raw data, possibly cleaned, aggregated, prepared and structured. This can be built on a Data Mesh architecture where ownership and responsibility are transferred to domain experts and offered as "data products" with solid data governance that promotes collaboration and synergies through increased use of data in the organization.
- **Data Processing Layer:** Further processing of data with data catalog, processing power for analytics jobs, and AI/ML capabilities. Data processing will increasingly be decentralized and distributed to *the edge* for processing close to the data sources.
- **Digital Twin Layer:** A layer or system for managing and orchestrating digital twins.

- **Visualization layer:** One or more layers for visualization, management, and intuitive navigation of available data, data models, and digital twins across domains and use cases.
- **Application layer:** Applications and packaged business functions that can be assembled into solutions. An example could be a digital maintenance system for condition-based monitoring.
- **Ecosystem:** A layer for securely sharing data with external partners and customers, exchanging digital twins, and establishing business models based on data or insights.

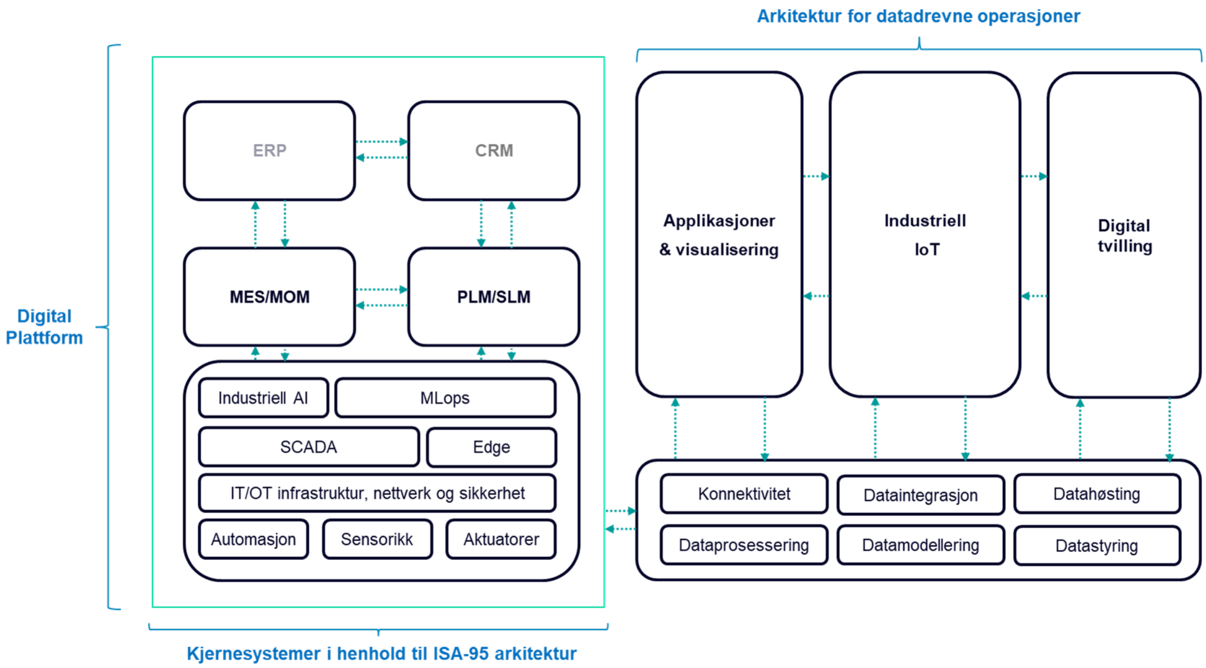


Figure 20 Conceptual architecture combining OT and IT functionality for data-driven operations, compatible with ISA95 and Industry 4.0 principles (Ref: Siemens).

Specific use cases:

- **Predictive maintenance:** Application real-time data and machine learning to predict machine failures and schedule maintenance, reducing downtime and costs.
- **Predictive quality control:** Analyze data from the production line to identify quality deviations and adjust the process in real-time to ensure quality standards.
- **Traceability and genealogy:** This involves tracking and documenting the origin of the product, including raw materials, components, and production data. By having a detailed overview of all transactions, you can ensure high quality, comply with standards and optimize production processes. This helps to reduce energy consumption and minimize waste.
- **Value chain optimization:** Data platforms can be integrated with supplier and logistics data to optimize the supply chain. For example, a platform can analyze data to predict demand, adjust production schedules and inventory, improving efficiency and reducing waste. This ensures a more streamlined and responsive supply chain.
- **Digital twins and metaverse:** Digital twins are virtual representations of physical processes or machines. They can be run in parallel with the real process and fed with real-time data and simulated data to evaluate different scenarios. This provides more precise decision support. VR/AR technology can be used to visualize equipment and processes in a realistic way, improving operations, collaboration, and training.

- **DataOps:** DataOps is a concept developed to structure and make data available, improve communication, integration and automation of data flow. DataOps tools connect data pipelines across systems, making data more accessible and easier to analyze. This contributes to better data management and analysis across the organization.

IT/OT (Information Technology / Operational Technology)

IT/OT convergence refers to the integration of information technology (IT) and operational technology (OT) to optimize industrial operations. This means connecting operational technology with information technology in a secure and robust way that safeguards cyber security and operational requirements. This is essential to be able to scale digital adoption. Trends in the years ahead will include hybrid systems that operate seamlessly from *edge* to cloud, to leverage operational systems, data, and applications more efficiently. At the same time, relevant data from industrial operations and production will be made available to multiple agencies, so that optimization can be done across the value chain.

Over the next five years, up to 2030, new systems will probably be built based on the traditional model of Industry 3.0. This involves IT and automation according to the Purdue model and ISA-95[c]. The reason is that these established standards safeguard both crepi and cybersecurity, and that most industrial companies have already built their IT and OT systems around them.

New standards for IT/OT convergence, such as NAMUR Open Architecture, build on existing standards. NAMUR Open Architecture (NOA) is a concept developed to make production data easily accessible and secure for monitoring and optimising assets and assets. NOA aims to transmit data over a secondary communication channel without affecting the traditional automation structures. This makes it possible to use NOA both in existing systems and new installations. Industrial companies that have not yet completed the transition to Industry 3.0 should focus on implementing automation and IT systems. At the same time, they can take advantage of elements of Industry 4.0 to create added value.

DataOps

DataOps is a new digital concept for industry, developed to meet the needs related to data architecture with Industry 4.0, digital transformation and smart manufacturing. DataOps, which stands for Data Operations, describes a methodology for simplifying the data architecture so that industrial data is more accessible and easier to analyze. This solution contributes to efficient data integration and offers scalable infrastructure for projects inside Industry 4.0 and digitalization. One of the key benefits with DataOps is that it simplifies the transition from a proof of concept to full-scale implementation with multiple production lines and factories. DataOps standardizes and normalizes data sets, and can be adapted to different needs as well as integrated with existing systems. This makes it possible to use a unified data structure across different data sources and generations of OT equipment.

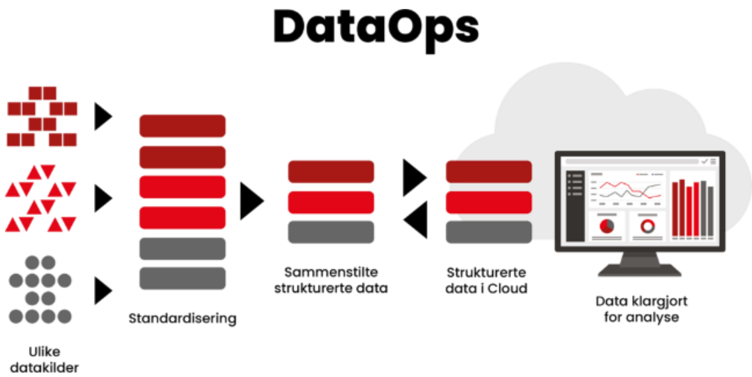


Figure 21 DataOps

DataOps combines disparate datasets from multiple sources to provide context to the data. This makes it easier to compile production and maintenance data to analyze, understand and possibly predict events in the production process. This ability is essential for the success with the implementation of artificial intelligence (AI) in industry.

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[c] The Purdue model, is a reference model developed in the 1990s to structure industrial control systems (ICS). ISA-95 is an international standard for integrating logistics and production control systems.

Robotics

Robots will play an increasingly important role in the process industry, where they will take over tasks that have hitherto required manual labor. This includes material handling, inspection and maintenance in demanding environments. The use of robots can be linked to the four L's in robotics: *Dirty, Dangerous, Dull and Difficult.*

- **Dirty:** Robots can perform tasks in dirty or contaminated environments, such as cleaning equipment or handling hazardous chemicals, reducing the risk to operators.
- **Dangerous:** Robots can operate in hazardous situations, such as at high temperatures, extreme pressures, or in explosive atmospheres, thus protecting workers from potential injury.
- **Dull:** Robots can take over monotonous and repetitive tasks, such as assembly or packing, which often lead to fatigue and errors in employees.
- **Difficult:** Robots can perform complex and demanding tasks that require high precision or work in inaccessible areas, such as inspecting pipelines or maintaining machinery in confined spaces.

By integrating robots into these roles, the industry can achieve higher efficiency, improved safety, and increased productivity, while freeing up human resources to focus on value-added tasks.

Norway is well below the average for the number of operational robots, with 103 per 10,000 employees, compared with the global average of 151 and the European average of 136. At the same time, Norway has recently had a positive development, with an increase of 14% from 2021 to 2022, which is higher than the average for Europe and Scandinavia, which are 8% and 7% respectively. In the Norwegian process industry, growth varies from 40% inside "glass, stone and ceramics" to 16 % in "polymers and chemicals".

Norway is ranked 107th out of 133 countries on the "High-Tech Imports" index, which measures the level at which an economy imports advanced technology to build and acquire knowledge. On the "Labor Productivity" index, which assesses how knowledge and technology increase the efficiency of the workforce, including through robotization, Norway is ranked 89th out of 133 countries[65].

Artificial intelligence (AI) and robotics are examples of "High Tech" technologies. By 2030, it is expected that the use of robots in the process industry will be integrated with AI and advanced sensors. This will pave the way for autonomous systems that can react to production parameters in real time. In order to take advantage of this opportunity and maintain competitiveness, it is crucial that Norwegian industry adopts "High Tech" technologies at a faster pace.

Although Norway does not stand out with a high density of industrial robots, there are examples of new robot solutions that have been developed in the Norwegian process industry with suppliers, for example:

Figure 22 Robots handling product from the new electrolysis process for copper at Glencore Nikkelverk in Kristiansand Photo: Enova

- **Glencore –** robotic handling of electrodes for an energy-efficient production process.
- **Jotun -** robotic palletizing to streamline stacking of products on pallets.
- **Elkem**- innovation contract with MOMEK Invest for the development of TappingMate®, a robotic solution for tapping metal from smelting furnaces.

Digital product passport

The European Digital Product Passport (DPP) is a new regulation, and in the future requires that almost all products sold in the EU must have a digital product passport. This initiative aims to increase transparency in product value chains by providing comprehensive information on each product's origin, materials, environmental impact, and disposal recommendations. The DPP will include essential details such as a unique product identifier, compliance documentation, and hazardous substance information. The DPP is thus a structured collection of data with a unique ID, linked to a specific product or product batch.[66] DPP increases transparency and traceability in value chains or when products cross between regulatory zones. In the future, DPP may become a central component in tracking, mapping and tax management of greenhouse gas emissions.

The regulatory framework is anchored in the Ecodesign Regulation for Sustainable Products (ESPR)[67] aims for products that fall within their focus areas to have DPPs. During 2026, it will define when the different market areas must meet the requirements of the DPP, thus giving companies a defined timeline for adapting to and complying with the new standards (TechInformed, 2024). Both EU-made and imported products must comply with DPP requirements, which affects businesses globally. [68]

DPP is described as a key tool for future investment inside resource utilisation of products and materials. All raw materials and components will be linked together in a *blockchain crepi* for each individual product. This highlights the product's content and the origin of all its components. In addition to circular economy, this also provides an overview of energy consumption, CO^2 emissions, waste, critical materials, etc. With the help of DPP, one can also secure value chains with regard to compliance with environmental requirements and ethical trade. Products can optionally be stopped into the EU market based on information in the DPP.

Eramet has been working with traceability for the past three years and has launched a traceability tool for mineralised sands. They are now developing traceability for manganese alloys, which is particularly relevant for the Norwegian factories in the group. The tool provides CSR information for each delivery and KPIs for production facilities. Using *blockchain* technology simplifies future audits of the tool. Eramet has designed the platform with future regulations, customer requirements in mind and to increase transparency for customers. Eramet is experiencing increasing interest from customers regarding their CSR practices, from cradle-to-gate data per tonne of manganese alloys to more detailed information about the value chain. The automotive industry, in particular, is pushing for more transparency, which affects steel producers working with Eramet. This initiative is in line with the company's CSR strategy and commitment to sustainability.

The EU Battery Regulation already requires product passports and the Ecodesign Regulation for Sustainable Products (ESPR) aims for the implementation of digital product passports.

CIRPASS[69] is a collaborative initiative to lay the groundwork for the gradual piloting and implementation of a standards-based Digital Product Passport (DPP) in accordance with the requirements of the proposed Ecodesign Regulation for Sustainable Products (ESPR), with an initial focus on the electronics, battery and textile sectors. CIRPASS is funded by the European Commission under the Digital Europe programme.

The roadmap covers the seven-year period from 2024 to 2030 and is divided into two sub-periods for practical purposes:

- **2024-2027:** This period is called the "DPP preparation phase". During this time, DPP will be introduced for the first product group, namely batteries, and possibly textiles as well. The roadmap will be more fact-based during this period, as many developments are already taking place.
- **2028-2030:** This period is called the "DPP proliferation phase". During these three years, DPP is expected to be introduced for more product groups. This list includes iron and steel, Aluminium, textiles, clothing, furniture, tyres, paints, chemicals, energy-related products, ICT products and other electronics.

CENELEC is a standardisation body established by the EU.[70] They have now given the assignment to Profile joint gasket Committee 24 (JTC24) to standardize the DPP system. This includes all features except product-related content, such as how data should be stored, where it should be stored, how it should be protected, access to data, and defining semantics. The work will be completed inside the end of 2025 and will be required by law in early 2027. The information to be stored is left to industry associations within the various product areas, with guidelines from ESPR. Standard Norway has established a mirror committee that follows the European work.[71] This work began in February 2024 and is intended to safeguard the interests of Norwegian industry.

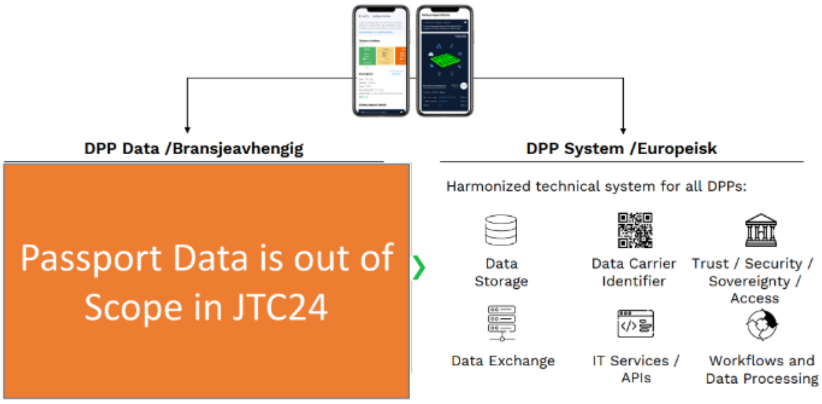

Figure 23 Standardization of DPP systems

The Digital Product Passport for Industry (DPP4.0) combines the DPP with regulatory data and all other mandatory documentation requirements, including certificates, CE documentation, data sheets and user information.[72] DPP4.0 is an industry-specific tool that conveys product information in a format that both humans and machines can read. By using DPP4.0, important product information becomes easily accessible, ensuring that all parties have access to accurate and up-to-date information. This can improve traceability, compliance with regulations and increase productivity in industrial processes.

Industry 5.0 and the process industry

Industry 5.0 represents a shift towards a more sustainable, resilient and human-centric (Sustainability, Resilience and Human Centric) approach to manufacturing.[73] Unlike Industry 4.0, which focused on automation and digitalization, Industry 5.0 emphasizes collaboration between people and advanced technologies. This new industrial paradigm aims to strengthen the role of employees, making them central to the manufacturing process, while using technologies such as AI and robotics to support and amplify human capabilities. The goal is to create a more adaptable and responsive production environment that can better meet societal challenges and improve overall welfare.

Key aspects of Industry 5.0 include sustainability, where companies strive to minimize their environmental impact, and resiliency, which focuses on building Heavy Duty systems that can withstand disruptions. Additionally, the human-centered approach ensures that technological advancements are used to improve working conditions and empower employees, rather than replace them. This holistic approach aims to increase productivity and efficiency, while promoting a more inclusive and sustainable industrial ecosystem.

The social significance of the process industry is considerable, and especially the documented economic one, where the ripple effects are spreading in large parts of the country. Not least the particularly great importance for host municipalities and neighboring municipalities.[18.19] Industry 5.0 puts this together and is an important concept where the focus is that the societal significance must take into account both the positive (e.g. jobs, economy) and negative effects, (e.g. environment), of the business.

Risks resulting from digitalization in the process industry

> *"Digitalization is the cause of large-scale and sweeping transformations across multiple aspects of business, providing unparalleled opportunities for value creation and capture, while also representing a major source of risk"*
>
> – *World Economic Forum: Digital transformation of Industries*

The process industry is undergoing significant changes as a result of the rapid development inside digital technology. Digitalization has led to increased efficiency, improved quality and reduced costs. At the same time, this technological advancement with brings with it a number of risks that must be carefully managed. In an increasingly interconnected digital industrial environment, there is a growing understanding of the need for a holistic approach to dealing with cyber domain threats.

Historically, the focus has been on IT risk, while risks related to operational technologies (OT risk) have been considered different and perhaps not received as much attention. From cybersecurity threats to system failures and human error, the industry faces challenges that require thorough risk assessment and Heavy Duty measures.

The Norwegian authorities have implemented a number of measures to address the increasing security threats that come with increased digitalisation in society, including the National Strategy for Cyber Security[74] and the National Digital Risk Picture[75]. Several of these initiatives also provide valuable advice to the business community.

New risk factors, which we do not know about today, will arise. These must be managed within the existing framework as they arise. This chapter describes known risks associated with digitalization and how they may affect the process industry. At a general level, there are two main issues related to the risk of digitalisation:

- **Risks of being digitalized:** What risks arise when you have digitized?
- **Risk of not succeeding with digitalisation:** What risks can prevent or impair digitalisation itself?

In accordance with the mandate of the expert group, this chapter describes known risks associated with digitalisation, with a focus on how they may affect the process industry. It is important to emphasise the importance of the right skills in order to succeed with digitalisation. The chapter on competence provides recommendations on what knowledge the industrial companies should prioritise.

Method

The expert group has held several working meetings to collect information from various sources. Great emphasis was placed on elicit the views of both industry, academia and suppliers to the industry. The information collected was then analysed and systematically categorised to identify patterns, needs and challenges in relation to the mandate. This process laid the foundation for further work and ensured that all relevant perspectives were taken into account.

To categorise risks and link them to firms, the group uses the "People-Organisation-Technology (MOT) model", as shown in Figure 24. This holistic approach highlights the interaction between people, organizational structures, and technological systems in a company, especially related to the risks of digitalization. In the Norwegian process industry, this model provides a framework for dealing with the complex challenges that come with digitalization, with a particular focus on human safety.

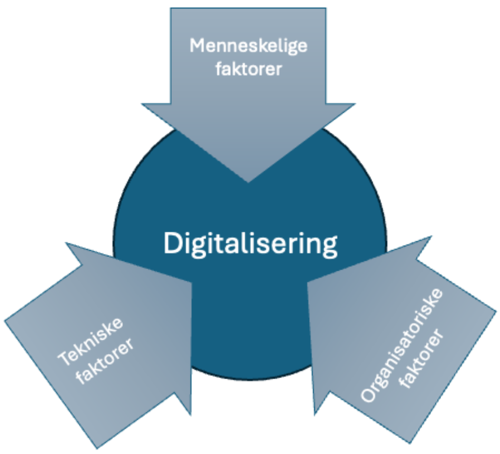

Figure 24 Model for analysing the risks associated with digitalisation [56]

- **People:** Employees' roles, characteristics and interaction in a digitally developing workday.
- **Organisation:** The organisation's crepi, culture and processes must be adapted to support digitalisation. Leaders play a key role in fostering a culture of innovation and collaboration.
- **Technology:** Digitalization introduces advanced technologies. The MOT model emphasizes that technology must be integrated in a thoughtful way to provide value for the company.

Human factors

Human risk factors are about people making mistakes, either with purpose or with accidents. In a digitalized process industry, human error, whether intentional or unconscious, can pose a significant risk. Digital tasks often involve a long time in front of a screen, with routine monitoring or recording of data. This can lead to mental fatigue and reduced attention, especially with monotonous tasks. Such conditions increase the risk of mistakes that are not detected in time, as people often perform routine work "automatically" without reflecting on the actions.

In digitized process environments, it is crucial to understand how human error can affect both physical and digital systems. For example, misinterpretation of data in control systems can lead to errors in the management of production equipment, which can have serious consequences for both safety and productivity.

Design of user interfaces plays a key role in mitigating risk. Intuitive interfaces that provide clear alerts and prioritize critical information can reduce the burden on operators and help speed up fault detection. Combined with measures such as training and automated fault detection systems, this can minimize the risks associated with human error in digitized processes. A well-designed system is not only effective, but also adapted to human limitations and needs.

People have a natural inclination to simplify their working day and choose the easiest way when possible, which can increase the risk of deviations from established routines. The introduction of digital solutions can limit this room for manoeuvre, as automation and more streamlined processes provide fewer opportunities to take shortcuts.

At the same time, digitalisation can introduce new challenges. Errors in data or systems can lead to misleading decision-making and undesirable incidents in the processes. This becomes particularly demanding if employees work physically distant from the actual data basis and thus have limited opportunities to detect and correct errors in time.

The main point is that human factors still play a central role in a digitalized industry. By recognising and understanding these tendencies, it is possible to better adapt systems, training and change management, so that both the likelihood of errors and the harmful effects of these are reduced. In this way, the needs of employees are respected, while achieving a safer and more reliable working environment.

Organizational factors

Dependencies in confusing networks

The digital network of industrial companies consists of internal and external components that interact in complex patterns. Economies of scale with data centers, concentration of services in a few, highly specialized suppliers, and other factors contribute to increased use of external components. Cloud-based solutions, where software is delivered as a service over the internet, replace solutions that each company previously had to install and maintain locally. This development inside IT is widespread in many sectors.

Industrial companies are now finding that suppliers of production equipment also offer software for monitoring and optimization. This software typically runs on the provider's infrastructure or in data centers, and the equipment connects directly to the software, often via mobile data.

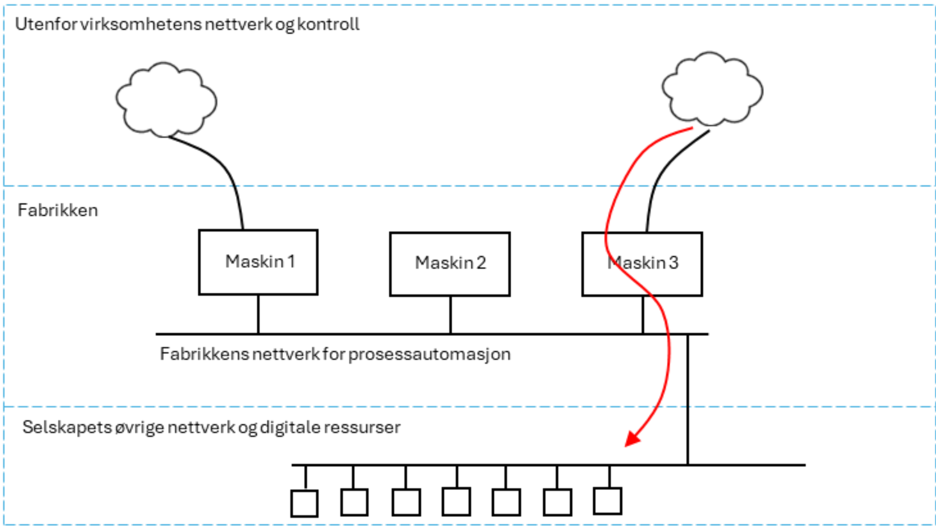

Figure 25 Components outside the enterprise's control with access to the internal network via production equipment

Such complex, confusing digital networks expose us to several categories of vulnerability[76]:

- **Mission-critical components and data can become inaccessible** due to factors beyond your company's control. The supplier of the component or necessary infrastructure may be affected by a cyber attack, technical breakdown, bankruptcy or other circumstances that affect availability.
- **Threat actors can sash the business** by exploiting vulnerabilities at the supplier. This can include the loss of information stored in the provider's infrastructure, or the introduction of malicious software via the provider's access to the company's network.
- **The supplier may use the company's data in unintended ways.**

Companies should have an active relationship with the criticality and vulnerability of the digital components, as well as ensure that they have relevant expertise and capacity when implementing major changes also in operating organisations.

Risk of non-compliance with regulations and ethical frameworks

Digitalisation in the Norwegian process industry entails increased use of data, automated processes and artificial intelligence (AI). At the same time, national and international regulations impose increasingly stringent requirements on how data is processed, stored and used. Regulatory violations can result in serious financial sanctions, loss of reputation and increased costs related to adaptation and compliance.

In the period 2024– 2026, several laws, directives and regulations will be incorporated into national legislation and made applicable. Many of these will affect Norwegian industrial companies. Here are some key areas companies need to address:

- **Violating the GDPR** can result in fines of up to € 20 million or 4% of global turnover. [77]

  Industrial companies must ensure that they operate within the law when processing, sharing and storing personal data, as well as when monitoring employees.
- **The Data Protection Authority publishes decisions** that include information about cases where the Authority has concluded with a breach of the GDPR, and any sanctions. The list of decisions with significant GDPR fines includes both Norwegian and international companies in several industries. [78]
- **The EU's AI Act** classifies AI systems according to risk level, where high-risk systems (such as predictive analytics that affect health and safety) will meet strict requirements for transparency, testing and documentation. Violations can lead to fines similar to the levels in the GDPR.
- **Cyber security directives (NIS2)** entail requirements for securing critical infrastructure, where breaches can lead to sanctions and orders for measures to improve security.
- **Process industries are increasingly required to report on sustainability goals** and data related to environmental impact. Errors or omissions can lead to legal consequences and reduced confidence from investors and partners.

Companies should take a proactive approach to these and similar regulatory requirements by establishing clear compliance and risk management procedures.

Technical factors

In the process industry, it is crucial to maintain high productivity, which must be reflected in the digital solutions that are adopted. Failures in such solutions, especially those related to critical processes, can lead to major financial losses and have a negative impact on health, safety and the environment. In addition, there is a significant risk of losing intellectual property rights through digital channels, especially in the event of increased data sharing or external partnerships. It is therefore essential to carry out a thorough risk assessment before new solutions are used.

Convergence of IT/OT, i.e. connecting operational technology with information technology in a secure and robust way that safeguards cybersecurity and operational requirements, is essential to scaling digital adoption. Trends in the years ahead will be hybrid systems that operate seamlessly from *edge* to cloud, in order to make more efficient use of operational systems, data and applications. At the same time, this will make relevant data from industrial operations and production available to more agencies, so that you can optimize across the value chain. [79]

IT/OT Cybersecurity – Risk in Highly Automated Factories and Supply Chains

Over the past few years, there have been several cyber attacks on industrial companies in Norway. Among the largest and most well-known is the attack against Hydro on March 19, 2019. Although the attack did not directly affect the production processes, the consequences for the company were significant.

Figure 26 Cyber attack against Hydro, 19 March 2019

The incident was a wake-up call for all Norwegian companies with regard to data security and vulnerability to malicious cyber attacks, and has contributed to cyber security being high on the agenda for Norwegian industrial companies. Attacks on control systems in industry can halt production processes, damage equipment, affect health, safety and the environment, and have significant financial consequences for individual businesses. Another risk is related to the planting of vulnerabilities that can be exploited in the event of further escalation or new conflicts. Therefore, protecting these technologies and improving their resilience has also become a matter of national security. This security challenge is exacerbated by the increasing use of digital solutions with extensive integration, both internally and externally.

Traditionally, players in the process industry have chosen closed solutions, where the supplier uses proprietary standards that create more closed systems. This provides increased security and reduces the risk of data breaches, but at the same time represents a barrier to digitalization. A high degree of digitalisation means that subcontractors, manufacturers, customers and consumers are more closely linked in digital value chains. Transitioning to cloud solutions, increasing awareness of ownership of production data, and at the same time supporting the needs for sharing data increases the risk of cyberattacks. Potential opportunities for an attacker to penetrate a business are becoming greater, which is amplified by the fact that cyber attackers are also becoming more sophisticated in identifying weaknesses in what can best be described as "hyperconnected industrial environments". Cyber risk can therefore increase with the number of interconnected systems and devices. Identifying and mitigating risks in "hyperconnected industrial environments" requires collaboration across organizations.

The boundary between traditional IT systems and process control (OT) systems is becoming increasingly blurred. This causes the totality to become more complex, with more subsystems that need to be kept up to date. The strict requirements for controlling changes inside process control make it challenging to stay up-to-date with the necessary security updates that IT systems require. In addition, securing and maintaining IT systems requires another skill set that is often not present in traditional OT systems.

Another important risk factor is that increased use of acquired digital systems and tools leads to greater dependence on third-party providers. A cyber attack on a supplier or customer can quickly affect the company as well. An example is the SolarWinds attack in 2020, where a vulnerability in a widely used IT tool was exploited to attack 18,000 customers of SolarWinds.[80] Data loss and downtime to restore the systems are estimated at more than NOK 100 million on average per company. Another example is the Airbus attack in 2023, where a compromised user at a customer of Airbus was used to extract sensitive data from Airbus. [81]

The likelihood of experiencing computer attacks increases every year. The development inside methods and tools for cybercriminals is fast, and few companies have access to sufficient resources internally to resist. The traditional preventive approach to information security, which focuses on staying ahead of the curve and closing all possible security gaps, is no longer sufficient. This method does not scale to meet constantly new challenges and threats.

As a result, a number of IT security companies have begun to use the term "cyber resilience" rather than cybersecurity, to focus on their ability to handle stress and disasters. In cybersecurity, this represents a shift where businesses recognize that new attacks will happen. Safety management is expanding from being solely concerned with what can go wrong and dealing with deviations, to concentrating more on limiting the extent of damage in the event of compromise through intelligent detection and alerting.

In Europe, a number of laws and guidelines are being developed with the aim of reducing threats from the cyber domain. Examples of this are NIS2[82], Cyber Resilience Act[83] and Cyber Security Act[84].

There are many opportunities for hacking and attacks because both companies and suppliers are in a learning phase. For example, see *Industrial Cybersecurity* for more information on cybersecurity.[The 85th] Infantry Regiment was *Roadmap for cyber security in Norwegian industrial companies on the way to Industry 4.0*[86] provides a good basis for security work.

Operational complexity

The implementation of advanced digital systems inside process control increases the complexity of the management of production processes. For the operators, however, this may seem easier, as the complexity is handled by the digital systems. Such systems introduce an additional complexity that can negatively affect the stability of the processes, as several subsystems must work together. In addition, a mix of existing systems (technical debt) and new digital solutions will increase the risk of deviations and instability in the production process.

It is therefore important that the process is still anchored and understood by the employees, and not taken over by digital systems and AI. The employees must have both enough expertise and information to make decisions about operations, even when there are conflicting or unfamiliar signals from the control systems. The increasing complexity of using digital systems also makes it more difficult for operators and engineers to fully understand the process, as it requires cutting-edge expertise in several areas, such as process, automation, digital (IT) systems, networks, and communication. Heavy Duty interdisciplinary teams must therefore be built up that can possess the necessary knowledge.

Updating systems for process control has traditionally been carried out with strong management and control, often with maintenance stops. With the introduction of digital (IT) systems that affect process control, the pace of change will increase, thus increasing the risk of instability in operations, as it can be difficult to verify all the consequences of the changes. Incompatibilities can easily occur between components, both between existing and new ones, but also between versions of the same component. Even small changes to a subsystem can have major consequences and lead to operational disruptions and downtime. Frequent changes also create challenges for operators and process engineers, as they need to stay on top of all the changes.

Increased use of digital systems for process control makes it more difficult to run processes without access to these systems. An outage of a single subsystem can cause the entire production to stop. Failure of systems is well known in the IT field, but rarely has fatal consequences. In process control, on the other hand, this can have disastrous consequences, and it is very important to have procedures in place to handle such situations.

Challenges with data quality

Mathematical models and advanced analysis models rely on data with good, or at least known, quality. If there are errors or major (unknown) deficiencies in the data delivered to the models, this can lead to errors in the process control, which can result in it no longer running optimally, or in the worst case, becoming unstable or stopping. Similarly, inadequate data collection will mean that important information is not included with the calculations, which will impair the quality of the calculations.

Collecting data from sensors and digital systems for use in models, analysis or optimisation without good management and control to ensure quality can cause more harm than good. This can quickly lead to operators no longer trusting the digital systems, and possibly stopping using them.

As the quality of data will vary over time, it is important that the models and calculations are able to handle such deviations in a good way. Without thorough testing with the use of data with anomalies, the challenges with the models and analyses will not be uncovered.

Challenge with procurement and maintenance of digital solutions

Both physical components and mathematical models as one piece of a digital network need continuous maintenance to ensure optimal performance and use. Often, it is assumed that digital solutions work without continuous checking, maintenance, and possibly repair. Changes to an IT system somewhere in the process network can have an undesirable effect on a system in another parts of the factory.

Digital solutions for the process industry are developing rapidly with many players involved. This has led to the development of several partially overlapping concepts and standards, making it challenging to specify requirements when procuring. Different standards can lead to incompatibilities when systems from different vendors are to be integrated.

Increased overall complexity in the digital systems places increasing demands on the expertise of those who order the systems. This applies both to new installations and to major upgrades and modernizations. Lack of knowledge can lead to increased risk in implementation. It is important to avoid dependency on specific suppliers and their technologies, as this can hinder or hinder future digitalization initiatives.

Competence needs in the event of increased digitalisation

The industry is undergoing transformations inside sustainability and digitalization, which requires a lot of new knowledge. It is crucial that management relates to the company's overall digital competence and ability to use new solutions. A lack of expertise inside digitalization can lead to decision-makers overestimating the effect of new technology and underestimating what is required to introduce new digital solutions in the company.

The Norwegian Digitalisation Agency describes digital transformation as *"a process, a major change, and a redesign of the business at all levels"*.[87] According to the Norwegian Digitalisation Agency, digital transformation includes the main topics shown in the figure below.

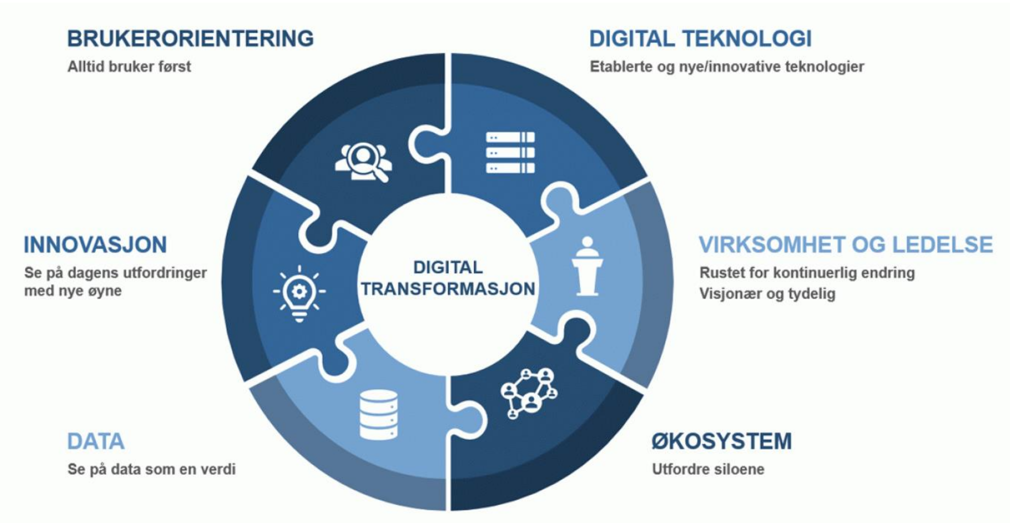

Figure 27 The Norwegian Digitalisation Agency's digital transformation wheel

The factory of the future is a structured interaction between advanced technology, smart production systems and skilled workers. The leaders of the future must have sufficient knowledge of the opportunities and consequences of technology, and how it can create new value for the company and its customers in interaction with employees and the production apparatus.

Furthermore, digitalisation is increasingly about business development made possible by the use of technology, and therefore affects all employees. To succeed, a culture must be built that fosters curiosity and continuous learning. The digital transformation requires strong support and focus from management. In order for the Norwegian process industry to succeed with digitalisation, it is necessary to strengthen expertise in the use of digital technology in all layers of the business.

The company's overall digital competence must enable it to understand how new technology opportunities affect work tasks, interaction and continuous learning. This competence must also be translatable into a lasting culture of change and development. A lot of research has been done on what characterizes the culture of organizations that succeed. Psychological safety, sharing culture, curiosity and the practice of learning from mistakes are important characteristics. [88,89]

The process industry companies of the future will need employees with a different type of expertise and professional profile than is typically the case today. This involves both strengthening the digital competence of existing employees and ensuring access to new employees with the necessary knowledge. Examples of this include:

- Increased competence in digital business development and digital business models among managers and middle managers.
- More analytical digital competence among operators.
- More engineers with cutting-edge expertise inside IT areas such as data analysis and modeling, machine learning, digital architecture and cybersecurity.

Methodological approach

The digital ecosystem of industrial businesses is becoming increasingly complex, with a growing and increasingly specialized mix of components. These include both solutions in the company's own infrastructure and with external partners and suppliers. The components are tightly integrated and in continuous development. The increasing complexity coincides with higher criticality for the digital systems. Increased complexity and criticality mean ever-increasing demands for control, security and collaboration across the ecosystem.

The most important goal for the digital competence of the future is to adapt to and exploit this changing ecosystem. The skills development required is not just about the technology itself. Increased agility and ability to change require a similar organizational shift as the technical one - from fixed, hierarchical structures to networks in continuous development. In the same way that the overall complexity of the digital ecosystems increases with the number of connection points, organisational development will also place increased demands on the operators and managers of the future.

The prerequisite for using digital technologies and data to create lasting value creation in an industry is about creating room for manoeuvre to develop and utilise the expertise where it is in the organisation, and to bring in new expertise to the right place in the business. This has implications for strategy, crepi, work processes and culture. Our recommendations are therefore divided into these areas, as well as competence development measures inside technology and data specifically.

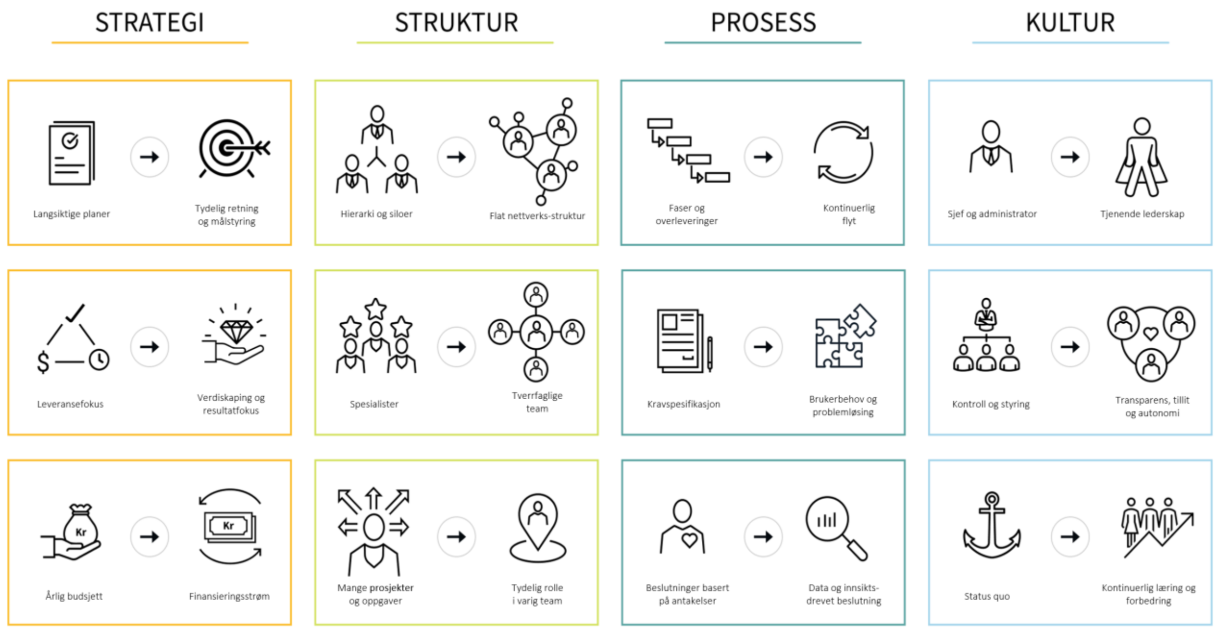

Figure 28 The transition from a project-oriented approach to a more product-oriented approach

Figure 28 shows the need to develop expertise inside several areas of an organisation in parallel, not just to build expertise about the technology itself.[90] There are often several measures that must be linked in order to succeed, including that the right employees must be involved in strategic decisions where knowledge and experience with technology provide opportunities that would not otherwise have been discovered.

According to ADKAR[91], a widely used methodology for change management, there is a step-by-step path to continuous and lifelong learning. Before one has the ability to translate knowledge into practical change, an awareness is required in the organization of the need for competence measures that employees in different roles can use to develop their daily work.

Figure 29 ADKAR

In industrial enterprises, there will be large variations in digital maturity. The need for competence development will require adaptation in all roles and therefore an effort that supports the flow from discovery to the introduction of several new technologies. This will enable industries to make use of the technologies to achieve their many goals.

Competence strategy

The influence of digital technologies and data is pervasive in most businesses. Successful use of data and technology requires a redesign of the business at all levels – people, work processes, technology and governance. It is important to understand the consequences of such a strategic decision, and this is a managerial responsibility that requires that the expertise is in the management and that the management is actively involved in the development of strategy. It is equally important to have the expertise to initiate the right measures that follow from the strategy on an ongoing basis and with the right financial support to implement.

No one can, or should, make all digital technologies their core competence. Therefore, the strategy should also include which competence partners it is wise to choose. Competence to make decisions based on the right criteria is a strategic attribute and requires knowledge of the supply chain ecosystem and criticality of the company's production lines, as well as understanding how digital technologies, data and ecosystems can create new business models and sustainable margins.

It is also crucial to have a flexible funding flow that is open to new things to emerge and ensures that good initiatives do not come to a halt unnecessarily. The need for competence is complex, and the choice of the composition of teams and decision-making processes will be an important support competence to acquire.

A strategic investment in lifelong learning and continuing education is necessary. The competencies that should be developed should be assessed in the light of the capabilities that the organisation wishes to possess or explore the value of, in accordance with the desired goals for value creation.

Process industry companies should consider creating competence strategies that define goals and plans for digital competence building in the company. The companies' strategic work with competence development and digitalisation is dependent on thorough anchoring in the union representative system. This is necessary in order to obtain the broadest possible knowledge base, but also to build a team with change agents and ambassadors who can credibly convey that the company's ability to survive depends on us succeeding with digitalization at all levels of production.

Invest in IT talent

There will be a future battle among all industries and industries for the best IT heads. The process industry normally has good knowledge of and a good collaboration with the strongest professional environments inside process technology, such as automation and instrumentation. However, within the more IT-oriented professional studies, such as computer technology and information security, the process industry is far less represented.

The process industry must therefore come into contact with new students earlier and prove to be an attractive and exciting workplace for the next generation of IT specialists. For example, they can actively offer collaboration on master's theses to master's students. In any case, limited resources can quickly become available nationally, so the possibility of recruiting internationally should also be considered. Investing in employees with higher education (PhD) can create interfaces and contribute to the development of closer collaboration with leading research environments. Digitalisation is a lot about changing work processes.

Contribute to the future of education for the process industry

The process industry should work actively with the educational institutions, technical vocational schools and engineering educations, to ensure that operators and skilled workers are trained with more analytical skills and a stronger professional background inside relevant IT and mathematical subjects. This may include work with the development of new learning curricula for young people and students. Although it is claimed that it takes a long time (3-5 years) to change existing education programmes and introduce new subjects as parts of the education, this is absolutely crucial for the education to keep with the needs of the industry.

Closer cooperation should also be established with universities and university colleges to ensure that IT graduates are educated with the necessary domain knowledge required to work in the process industry. For example, Yara has entered into a 4-year agreement with the University of South-Eastern Norway, which is funding a professorship inside the topic of machine learning aimed at the process industry. This collaboration brings together the competence environments in Porsgrunn on process, Kongsberg on automation and Horten on sensor technology.[92]

Agility

The structuring of the work with innovation, introduction or improvement of digital technologies can determine whether the work will be successful. Competence in team composition, interdisciplinarity and the right framework are prerequisites that require practice and experience to master.

In recent years, technology development has been strongly characterized by agile *(agile)* methods. It is a strategic choice to build expertise in agile business development, because it will lead to changes and a need for expertise in agile methods at many levels. Although the process industry in Norway is good at "Lean Manufacturing", agile development is about navigating in a technology landscape where you do not quite know what the end result necessarily looks like, but the goal is a clearly defined value creation. These are new methods of structuring work that must merge with "Lean Manufacturing" and HSE and safety structures.

Process

A major shift inside digital transformation is to move from procuring standard software products to adapting solutions to special needs, also to provide competitive advantage. This shift also involves moving from projects with a clear beginning and end, such as procurement and implementation, to more enduring and combined responsibilities for both development and operational processes in the line. This is because the technology is constantly evolving, and the expertise about the technology and its area of application will be utilised smarter in a fixed organisation than if it has to be moved from procurement or the development and innovation unit to an operation and maintenance organisation.

Within the IT world, there is a marked increase in product and team organization, where the whole is taken care of by a fixed group to maintain competence, speed and flow with operations and continuous development side by side.

An important part of a company's competence base is that which is internal to the company, and which the management can influence. Another part is the expertise that is external, and which the company can utilise and benefit from through its networks, partners and value chains. It is important to balance internal competence building with external access through the use of consultants, in collaboration with suppliers and research environments. Digital ecosystems can create dependency on external expertise that performs work processes you depend on, where security assessments must determine which competence should be developed internally and which can be outsourced. Work processes that support good collaboration between several organizations and customer needs with deep and relevant technology expertise are becoming more important to work with in a structured way over time.

Culture

The process industry consists of traditional and proud professions, and change will not always be easy to implement. In order to build sufficient digital competence among all employees, work must also be done with creating enough willingness to change and reducing resistance to change.

The next generation of skilled workers, operators and engineers have grown up with technology and basically have higher basic digital skills than previous generations. This can often be an advantage with terms of creativity, but they may have to leave a lot of this behind when they enter the factory. Many of the largest technology and equipment suppliers are sceptical about opening up for others to access with their technology – this has to do with both with guarantee and information security. However, it has been shown that the companies that have come furthest with digital transformation are those that have a culture where it is allowed to try and fail. The best skilled workers are those who are one piece of a company culture and who are given the opportunity to "play" with alternative technologies. This can create enormous creativity, but it must be done in a systematic, safe and secure way.

The process industry has, and will always have, a need to think about HSE, and build a culture to think through what you do and why. Continuous improvement and "Lean Manufacturing" are also methods that incorporate a culture of gradually seeing improvements in existing processes, tested iteratively and incrementally. By involving and owning all employees, the foundation is formed for a culture in the company that integrates agile methods with "Lean Manufacturing" and HSE and safety structures, and that promotes innovation and mastery.

Smaller teams with a framework to make certain decisions will help create the power with change in more areas of the organization, than if all the decisions have to be passed on to management. The process industry must build expertise in both safety culture and innovation culture at the same time.

There are several that offer courses for the process industry. Digital Norway has, among other things, courses on industrial data and artificial intelligence, aimed at the process industry[93]. This joint effort in the industry with partners should be supplemented with separate courses for continuing education and skills development for workers in the process industry. This can be done, for example, with educational institutions. There is generally good reason to rethink how operators are trained and trained. An interesting opportunity is to train operators using existing test and production facilities, for example under the auspices of Katapulter[94], and the use of VR/AR.

Work should also be done for a scheme with double trade certificates that provide an opportunity to strengthen the digitalisation skills of existing skilled workers, as one piece of continuing education of skilled workers.

Academic communities that can contribute to the digitalisation of the Norwegian process industry

It is challenging to create a detailed overview of different professional environments that work with promoting and developing digital solutions for the process industry in Norway today. The professional communities are often quite small and are often part of groups that work with digitalisation in general, where the process industry represents only one of the customer groups. The professional communities that work with digitalisation in the process industry can be divided into three main groups, based on professional approaches:

- The primary competence is process technology, with digitalisation as a secondary competence.
- The primary competence is automation, cybernetics, instrumentation and the like, with a particular focus on applications in the process industry.
- The primary competence is IT, with a particular focus on applications in the process industry

The traditional distinction between the latter two groups seems to be less clear now than before, as modern automated and digital solutions also require industrial IT expertise.

Another way of dividing professional communities that work with digitalization of the process industry is based on which organizational units the professional communities are affiliated with. An attempt has been made to make this approach visible in Table 1.

These two ways of categorizing the work with digitizing the process industry have their limitations, as there are fluid transitions between the different actors' involvement. Traditionally, research in the university sector has been characterised by the expertise and recognition of individual researchers. There now seems to be a deliberate tendency for different researchers to coordinate and clarify their R&D activities inside different disciplines, including inside the digitalisation of the process industry. This typically involves more Heavy Duty research groups, research centres and clusters. Nevertheless, the research can still be considered to be quite person-dependent, where the expertise and recognition of individual researchers weigh very heavily.

In the case of relevant study programmes, the link to the process industry is often not apparent in the names of the study programmes, as the names typically describe relevant fields, such as automation, cybernetics, mechatronics, etc., even though examples from the process industry will be central to the study programmes. At the same time, there are educational programmes at both tertiary vocational school level and college/university level inside process engineering/technology, where digitalisation of the process industry can be central to the studies.

Traditionally, basic research has been an important research activity at the old universities, such as UiO, UiB, NTNU and UiT, alongside applied research. After the establishment of the new universities after the turn of the millennium, there has been a conscious focus on retaining basic research at the well-established universities, while at the same time the new universities should have a more professional and working life-oriented profile with local roots. To some extent, this continues the profile of the former university colleges, which have now been accredited as universities.

At the same time, there are clear expectations of increased research activity at the new universities, both in collaboration with regional and international actors inside fields of working life. This also enables more regional research inside the digitalization of the process industry, through research projects with the new regional universities. In addition, they contribute to regionally adapted professional education.

The role of vocational schools is primarily to offer vocational education at a level above upper secondary education, including inside digitalisation and process engineering, and are thus an important partner in educating qualified labour for the process industry.

The research institutions in Norway, in a similar way to the higher education sector, have undergone one piece of mergers in recent decades. As a result, one can see the contours of stronger and more Heavy Duty professional environments with a focus on digitalization in general, and with groups that have a special focus on digitalization of the process industry. Centres and cluster collaborations have also been established to strengthen cooperation and further development. One example is the DigiPro Centre, whose main purpose is to work for the digitalisation of the process industry. [39]

Furthermore, both the supplier industry, system integrators and the process industry itself carry out considerable work to create or improve digital solutions inside the process industry, either independently or in close collaboration with other players.

Table 1 Role and position of the various academic communities

Academic environments	Primary role (mandate)	Contributes to (value proposition)	Through, using (deliverables)
Old universities	- Research at low TRL levels, with a special responsibility for conducting basic research, but also applied research - Accredited to educate the workforce of the future at Bachelor's, Master's, and PhD levels - Provider of further education	- Contributes to basic understanding and technological development that can lead to digital solutions in the process industry	- Cooperation with the process industry, the institute sector and suppliers. - Support schemes from the policy support system
New universities and university colleges	- Research at low TRL levels, with a special responsibility for conducting applied research - Accredited to educate the workforce of the future at Bachelor's, Master's, and PhD levels, with a particular focus on professional education - Provider of further education	- Increased focus on digitalization of the process industry - Collaborates with the process industry on research and technology development	- Cooperation with the process industry, the institute sector and suppliers. - Support schemes from the policy support system
Vocational schools	- Offer vocational education at a level above upper secondary education - Provider of further education	- Vocational education at a higher level than upper secondary education	- Collaboration with the process industry on education
Research institutions	- Research at low and medium TRL levels, with a special focus on applied research	- Increased focus on digitalization of the process industry - Collaborates with the process industry on research and technology development	- Collaboration with the process industry, academia and suppliers. - Support schemes from the policy support system
Research clusters and centres	- Collaboration on R&D activities within a field and/or region	- Contributes to a more visible and robust investment in R&D activities inside the digitalisation of the process industry	- Collaboration between academia, the institute sector, suppliers and the process industry. - Support schemes from the policy support system
Supplier industry	- Development and sale of instruments, equipment to the industry	- Realizes and implements digital solutions	- Independent work, and collaboration with R&D actors and the process industry
Industry players	- Responsible for production inside the process industry, and performs R&D activities	- Implements and operates the process plants with the digital solutions	- Independent work, and collaboration with R&D actors and the supplier industry

The policy support system

Industry-oriented policy instruments are measures aimed at supporting and developing the business sector, with the aim of promoting value creation, innovation and competitiveness. Their main function is to facilitate sustainable economic growth and restructuring in the business sector.

These instruments can be broadly divided into four categories:

- **Financial support:** Grants, loans, and guarantees to reduce risk and finance innovation and investment.
- **Competence building:** Support for research, development and collaboration between companies and academia.
- **Market support:** Export promotion, internationalization and networking to give companies access to new markets.
- **Regulatory design:** Create favourable framework conditions, such as tax incentives or simplification of regulations.

Rollers are to strengthen companies' ability to create jobs, meet future challenges and contribute to society's economic resilience. A description of the actors and policy instruments can be found in Appendix 3.

Digitalization in the process industry– general considerations

The process industry is characterized by large investments with a long service life. The factories often consist of a machine park with a large age variation, from units that are over 30 years old to modern, new equipment. This creates challenges with holistic integration between process units, both within the same process and in parallel processes. Older equipment can be monitored to a greater extent with modern digital technology, but integration with control systems presents challenges. In order to increase the integration of digital technology in the various facilities, it has been necessary to focus on infrastructure and data integration. This has been a priority area in recent years, and the foundation for realising the benefits of digitalisation is now being established.

Integrating new digital tools and processes into existing systems, facilities and processes is a complex task. Even when a digital tool, such as optimising a sub-process using sensor measurements and machine learning, has been developed and tested on its own, it remains to get this tool to work with the systems and the rest of the surrounding processes. This requires a high degree of organizational innovation and development in addition to the technological one. When this is also to be done for a number of production lines at several locations, the complexity increases.

Establishing innovative projects with several partners who will develop and implement new digital solutions can often be demanding with terms of contractual conditions. Risk, responsibility and finances related to goal attainment in the project (how well the new solution works), as well as ownership and usage rights to data, code and software must be managed. This can be particularly demanding in projects that deal with digitalisation, as it is not as easy to draw the boundaries as one can do when developing a new physical component or a chemical process.

In the case of digitalisation research projects, such as an IPN project, the technology is often developed, adapted and tested in a real process environment in the final phase of the project. This can be illustrated with a measurement campaign over a limited period of time, where several unanswered questions emerge in the overlap between the understanding of the technology, the process and how the two things are connected. Overall, goals, instruments and orientation should be defined for effects and results. See Appendix 4 as an example.

This is where the research and knowledge transfer that took place during the project is not always utilized to the maximum, or in the worst case, not utilized at all. One challenge is that those who have domain knowledge must take the technology further, without the cutting-edge expertise to understand what the project has contributed with.

The Industrial Development Journey

The industrial development journey is complex and can perhaps best be described as an ecosystem consisting of different elements that interact in different ways in different phases. The ecosystem consists of the companies, including their suppliers and customers in the value chain. The industrial landscape around the company includes educational institutions (at several levels), contractors and spin-offs, R&D institutions, clusters and technological testing capacities (catapults), as well as policy instruments, both direct, indirect and collaborative, in addition to county and municipality. It is probably as the government describes in Green Industrial Boost[1], namely that everything is connected with everything.

Since the 2000s, Norway has had a strategy to strengthen business clusters and catapults through a national cluster programme. An evaluation carried out by Socio-economic Analysis on behalf of Innovation Norway in December 2017 concluded with that the companies in the business clusters work more across the board, have higher employment, increased sales revenues and greater value creation than companies that are not members of a cluster, especially in the first few years. [95]

Norway has not had a tradition of preparing national industrial policy strategies for industrial value chains. It therefore appears that there is little overall expertise and experience with the development of value chains in a national perspective, and how different tools and instruments can collectively support this. However, value chain development has become relevant in recent years.

The report "Norwegian opportunities in green electrical value chains", prepared by several major business players, describes both potential and opportunities for increased Norwegian value creation through targeted investment in value chains. [96]

The report points to some common challenges for value chains, including weak interconnected supply chains (which must both be established and developed) and a lack of coherence between different parts of the value chains.

The policy instruments are intended to stimulate cooperation between the expert communities, the supplier companies and the process industry. These serve as important "ecosystem" builders. An example of such a tool is Norsk Katapult, which offers innovative companies the opportunity to collaborate with industry on technology development with less risk. Such collaborations give the process industry a competitive advantage and also provide growth potential for start-ups and SMEs.

Prosess21 believes that more focus should be placed on the effects to be achieved and the goals to be achieved. This should also define the structure of the policy instruments. In interaction with and supported by digital transformation, this is a development that will increase in speed and complexity over time. We believe it will be important that Norwegian policy instruments follow this development and can offer the necessary flexibility.

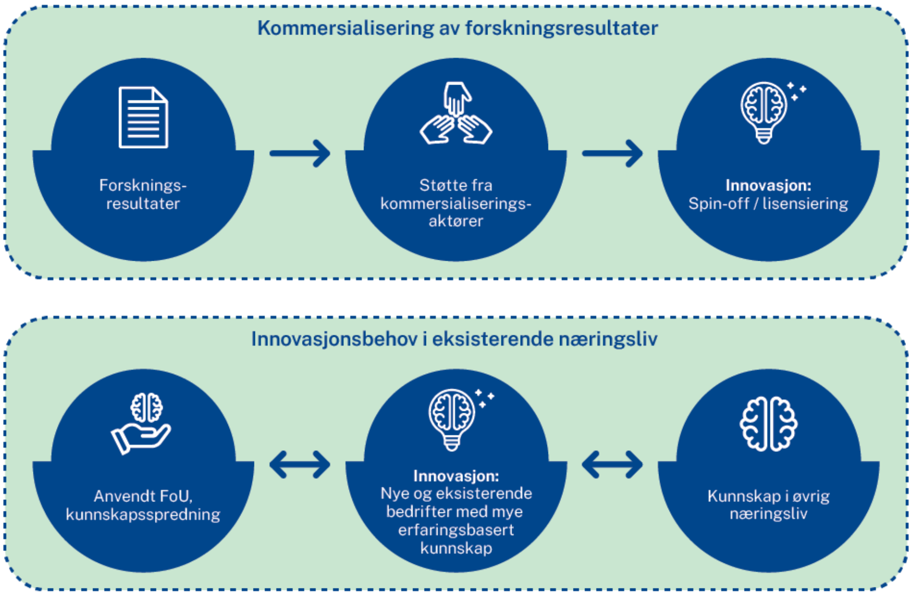

Figure 30 Two variants for innovation in an innovation ecosystem

Development and innovation processes can be described as they were done in the main report of Prosess21[97]. Here, two development tracks were presented. The first track is a traditional commercialisation of research results (see Figure 30), while the second track utilises knowledge and innovation needs from existing business and industry. The first description follows a more traditional way of thinking that research should be commercialised through support from commercialisation actors in order to contribute to new companies and jobs. This is important, but it is also essential to start from knowledge needs and technological barriers from existing business and industry, so that research and commercialisation are also aimed at defined needs in the market.

In addition, there is a third industrial development track, the purpose of which is the application of new enabling technologies, especially digital transformation technologies for the optimization of production processes. This involves the implementation and integration of technology in interaction with competence development, with a focus on strengthening production capacity through continuous improvement for increased productivity. These are operational development processes integrated into the daily operations, without requirements for traditional research height or extensive innovation height.

The idea and requirements for a specialised technology product for the industry often arise in an interaction between several actors. A plant owner has the basic need – the process to be optimized, the machine to be monitored, the product to be inspected, and so on. Often, the plant owner must operate the product themselves, but sometimes the need is met via an external service provider, such as a maintenance company, a contractor or a classification society. Finally, a product owner is often required – a player who is a specialist in the development, management, sale or rental of products.

Figure 31 Typical requirement owner structure for commercial products

The research institutes and consulting companies are specialized in ways that can complement and accelerate the development of innovative solutions and products with advanced digital capabilities. The institutes have a central role in driving forward new technology and knowledge through research and innovation, while the role of the consulting companies is more aimed at industrialisation, integration and introduction into the relevant user environments.

The catapults, with their testing and technology capabilities, as well as their industry experts, play a clear and clarifying role in such industrialization processes. By involving all the environments early on and drawing on their respective specializations, the client can achieve earlier value creation and efficient product development.

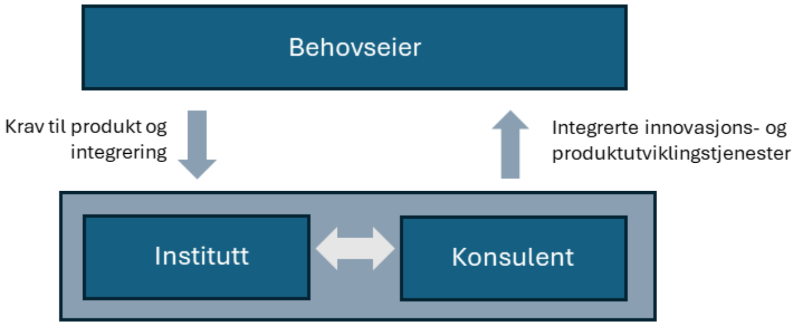

Figure 32 Collaboration model for product development

The illustration is simplified – important players such as sensor suppliers, tool builders, industrial designers, catapults and so on are included as "Consultants" in the model.

By using research institutes and consulting companies that work closely together, need owners can use delivery models that cover the entire TRL scale. This ensures that the product is appropriately integrated and that the value is taken out in the receiving organization.

The model is adapted to the current policy support system in that solution components with TRL grade 6 or lower are handled by the research institutes with public funding. Solution components with high maturity, system integration and other tasks with a lower innovation threshold are handled by the consulting companies with funding from the need owner or carried out by the companies' own R&D departments.

By combining and parallelizing the research institutes' expertise in technology development and the consulting companies' strengths inside implementation and industrialization, need owners can achieve faster and more efficient results in the development of products with digital functions.

The interaction and bridge-building between these processes, as well as the establishment of wise cooperative models, will be central to increased effects and results in the process industry. Furthermore, better and more coordinated and coordinated exchanges between the instruments' programmes, instruments and schemes will create room for more comprehensive and coherent industrial development journeys.

Do the instruments hit the target?

The transition to zero emissions in the process industry requires advanced technology development and large investments, as well as extensive planning and a long write-down period. In general, the process industry has a positive attitude towards the existing policy instruments, and understands how the players can provide risk-mitigating and triggering support.

In order to produce smarter, through more advanced and competent application of digitalisation and digital technologies, the pace of change must be accelerated, also among small and medium-sized supplier companies in different parts of the value chain. This involves increasing the degree of automation and the utilization of digitalization, including the use of data, IoT, and AI, to facilitate efficient production with reduced emissions.

Increased interaction between the policy instruments could facilitate a more comprehensive and coherent offer to the industry. This will contribute to increased power and pace in the transition by supporting the need for both increased automation and digitalization in the process industry. In Prosess21's assessments, it makes sense to point out the following general, but also relevant to the process industry, challenges related to increased digitalisation among the policy instrument actors:

1. **Generic instruments:** Most of the support schemes are generic and industry-neutral, which means that they are not specifically aimed at automation and digitalisation. Manufacturing consists of a number of very different industries and activities with very different needs.

   Set from the industry's perspective, the policy instruments that are relevant have medium relevance because they do not have automation and digitalisation as their main concern/purpose (e.g. reducing greenhouse gas emissions). The policy instruments therefore appear unclear, and thus unclear whether they can support projects that cover the industry's need for development inside automation and digitalisation.

   This can limit their effectiveness in meeting the needs of the industry. There may be a significant lack of information in this regard, but most likely the policy instruments are not sufficiently clear with regard to providing support for projects in the field of automation and digitalisation. There is also with both ongoing application management and more specific application deadlines for the relevant instruments.

   Projects inside automation and digitalisation often have great common features. Generic policy instruments can therefore be used across sectors and needs, but it can be clarified to a greater extent to focus on the area of automation and digitalisation in the context with sustainable production. By clarifying the need for automation and digitalisation, which the government's "Roadmap for a green industrial boost"[1] has pointed out, this can be with to engage companies.

2. **Lack of coordination:** There is a weak/poorly coordinated and coherent range of policy instruments that support the projects through several phases and meet the needs of the companies.

3. **Limited funding:** Digitalisation and automation projects in industry in most cases involve acquiring new but well-known technology and using it to improve production processes that are needed for the transition to a low-emission society, among other things. The projects are thus in phases that often cannot be classified as research and development or innovation. Rather, they are improvement and efficiency projects in existing processes or production. However, significant uncertainties associated with such projects (technology, expertise, etc.) mean that many companies consider it risky to invest in new production technologies. They are therefore hesitant with investing until adequate financial security and risk control are established. The pace of modernization, automation and digitalization will thus be slow on the way to meeting national goals and international climate commitments.

   For most companies, ordinary financing loans will be the way to finance this type of investment. But for some, a state/public financing scheme, either in the form of loans, guarantees or leasing, may be the only realistic possibility of realising investments within a reasonable time horizon. Several of the instruments can help trigger investments in technology and production equipment (e.g. loans from IN and Eksfin). The financial framework for the existing policy instruments may also be insufficient to meet market needs. This is not considered in more detail here. However, it would be appropriate to point out that it will be important to ensure efficient and sufficient solutions for financing production equipment.

4. **Lack of competence:** There is a general lack of competence inside automation and digitalisation both in companies and among policy actors. This is a major cause of uncertainty and risk associated with automation and digitalisation, which thus hinders the effective implementation and utilisation of new technology. As it is assessed, it is in this field that companies have the greatest need. Here there are existing instruments that meet the need and where improvements in the offer can have a good effect.

5. **Innovation height:** Many of the industrial challenges are inherent in their everyday operations. This operational development process and this digital transformation is about building competence, integration and application of digital technologies The policy support system should to a greater extent recognise the level of innovation that lies in integrations, to get new systems to interact with old/existing ones.

These weaknesses point to the need for a more targeted, coordinated and flexible approach to support schemes to promote automation and digitalisation in Norwegian industry.

Concluding reflections

The road from idea to implementation and application of new technology, including new digital tools and systems, can be long and complex in the process industry. Ideally, the policy support system should have instruments that can incentivise and support the entire process, with a low administrative burden when projects move from low maturity to implementation. In this way, the industry will be able to more easily implement ambitious projects with a long maturity and potentially large gains. The policy instruments may appear to be fragmented and not sufficiently coordinated across the actors. This underpins the need for clearer exchanges and increased coordination between the various policy instrument actors.

The National Digitalisation Strategy points to a number of goals and measures on the part of the Government. With regard to competence, we would particularly like to highlight the Government's goal of prioritising lifelong learning in areas that are necessary for the business sector of the future. This can support the process industry's need to build digital competence on top of strong domain expertise, for example in the classical technology and engineering disciplines. Furthermore, the strategy underpins the important goal of *"meeting the business sector's need for digital competence through stronger cooperation between relevant educational institutions, the business sector, policy actors and the social partners."* It will be crucial that candidates are educated who are either focused on digital/ICT subjects, or who add more digital competence in other disciplines, such as more classical technology subjects. It is very important that the depth and competence in the classical subjects are not given lower priority. Strong domain expertise in, for example, process science, chemistry and metallurgy is fundamental to being able to build good digital solutions that will have an impact in these areas.

Furthermore, increased user competence is important in order to be able to use the limited digital competence as effectively as possible. The need for increased digital professional competence probably applies to most professions and professions in the process industry. For example, leaders need to see the critical importance of cybersecurity to the business and the ability to engage the right resources to address the challenge. At the same time, employees in all functions must see the consequences of their own use of technology for the company's overall security. The pace of change will increase, and the individual employee's familiarity with the constant transition to new digital technology and new solutions is crucial for the effective use of digital technology in the business sector. If the Norwegian process industry is to be able to further develop its competitiveness, it must become both greener and more digital. The scope, depth, speed, scale, and importance of such a twin transformation are unparalleled. Digital technologies are radically changing the process industry. They enable new business models and increased productivity through smartness, intelligence and connectivity, while digitalisation supports the decarbonisation of the economy. Thus, the digital transformation will also be an important parts of the sustainability transformation. These will and must be transformed together and at the same time.

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Appendix 1 – Participants in the expert group

I would like to express my deepest gratitude to all those who have participated in meetings, workshops, interviews and writing work. It has been a great pleasure to work with such knowledgeable and committed people who really want the best for the process industry in Norway.

Special thanks go to Johannes Aalbu (Hydro), Ivar Kornbrekk (Bouvet) and Gaute Andreas Knutstad (Siva). Their leadership in their respective work packages and their efforts with the text and content of their chapters, with our participants, have been crucial to our completion of this report.

The industrial companies have supported the process significantly with many skilled participants who have ensured a strong connection to the reality and challenges of the process industry. Consultants and product suppliers, as well as SINTEF, NORCE, UIA and USN, have contributed knowledge with "state of the art" technology and together with the industry they have given us a balanced description of current and future needs for digitalization in the process industry.

Finally, I would like to send a big thank you to the key people who have been appointed by Prosess21. Their contributions have added weight and expertise to the report. Special thanks also go to Anders Hansen (Sintef), Konrad Eichorn Colombo (Eramet) and Nina Meldahl (Bouvet) for their extraordinary efforts.

Thank you very much to all of you for your contributions. We hope that this report will have a significant impact on the process industry in Norway in the future.

Regards, André Larsen, Leader of the Expert Group and DigiPro Centre

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Appendix 2 – Mapping of the process industry's priorities inside digitalisation

In the time ahead, the process industry will prioritize digital solutions that have a short path to realization and a solid business case with a focus on cost reductions. Data quality and access to important measurement parameters are prerequisites for the use of digital twins and digital analysis tools. Security and competence will be prioritized with the goal of digital transformation and efficiency.

To get a more comprehensive answer from the process industry, we have asked the same questions to ten companies: Hydro, Elkem, Vianode, Eramet, Jotun, Borregaard, INEOS Inovyn, Glencore, Yara and Hydrovolt. Their answers have been collected in an archive, and we have asked Copilot to generate answers to our questions with only the archive as a source. The goal with this process is to get an objective and representative answer from the process industry to our questions.

The answers are generated by Copilot based on input from 10 different companies. As a result, the proposals have not been concretised in specific solutions, but this mapping forms the basis for some of the overarching recommendations in this report.

Which digital solutions will be prioritized in the future?

- **Optimization of control systems and predictive models:**
    - The process industry will continue to develop predictive models to manage factories more energy-efficiently and productively, as this provides direct returns.
- **Predictive Maintenance and Instrumentation:**
    - Focus on predictive maintenance and instrumentation in the field to anticipate challenges with components and machinery, thereby reducing the risk of downtime.
- **Digital competence and security:**
    - Continued work with building digital competence and ensuring that security is always in focus. Significant progress has been made in collaboration with academia to standardize training materials and define learning objectives for digital applications.
- **Digital Twin solutions:**
    - Implementation of "Digital Twin" solutions for projects, operations and maintenance to optimize the value chain across the organization.
- **Data quality and accessibility:**
    - Improving data quality on cloud platforms for efficient integration of new digital solutions. Making data available to those who can use it effectively is critical to moving towards proactive or condition-based maintenance.
- **Artificial intelligence (AI) and multivariate data analysis:**
    - Application of AI and multivariate data analysis to find valuable insights into the transitions between different data sets. This requires accessible and correct data.
- **Smart sensors and robotization:**
    - Increased application of smart sensors, data-driven methods and robotization to improve process control and safety.
- **Digital transformation and analytical solutions:**
    - Focus on digital transformation with broad access to data from all process plants, both real-time and historical data, for better decision-making and analysis.

Generated using AI with only process industry feedback as a source. The content is quality assured by the expert group before publication.

What digital choices should be made for new factories and/or processes?

When companies plan to build new factories or processes, there are several digital choices that should be considered to ensure a robust and future-oriented infrastructure.

- **Infrastructure:** Both wireless and physical infrastructure must be in place. This includes a solid data platform, preferably cloud-based, to handle future solutions. IT security must be built into the infrastructure from the start, both wirelessly and physically.
- **Data exchange and standards:** Standardized data interfaces simplify and reduce the cost of data exchange between different providers. Application known, established technologies and protocols such as OPC-UA for automation and ISO standards for interoperability.
- **Traceability:** Create digital traceability solutions such as *blockchain* to track materials, production history, and compliance data throughout the supply chain. This improves quality control and compliance with industry regulations.
- **Control systems:** Choose control systems that allow for autonomy and future opportunities. Ensure that these systems can integrate seamlessly with existing and future solutions.
- **Competence and organisation:** Build internal competence inside digitalisation and automation. It is important to have this expertise in-house for continuous improvement. Involve all relevant stakeholders early in the process, including operators, electricians, mechanics, maintenance engineers and department managers.
- **Continuous improvement:** Focus on continuous improvement of work processes and ensure that the right digital solutions and control systems are in place. Have a clear strategy for what skills are needed to drive improvements forward.
- **Cybersecurity:** Cybersecurity must be ensured at all stages of development. This includes network security, communication security, and endpoint protection.
- **Advanced sensors:** Invest in advanced sensor technology with real-time data capabilities for optimized operations.
- **Project implementation:** Application plenty of time on the pre-project to ensure that you build what you really want and avoid costly changes along the way. Ensure that production and process data is available to those who can use it effectively.

Abstracts from interviews with industry leaders using AI from Microsoft CoPilot. The content is quality assured by the expert group before publication.

Risk of establishing new digital solutions?

In the process industry, it is crucial to maintain high productivity, which is reflected in the digital solutions that are introduced. Failures in such solutions, especially those associated with critical processes, can lead to significant financial losses. Therefore, a thorough risk assessment is carried out before new solutions are used.

Risk factors

- **Infrastructure needs:** Installing wireless technology and other infrastructure can be costly. It is important to have a robust infrastructure in place to support new digital solutions.
- **Skills gap:** There is a significant need for skills development among both experts and operators. In order to drive change processes efficiently and maximise the value return of new solutions, adequate training and competence development must be ensured. To reduce the risk associated with the start-up of new solutions, the industry is working with educational institutions to increase the level of expertise inside IT and digitalisation. This is a long-term investment that requires time and resources.
- **Personal safety and working environment:** Focus on process safety also contributes to the improvement of the working environment, for example by improving air quality. The risks of not improving process safety are considerable. Automation (e.g. robots) is expensive, but improves personal safety and reduces the risk of injury.
- **Supplier selection:** Choosing reliable IT providers is critical. It is necessary to integrate them at the heart of the system to ensure that the solutions are fully utilized. Wrong choices can lead to systems being left unused. Suppliers with no experience working in the process industry increase the risk when implementing solutions, especially inside AI.
- **Digitalization and Data Management:** Digitization requires robust infrastructure for storing, cleaning, and analyzing data. Systems need to be interoperable and reliable to provide accurate data.
- **Experience sharing and standardization:** It is necessary to share experiences from others to understand what works in practice. A lack of standardization can hinder scaling and reduce the value of investments.
- **Value proposition:** Documenting the value of digital investments can be challenging.
- **Supplier knowledge:** Management and ownership of data in cloud solutions must be taken care of before implementation. Partnerships with large companies can be considered, but this can lead to lock-in effects. The distance between developers and users in large organizations can also be a barrier. Many elements must work together, and it can be difficult to have an overview, especially when new upgrades are made.

Abstracts from interviews with industry leaders using AI from Microsoft CoPilot. The content is quality assured by the expert group before publication.

How can the policy support system provide support?

In order to provide better support to the process industry, the policy instruments should focus on the following areas:

- **Defining Real Problems:** The industry itself should identify its problems and needs. The policy support system should help to reduce risk, so that supported projects solve real challenges and promote a clear strategic direction.
- **Institutes, academia and industry:** There is a lot to gain from collaboration between departments, academia and industry. Especially when several industry players join forces, this can provide scalable solutions that benefit more people. Collaboration across sectors can identify common factors and lift both large and medium-sized companies, as well as smaller players.
- **Standard solutions:** Many problems can be solved through joint efforts and the development of standard solutions such as source code, feature descriptions and risk assessments. This will benefit many companies, and reduce the need for each company to develop everything themselves. Allocation of funds to such collaborative projects will be very useful.
- **Financial Support:** Governments and the EU can provide financial support for projects that would not otherwise be possible. Initiatives such as Enova can be effective in testing the feasibility of projects, even if it involves higher risks. A "Digital Enova" that supports the implementation of digital solutions would provide a significant improvement in the current situation.
- **Networking Opportunities and Information Sharing:** Initiatives such as DigiPro can offer networking opportunities and semi-open access to information for specific digital issues. This should also include collaborating with other organizations to share experiences and solutions.
- **Policy development:** Information about network protocols, standards, official guidelines, cybersecurity, cloud solutions, and energy requirements affects the entire process industry. The policy instruments should support the development of such guidelines to ensure a comprehensive approach.
- **Support for Technological Maturity:** Increased support for open knowledge development and the use of available technology and agile methodology can help to increase the organisational and technological maturity of companies.
- **Additional funding:** For digitalisation projects, additional funding is important with building knowledge about the new technology as implemented in the main project. This can prevent projects from ending up in the "valley of death" and ensure value creation from public funds.

Abstracts from interviews with industry leaders using AI from Microsoft CoPilot. The content is quality assured by the expert group before publication.

Appendix 3 – Description of actors and tools in the policy support system

The Norwegian process industry is a competence industry that has a tradition of actively using R&D to ensure increased value creation and strengthen its competitiveness. His efforts range widely from research on biochemical processes to materials research and the development of advanced process technology. The process industry has generally good knowledge of the policy instruments and uses the various support schemes actively to obtain support for its R&D projects. See Table 2 for roles and functions for the most important policy instruments.

The Research Council of Norway

The Research Council works to promote a society in which research is created, used, challenged, valued and shared through effective and comprehensive instruments for research and research-based innovation. New knowledge takes place through research and innovation, where both product and process development are addressed. The industry-oriented research is primarily aimed at innovation at low TRL levels. The Research Council's portfolio includes Knowledge-building and Collaborative Projects (KPS) and Innovation Projects for the Industrial Sector (IPN) that appear to be working well and are being used extensively. The best experience is when the industry itself has ownership of the project or is actively allowed to participate in the design and implementation of research projects with research groups and other partners. In the following, a brief account is given of the most relevant arrangements.

SFI and FME scheme

Centres for Research-based Innovation (SFI) or Centres for Environment-friendly Energy Research (FME) is to promote innovation by supporting long-term research through close collaboration between R&D-intensive enterprises and prominent research institutions. SFI aims to strengthen the innovation capacity of Norwegian business and industry through research that responds to long-term needs, challenges and future value creation opportunities. The research must take place in a binding and long-term collaboration between research organisations and companies, preferably also in collaboration with the public sector. The research must be at a high international level and provide a basis for innovations and increased value creation in Norwegian business and industry.

The Competence and Collaboration Project (KSP)

The purpose with KSPs is to stimulate research organisations to collaborate with the business sector to build knowledge that business and society need to solve major societal and business challenges. It is a prerequisite that industry actors are partners in the project and finance part of the R&D actors' costs. The research in the project can be both basic and applied.

Innovation Project for the Industrial Sector (IPN)

The IPN scheme supports companies that, with partners, want to carry out a project that includes research-based innovation (industrial research) and/or that will demonstrate new technology (experimental development).

The projects must lead to socio-economic benefits by making new knowledge and new solutions from the project available to more people. Strengthened competitiveness and innovation capacity are also important for solving major societal challenges and for developing more value-creating and sustainable industries. The scheme finances projects that can strengthen existing business and industry and form the basis for new ones.

The results can be a new product, a new service, a new manufacturing process, or a new way of delivering products and services. Significant improvements, or new features of existing products, services or processes at the companies, can also be a result.

IPN projects have a scope and a risk profile that indicate that companies will not be able to carry out the project without funding from the Research Council. This means that the support must be a trigger for the implementation of the R&D activities.

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[d] https://www.forskningsradet.no/siteassets/publikasjoner/2024/forskningsradets-strategi.pdf

[e] https://www.forskningsradet.no/

Table 2 Rollers and functions for the most important policy instruments.

Policy providers	**Primary role (mandate)**	**Contributes to (value proposition)**	**Through-using (deliverables)**	**Programmes and instruments**
Siva SF	The company for industrial growth – develops, owns and finances a national infrastructure for innovation and business development consisting of incubators, business parks, catapult centres, innovation companies, as well as innovation centres and industrial buildings.	Connects companies from across the country to regional, national, and international networks with industrial advisors that also include access to internationally leading industrial testing infrastructure and expertise.	With consulting services for industrial service development and industrial scaling, testing of products, solutions and services. Through investments in properties and the facilitation of green industrial sites, barriers to the establishment of new business activities are lowered.	Through regional innovation companies, nationwide incubator networks and through 13 catapults, a national network of industrial test centers with industrial expert expertise. Green Platform (together with NFR and IN)
The Research Council of Norway	The Research Council funds research and innovation that strengthens knowledge, value creation and sustainability in Norway. The Research Council supports both basic and applied research inside priority areas and promotes collaboration between academia, business and industry and the public sector.	Ensures necessary technology development, innovation and competence building in nationally prioritized areas as well as access to international research programs such as Horizon Europe (EU). This promotes cross-border cooperation, strengthens the competitiveness of Norwegian industry, and contributes to the necessary restructuring.	Through investments in research and innovation projects, guidance in application processes and advice to facilitate collaboration between the business sector and R&D communities, as well as participation in international research programmes such as Horizon Europe.	By using key policy instruments such as Knowledge-building and Collaborative Projects (KSP) and Innovation Projects for the Industrial Sector (IPN) for research-driven innovation, the Green Platform for the Green Transition, as well as Skatte FUNN for R&D support in companies.
Innovation Norway	Innovation Norway is the central and county authorities' instrument for realising value-creating business development throughout the country	Trigger commercially and socio-economically profitable business development, based on the different regions' business opportunities	Through services inside financing, advice, expertise, networks and profiling of Norwegian companies	Through grant schemes such as the Environmental Technology Scheme and innovation contracts or loan schemes and the Green Growth Loan, the Green Platform for Green Transition

SkatteFUNN

SkatteFUNN (Tax Deduction for Research and Development in an Innovative Business Sector) is a rights-based tax deduction scheme for Norwegian companies. You can apply for a tax deduction for 19 per cent of the costs of a research and development project. The scheme is administered by the Research Council of Norway, in collaboration with the Norwegian Tax Administration.

The projects must:

- aim to develop or improve an existing product, service or production process
- generate new knowledge or use existing knowledge in new ways, i.e.
    - address an R&D challenge (problem) that has no known solution today
    - describe how you will proceed systematically to obtain new knowledge
- Be targeted and delimited, and it must be possible to separate the project from the normal operations and activities of the company

Innovation Norway

Innovation Norway offers services inside financing, advice, expertise, networks and profiling in a wide range of areas[f] It is true that Innovation Norway does not have any funding schemes that specifically target automation and digitalisation of industry, but digitalisation and automation can be included as elements in projects that receive support through grant schemes such as the Environmental Technology Scheme and innovation contracts or loan schemes and the Green Growth Loan.

The process industry makes limited use of the funding opportunities through Innovation Norway. This applies in particular to corporate collaborations or consortia. Small businesses are often the creative engine of business development and innovation, and not least this is the case inside digitalization. This is probably an untapped funding opportunity for the process industry's digitalisation projects. The following is a brief presentation of the most relevant schemes:

The Environmental Technology Scheme

The environmental technology scheme allows for grants for R&D activities related to technologies, processes, solutions and services. The purpose with the environmental technology scheme is to solve an environmental problem. The extent to which a new technology contributes significantly to solving environmental challenges is assessed in the light of the EU's taxonomy. Measures that primarily contribute to efficiency and productivity improvements, without a significant environmental effect, are not considered to be environmental technology. The extent to which digitalisation and automation will have a significant (positive) effect on the environment is assessed on a case-by-case basis.

Innovation contracts

Innovation contracts allow for grants for R&D activities, and are intended to provide risk relief for projects that are innovative and have international potential. This requires that the innovation project is associated with significant market and/or project risk. The core of innovation contracts is development in close collaboration with the market and pilot customer, with the goal of commercializing a new solution – and the potential for scaling and growth. Digitalisation and automation can be included as elements in these projects.

Innovation loans / Risk loans

Innovation Loans are a financing scheme from Innovation Norway that supports profitable development and investment projects, especially for companies that cannot obtain ordinary bank financing due to a lack of collateral. The loan is available to companies all over the country and prioritises projects that promote innovation, growth and internationalisation. It can be used for investments in buildings, machinery and equipment, as well as development projects that contribute to the company's growth and innovation. Innovation loans are a favourable top-up financing that helps companies with realise ambitious projects.

Green growth loan

Green growth loans can be granted for investments in tangible and intangible assets to establish the production of climate solutions. The loan enables the company to build production facilities for new systems, solutions, products

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[f] https://www.innovasjonnorge.no/

and services that reduce greenhouse gas emissions when rolled out to the market. Whether digitalisation and automation will have a positive environmental effect is assessed on a case-by-case basis.

Low-risk loans

Low-risk loans are primarily offered to small and medium-sized enterprises across the country and in all industries and industries, but the offer also includes large enterprises. Financing with low-risk loans covers the company's need for long-term debt financing of fixed assets, but also capital strengthening, internationalisation and development activities.

Green Industrial Financing (New with 2024)

The goal is to innovative, green industrial projects in different parts of the value chain. The scheme is aimed at companies that have, or will have, value-creating activity in Norway. Green industrial financing will primarily be a scheme for risk loans with subsidised terms, and substantial private co-financing is required in all projects. This initiative is one piece of the Government's commitment to a *Green Industry Boost,* which will promote attractive jobs, values and welfare for the future, reduce emissions and contribute to the green transition.

The Cluster Program

The cluster programme, run by Innovation Norway in collaboration with Siva and the Research Council of Norway, is a catalyst for value creation in the Norwegian business sector. It promotes collaborative development that otherwise would not have happened so quickly or on such a large scale without public intervention. The programme is structured in three levels with a timeframe of three years each, and clusters can receive operating funding for up to ten years under the state aid rules (GBER Article 27).

With a transition period in sight, the existing modules such as Arena, Arena Pro, GCE and NCE, as well as support for mature clusters, will be phased out and replaced by new program levels: NIC Connect, NIC Explore and NIC Impact. These new programs are designed to take over the baton and continue to drive innovation and collaboration in Norwegian business. Until the end of 2026, clusters from previous programme levels will exit the programme.

In the process industry, there are three established clusters that are managed by the companies respectively. The Eyde Cluster (NCE), Arctic Cluster Team (Arena-Pro) and Industrial Green Tech (Arena).

Siva

Siva– the company for industrial growth– owns and finances a national infrastructure for innovation and business development consisting of incubators, business parks, catapult centres, innovation companies, as well as innovation centres and industrial buildings.

Norsk Catapult

The purpose of the Norwegian Catapult scheme is to build up a national test infrastructure that will contribute to faster industrial value creation and green transition in industry and business throughout the country. In collaboration with Norway's leading industrial environment, the scheme facilitates the establishment and development of catapults (industrial test arenas) in selected areas of great value to Norwegian industry. Here, companies get easy access to equipment, technology and expertise from the country's leading industrial environment, and Norway as a nation gets more innovation, faster restructuring and strengthened competitiveness.

To date, five catapults and eight nodes have been established in enabling technology areas (production technology, materials technology, digitalisation) and in sectors of great national importance (renewable energy and ocean industries). See Figure 33.

[9] https://siva.no/virkemidler/

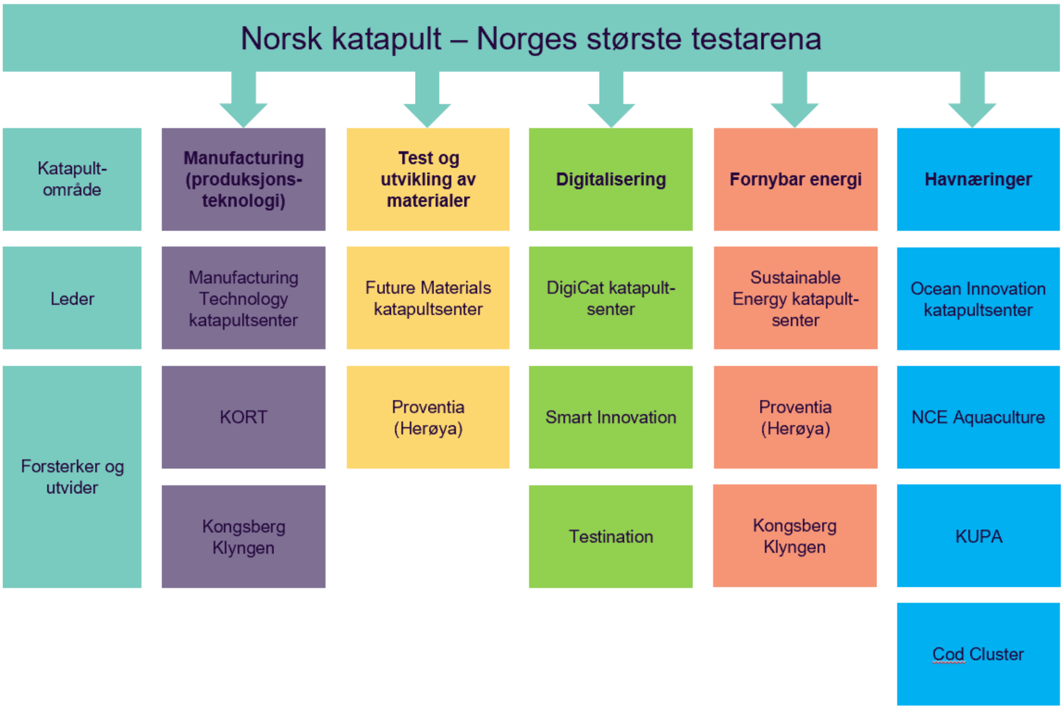

Figure 33 Current catapult crepi (as of December 2024).

The catapult centres' range of services helps companies to quickly clarify their challenges, increase the pace of innovation and increase industrial expertise. The scheme has now been expanded with eight nodes that will strengthen the test infrastructure and ensure increased innovation capacity, faster restructuring and strengthened competitiveness. This means that the Manufacturing Technology Norwegian Catapult Centre (MTNC) and DIGICAT, which are particularly relevant for automation and digitalization, have been reinforced in the areas of: application of robotics, system technology and value chain integration, as well as the application of AI technology.

Through the catapult scheme, a large number of industrial experts (from the industry itself) have been made available who transfer their industrial expertise through many projects. A recent report from Menon points out that the most important result from the projects at Norsk Katapult is increased industrial expertise. The catapults enable companies to test and develop new solutions inside automation and digitalization, as well as add significant expertise from, for example, the industrial experts or core partners, before they are implemented at full scale. This makes it possible to clarify before the company itself invests in new solutions. This is what makes the scheme unique and helps the core partners to be in a position so that SMEs can benefit from them. Here, Norway is probably at the forefront of Europe.

For the process industry, the domain Future Materials, Digital and Manufacturing Technology are the most relevant.

The business garden and incubation programs

Siva's business garden programme and incubation programme are key and industry-neutral policy instruments for companies throughout the country. With 39 business parks and 35 incubators located throughout the country, the companies through the Siva structure gain access to relevant and crucial expertise, networks and capital to succeed with their development and growth. The business parks and incubators are close to the business community and offer a total of more than 600 advisors. The companies receive follow-up in a critical phase of the development and are linked to relevant policy instruments, investors, industrial partners, research environments, etc.

The business garden and incubation programmes are intended to help develop sustainable and future-oriented business in rural areas, and to develop the sustainable growth companies of the future throughout the country. The business parks and incubators are key tools for succeeding with a green industrial boost, and will help companies and start-ups across the country to both establish and scale.

The main objective of the business garden programme is to contribute to increased value creation based on regional advantages, by facilitating the development of sustainable and adaptable companies. The business garden programme is a regional policy instrument.

The incubation programme will contribute to increased national value creation by effectively identifying, further developing and commercialising good ideas for new growth companies, and triggering growth in established businesses. The target group for the incubators is innovative ideas and companies with mainly international growth potential.

Through the business garden program and the incubation program, Siva offers expertise, networks and access to capital to companies. The business parks and incubators follow the companies closely through the development. They assist companies with gaining access to policy instruments from Innovation Norway, the Research Council of Norway and other policy instruments. Innovation Norway refers companies to Siva's business gardens and incubators for closer follow-up.

Real Estate Investments

Siva Eiendom is a national real estate player that invests, develops and manages real estate for industry and business development. We invest where there is insufficient risk capital available. Through its real estate investments, Siva will lower barriers to establishment where market mechanisms make this particularly demanding, also for larger industrial real estate projects.

Joint offers/instruments

Green platform

The Green Platform is both a financing service for large, green collaborative projects and a competence service. The goal with the Green Platform is to speed up the green transition in the business sector and ensure a socio-economically profitable and internationally competitive Norwegian business sector. The support is given to consortia that contribute to business development for lower emissions and better resource utilisation in a way that safeguards biodiversity and the environment. In addition to the financial support, the consortia receive competence services inside business modelling, among other things.

The projects are co-funded by the Research Council of Norway, Innovation Norway and Siva. The consortium consists of research institutes, industrial companies, innovation companies and the catapults. The Green Platform works with both research and innovation on new technology, as well as testing and verifying the applicability of the technologies.

Pilot-E

PILOT-E is a funding offer to Norwegian business and industry, established by the Research Council of Norway, Innovation Norway and Enova. The aim with the scheme is to speed up the development and adoption of completely new products and services inside environmentally friendly energy technology in order to contribute to emission reductions both in Norway and internationally. A PILOT-E project must cover the entire process from research to full-scale demonstration of new concepts or innovative solutions under real operating conditions.

European Innovation Digital Hubs

Digital Europe is the EU's programme for digital transformation in business and the public sector. The purpose is for increased use of digital technologies to strengthen the competitiveness of the business sector, improve public services, and contribute to solving global challenges inside climate, environment, health and safety. The programme will also contribute to the EU becoming more technologically independent from other countries and regions. One of several initiatives inside the programme is investments in technical infrastructure and digital competence that Norwegian companies, clusters and other research and innovation actors can benefit from. Norway is with Digital and there are two EDIHs in Norway, the NemonoorComposite[panel] and the Oceanopolis[panel].

Gassnova

Gassnova's mission is to realise carbon capture and storage, and has overall responsibility for the Climit programme. Of the annual funds for Climit, half goes to Climit R&D and the other to Climit demo. Climit is an important tool for the Norwegian process industry in the future as well. Although it is primarily about carbon capture and storage, the twin transformation is becoming increasingly important, and then digitalization is also becoming a key element for success.

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[h] [panel] https://nemonoor.no/

[i] https://oceanopolis.no/

[j] https://gassnova.no/

Enova

The purpose with all of Enova's technology programmes is to accelerate technology development and innovation that contributes to emission reductions towards a low-emission society in 2050. Through Industry 2050, Enova will contribute to new technology being developed, improved and adopted more quickly, thereby enabling a faster and cheaper transition to a low-emission society. In the long term, such technology and solutions must be able to be preferred in the market on commercial terms without support.

Eksfin

Eksfin's investment loan scheme can finance investments in production equipment if this contributes to increased exports. For green investments, there must be a potential for exports 5-10 years into the future, and Eksfin has the opportunity to look at value chains as a whole. This means that all production that is part of a green value chain with export potential can qualify for the scheme, even if the customers of the company in question are only domestic. For investments that are not defined as green, the link to exports must be stronger.

EU programmes and initiatives

A.Spire is the process industry's European industry association and represents sectors and organizations related to the sustainable process industry. They focus on promoting collaboration and innovation to reduce resource use and environmental impact in industrial processes. A.Spire coordinates initiatives and projects under EU programmes such as Horizon Europe, and acts as a bridge between industry, research communities and authorities.

Processes4Planet

Processes4Planet (P4Planet)[k] is a public-private partnership (PPP) between the EU and the process industry, initiated by A.Spire. P4Planet focuses on transforming European process industries to achieve circularity and climate neutrality inside 2050, while strengthening their global competitiveness. Here are the key focus areas:

- **Development and implementation of climate-neutral solutions:**
  - P4Planet works with bringing both technological and non-technological innovations to a level where they can be widely implemented to contribute to climate neutrality
- **Energy and raw materials:**
  - The process industries develop and implement sustainable circular business models through innovations, cross-sectoral collaboration and engagement with local ecosystems. The goal is to achieve almost zero landfilling and near-zero wastewater discharge inside 2050
- **Global leadership in climate-neutral and circular solutions:**
  - P4Planet wants to accelerate innovation and trigger both public and private investment to make climate-neutral and circular solutions more attractive. This will strengthen the competitive position of European process industries

The EU's efforts to build capacity for increased competitiveness

The EU is increasingly pointing to innovation ecosystems as a crucial factor for many companies to succeed in their development processes and strengthen their competitiveness. *European Innovation Ecosystems* (EIE) collaborates with EU programmes such as *the European Innovation Council* (EIC), *the European Institute of Innovation and Technology* (EIT) and *Horizon Europe,* to create more interconnected and efficient innovation ecosystems. The aim is to support growth, encourage innovation and promote collaboration across national and regional actors.

In particular, the EU has promoted initiatives under *the Digital Europe programme,* such as EDIHs *(European Digital Innovation Hubs)* and TEFs *(Test and Experimentation Facilities),* to increase companies' ability to use digital technologies in a value-creating way. In addition, the Digital Europe programme has initiated major initiatives that will contribute to common standards for data sharing and facilitation of common data lakes.

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[k] https://www.aspire2050.eu/p4planet/about-p4planet

In 2024, the Commission has initiated a major project to develop a strategy for technological infrastructure (TI) that will contribute to faster implementation of digital technologies, among other things, and the realisation of solutions that provide a lower^{CO2} footprint. TIs will complement existing research infrastructure by offering industrial expertise from companies and institutes that are opening up their technology platforms and test facilities. When TIs interact with what the EU defines as *industrial infrastructure,* which are pilot and demonstration lines, companies will have capabilities they can play on right up to implementation. Existing technology and test infrastructure at institutes and catapults will be well positioned for the new EU TI strategy.

National level

At the national level, the catapults have been tasked with offering test facilities and expertise that help industrial players with services that, among other things, will contribute to faster implementation of digital processes. The catapults have five main areas, where material, production and digital are the most relevant for the process industry. The digital catapult has a partnership of leading technology companies, institutes, NTNU and large international IT/technology giants. The catapult consists of a center, two nodes and the EDIH Nemonoor. They collaborate strategically and operationally so that companies receive the services where it is most appropriate.

Placement of instruments along the TRL scale

The TRL scale (Technology Readiness Level), the CRI scale (Commercial Readiness Index) or MRI (Manufacturing Readiness Index) are commonly used terms with research, industrial development, market introduction and scale-up. These are well established and used to indicate the maturity level of development.

Basic research (TRL level 1):

Basic research uses recognized scientific methods and theories, and also contributes to the development of these. Basic research is motivated by contributing to scientific innovation at the theoretical, methodological or empirical level. Basic research is generic and forms the basis for other types of research. The most important benefit of basic research is that it provides new insights that change areas of knowledge and that other research can build on.

Industrial Research (TRL Level 2-4):

Corresponds to planned research or critical inquiry aimed with the acquisition of new knowledge and skills, which are necessary to be able to develop new products, processes or services or to be able to bring about significant improvement in existing products, processes and services (i.e. experimental development).

Experimental development (TRL level 5-7):

Experimental development may include the production of prototypes, demonstrations, the manufacture of pilots, and the testing and validation of new or improved products, processes or services in contexts that are representative of the real operating conditions, with the primary purpose of technically further developing products, processes or services, which have not yet taken their final form. This may include the development of a commercially viable prototype or pilot, when this must necessarily be the final product, and if it is too expensive to manufacture to be used solely for demonstration and validation purposes.

Commercial development phases (CRI levels 1-6)

One of the challenges with TRL classification is that you can have a dispersed range of technologies that have achieved the highest TRL level (TRL-9) but have very different starting points for competing on commercial market terms. In such contexts, it may be appropriate to supplement the TRL classification with a scale that takes these differences into account. This can be done, among other things, through a so-called CRI scale – Commercial Readiness Index.

Figure 34 shows how instruments and capital instruments interact along the TRL and CRI scales.

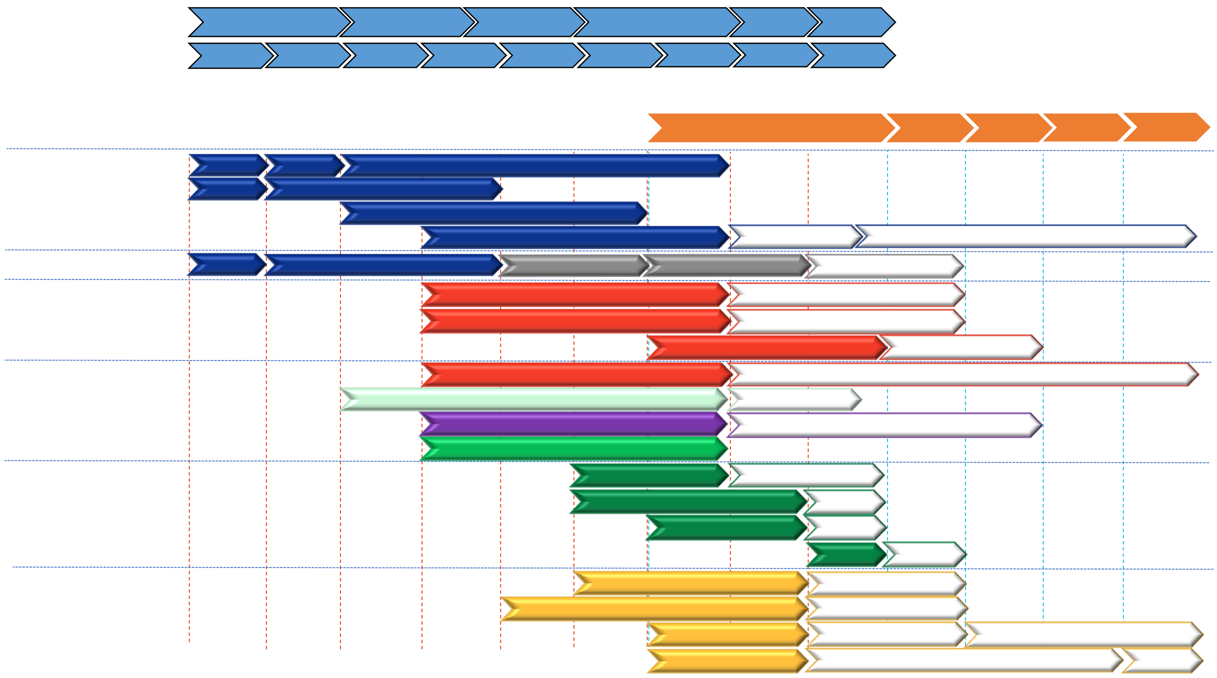

Figure 34 How instruments and capital instruments interact along the TRL and CRI scales.

Appendix 4 – Objectives for digitalisation projects

Rollers are to strengthen companies' ability to create jobs, meet future challenges and contribute to society's economic resilience. As a reinforcement of this overall description of the role and function of the policy instruments, we have developed six proposals for objectives or goals for the digitalisation of the process industry.

1. **Increased production efficiency**
   - **Objective:** Increase production efficiency through automation, predictive maintenance and optimization of production processes.
   - **Description:** By adopting digital tools and technology for optimization and automation, the process industry can streamline production processes, reduce downtime, and increase production capacity. For example, predictive maintenance can prevent machine breakdowns, reducing downtime and repair costs.
   - **Effect:** Increased production capacity, lower operating costs and higher resource utilisation.
   - **KPIs:** Reduction in input factors (measured in xx or yy); Reduction in downtime (measured in hours per month); Increase in production capacity (measured in units produced per hour); Reduction in maintenance costs (measured in NOK per year)
2. **Improved product quality and new areas of application**
   - **Objective:** Use digital tools to ensure higher and more stable quality of products and processes through real-time monitoring, monitoring and automatic control. Increased usability of products in new customer groups/end products as a result of digitally supported product development.
   - **Description:** Digitalization enables precise, real-time measurement and analysis of production parameters such as temperature, pressure, and composition. New sensor technology for inline measurements, and new methods of data analysis (e.g., inside machine learning and AI) enable automatic adjustment of production processes so that products can better meet quality standards.
   - **Effect:** Reduced waste, fewer faulty productions and higher customer satisfaction.
   - **KPIs:** Reduction in the number of faulty productions (measured as a percentage); Increase in customer satisfaction (measured in customer satisfaction index); Sales to new customer groups or end products; Reduction in waste (measured in tonnes per year).
3. **Reduced climate and environmental impact**
   - **Objective:** Minimise emissions and resource loss through digital solutions that contribute to more efficient energy and resource management.
   - **Description:** Through digitalization, the process industry can adopt more energy-efficient and circular economy solutions, which can help reduce greenhouse gas emissions and provide better resource management such as lower raw material consumption and less by-product. As an example, digital twin technology, IoT and AI can be used to monitor and simulate production processes, identify areas for energy savings, improve logistics and distribution.
   - **Impact:** Reduced CO emissions, lower energy consumption, optimized resource input, and more sustainable production that can also help meet regulatory requirements.
   - **KPIs:** Reduction in the number of faulty productions (measured as a percentage); Increase in customer satisfaction (measured in customer satisfaction index); Reduction in waste or emissions (measured in tonnes per year or emissions per unit). Specific consumption of input factors per unit produced; Increased **premium** on products as a result of sustainable production
4. **Increased flexibility in production**
   - **Objective:** To increase flexibility in production to adapt to rapidly changing supply supply, market conditions and customer needs (e.g. by increasing the requirement for products with environmental passports).
   - **Description:** Digital technology enables businesses to adapt quickly to changes in the market and customer needs, as well as to develop more scalable and modular production systems. Agile production processes can be adjusted quickly through automation and dynamic planning.
   - **Impact:** Faster adaptation to changes in the market, higher customer satisfaction and competitiveness.
   - **KPIs:** Reduction in time to adapt production lines (measured in hours); Increase in the number of product variants produced (measured in numbers); Reduction in inventory (measured in days).
5. **Improved security and risk management**
   - **Objective:** Reduce safety risks and improve the working environment through digital monitoring and automation.

- **Description:** Digital solutions such as sensors, AI and robotics and drone technology can identify and handle dangerous situations quickly and with reduced risk levels. Digital systems can monitor production processes in real-time, making it easier to detect and respond to potential hazards before they become serious problems. Automation and the use of robots can also reduce the need for manual work in hazardous environments, reducing the risk of workplace accidents. In addition, automation can help to remove physically demanding manual tasks that lead to wear and tear injuries, or tasks that are not very stimulating.
- **Effect:** Reduced number of occupational accidents, better working environment and improved risk management.
- **KPIs:** Reduction in the number of occupational accidents (measured in number per year); Increase in the number of safety inspections (measured in number per month); Reduction in costs related to unforeseen downtime (measured in NOK per year)

6. **Improved service development, increased and streamlined traceability**
   - **Objective:** Develop new services that can supplement physical products such as traceability documentation ala product passports
   - **Description:** It may be appropriate to develop supplementary products that can be associated with physical products produced in industry. Increasing requirements for traceability may force digital solutions that state quality, history, environmental footprint, etc.
   - **Effect:** Manufacturer and customer must work more closely together, which increases the likelihood that the manufacturer will remain the preferred supplier. Customer helps to sharpen product quality and precision.
   - **KPIs:** Number of service-based customer relationships developed, Increase in customer satisfaction (measured in customer satisfaction index); Reduced time consumption and increased level of precision and detail in the preparation of product passports/traceability; Increased premium on products as a result of knowledge/services with

Annex 5 – The mandate of the expert group

Background and rationale for the establishment of the expert group

Prosess21 has been established by the Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment. Prosess21 will provide strategic advice and recommendations on how Norway can best achieve a development towards minimal emissions from the process industry in 2050, and at the same time facilitate sustainable transition, growth and value creation. The process industry is part of the government's initiative - Green Industry Boost. Prosess21 received a new mandate and steering group from the Ministry of Trade, Industry and Fisheries in February 2024. The Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment have observers in the steering group.

Prosess21 established an expert group with its own mandate that focused on the specific digital challenges and opportunities that apply to the Norwegian process industry. The group held workshops, but unfortunately there was never time to complete a separate report. The conclusion of the work was nevertheless incorporated in the Prosess21 main report and with its own recommendation: *"The industry should establish digitalisation strategies that include opportunities for improvement in all parts of the business*[I] and in the summary of the main report you can read:

"In both a 10-year and a 30-year perspective, the Norwegian process industry needs extensive restructuring. The need includes increased digitalisation with associated skills development. The process industry in Norway is at the forefront inside automating production processes, but compared with other industries, the process industry is late with developing and adopting the full range of new digital technologies. Especially inside customer-oriented processes, service innovation and automation of administrative processes, the process industry has a lot to learn from other industries"

It has been more than three years since the Prosess21 expert group on digitalisation completed its work. A great deal has happened in the field in recent years, and it is therefore appropriate to update the knowledge base and propose updated recommendations and advice.

New digital platforms are being developed and source codes/computer programs are being made available openly on the internet so that others can inspect, modify and use them free of charge *(Open source).* IOT *(Internet of Things)* increasingly enables various components to be connected to the grid and controlled remotely. This, in turn, requires better control with cyber-security. Artificial intelligence has and will continue to develop at record speed with the possibility that calculations can be made close to where data is actually collected, rather than on a centralized cloud facility. Equipment such as sensors, visual systems, drones and autonomous vehicles will streamline and professionalize production processes. This is weighed against the fact that existing industry has an equipment park with a long lifespan that cannot easily be controlled by new digital tools without significant investments. There are also great opportunities in market solutions and customer follow-up as value-creating solutions for companies.

Companies must be aware of where in the company's systems various digitalisation initiatives are being implemented. The effect of the projects must benefit competitiveness and cannot be based on "nice to have". Digital training of current employees will need to be increased and companies must be able to accept new employees with significant digital user understanding. The EU's Industry 5.0 points out, among other things, the need to put employees at the centre of development.

The JRC's report to the European Commission *A Europe fit for the digital age* focuses on strengthening one's own digital sovereignty through the use of data, technology and infrastructure. The risk of becoming too dependent on technological development in other regions must lead to development in cooperation between EU countries. The focus is on *Twin Transition*, which equates the need to manage sustainable transition with the use of digital solutions*- the green and digital transitions.*

The Government, through the newly established Ministry of Digitalisation and Public Administration, has announced the completion of its own digitalisation strategy in 2024 with the goal of stronger coordination and development of a comprehensive policy across the public and private sectors. The AI billion was allocated in September 2023 and the funds have mainly been allocated to the Research Council, which in 2024 is announcing up to NOK 850 million to four to six AI centres in the range of NOK 75– 200 million.

The industry in Norway has a good starting point for achieving competitive advantages through the use of digitalisation:

- High level of competence and in-depth knowledge of the basic mechanisms of the production processes at all levels of the organizations, from operator to senior management level.
- Close cooperation between the industry and the university and institute sector.
- A culture of collaboration and sharing of information.
- Compared with many other countries, a combination of high expertise and a high wage level means that there is great motivation to use new technology to maintain competitiveness.

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- A high degree of trust between and willingness to change among the social partners.

In light of this, the steering group for Prosess21 has decided to continue its work on digitalisation by establishing an expert group to evaluate how digitalisation can contribute to increased value creation in the Norwegian process industry.

Impact goals for the expert group inside digitalization

The expert group's report will be an aid for the Norwegian state and the individual process industry companies' managers and employees in their goals and work to facilitate value creation in Norway in the form of improved financial results, reduced greenhouse gas emissions and improved HSE results (health, safety and the environment, in addition to climate).

The overall effect goal is for the Norwegian process industry to take a leading position globally in realizing the potential for increased value creation from digitalization. It is also expected that digitalisation will contribute to more resource-efficient production and reduced greenhouse gas emissions. The most important contributions to reducing greenhouse gas emissions will be:

- New products and services that will be prerequisites for the low-emission society of the future.
- Reduced consumption of input factors in production as a result of increased dividends, with a positive contribution to the consumption of raw materials and energy.
- Increased production in existing production facilities so that the need to build new plants is reduced.
- Efficient logistics.

In addition to value creation in the process industry, value creation should take place in the associated supplier industry, the university and institute sector and in society at large.

The expert group's performance goals and scope of work

The expert group will describe and assess the prerequisites for and measures required for digitalisation to contribute to increased value creation and reduced emissions from the process industry. The expert group's performance targets will largely be the same as from the previous mandate, with a focus on:

- Common understanding of the current situation of digitalization in the process industry, both from a global perspective and in the Norwegian process industry companies (including a focus on highlighting proven, positive success stories that can be shared and learned from)
- Mapping of relevant professional communities that can contribute to the digitalisation of the Norwegian process industry.
- A compilation of the current situation, future plans and challenges regarding the introduction of digitalization for a representative sample of the process industry companies in Norway, as well as an understanding of whether it is enough to meet the ambitions Norway has
- Description of a high but pragmatic level of ambition for digital change in the Norwegian process industry (jobs, greenhouse gas emissions, global competitive position, profitability, safety and health)
- Evaluate the risks associated with increased digitalization in the process industry.
- Evaluate and describe the need for digitalization in the process industry: from the country in general (expertise, institutions and institutes, regulation) and from industry (process research, product development, industry groups)

• Prepare clear recommendations related to digitalisation of the process industry in Norway The expert group will provide clear recommendations as requested in the mandate with digitalisation as a starting point by:

- Update and strengthen the knowledge base from the first phase of Prosess21
- Contribute with a knowledge base, input and advice in connection with the follow-up of the Green Industry Initiative, the climate partnership with the process industry and other relevant processes.
- Prosess21 will work with, and highlight, strategically key topics such as circular economy and digitalization. The expert group should therefore assess national framework conditions and policy instruments inside digitalisation and assess the attractiveness of Norway as a host country, compared with conditions in other regions, with an increased focus on the EU.
- Prosess21 will contribute to good priorities on the part of the authorities, within a limited room for manoeuvre in the national budgets in the future. Any proposals must be investigated, including advantages and disadvantages for affected actors and consequences related to power and land use.

Deliveries from the expert group

The main task of Prosess21 is to provide strategic advice and recommendations on how Norway can best achieve a development towards minimal emissions from the process industry in 2050, and at the same time facilitate sustainable transition, growth and value creation.

The deliverables from the expert group inside digitalisation will provide strategic advice and recommendations within their own area of responsibility. The expert group's deliverables will be included as one piece of the decision-making basis for Prosess21 and the strategic advice and recommendations that will be given.

The deliveries consist of:

1. Study/report describing the potential for increased value creation and reduced emissions from the process industry in Norway through facilitated use of digitalization.
2. Presentation in PowerPoint format with strategic advice and recommendations.
3. Any op-ed in the media and other forms of communication to external stakeholders

The members of the expert group contribute with quality assurance of the report from the study and the presentation in PowerPoint format before presentation to the steering group in Prosess21 and to the client (NFD and KLD). The export group should also consider other platforms where the work can be presented by the expert group's members.

Working method, time perspective and resource needs

The expert group is responsible for recommendations, advice and analyses. The work is carried out in collaboration between the members of the expert group and the expert group's secretariat. The Digipro Centre has been chosen to be the secretariat of the expert group by the Centre's leader.

The work should be organised through meetings and workshops to ensure broad support in industry and research environments. In the initial phase of the work, the expert group must familiarise itself with the mandate (purpose, working method and deliverables), consider inviting further participation and input from experts inside digitalisation. The need for an input meeting should be considered, where the members of the expert group provide information about relevant activities in their own company and share other information that may be relevant to the work. At this meeting, the final mandate for the work of the expert group with associated plans will also be decided.

At the conclusion of the work, an evaluation meeting should be held, where the experts provide feedback on the preliminary deliverables from the work and the final meeting, for approval of the final report and presentation.

Digipro is also free to organize the work as they see fit.

It is agreed that the expert group will submit "trail reports" in the work of the steering group meetings in Prosess2 throughout the autumn of 2024.

It will be desirable to have the expert group's work completed inside the end of 2024. The expert group should itself consider an appropriate time to communicate the content of the work after the presentation to the steering group in Prosess21.

Communication plan

A communication plan for the deliveries from the expert group will be prepared in collaboration with the secretary of Prosess21.