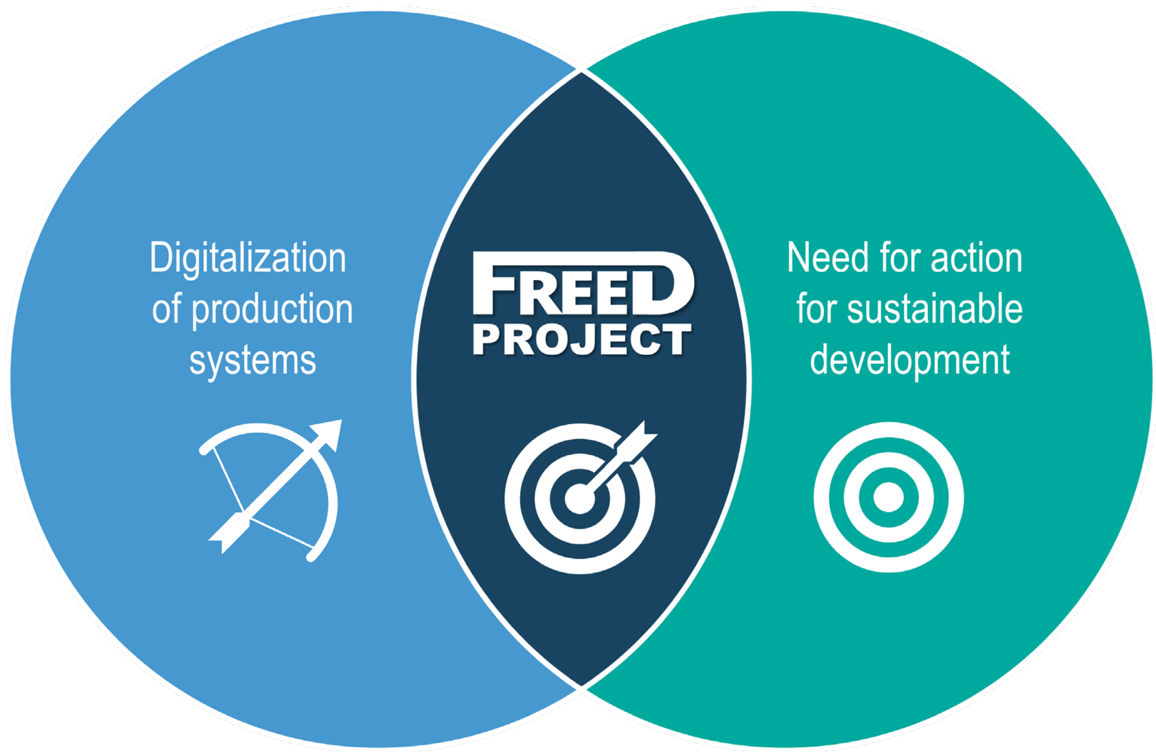
# Factory Resource and Energy Efficiency through Digitalization (FREED)

**Preliminary project report**




Develop a practical toolkit to support **data-driven decisions** for more **environmentally sustainable** production systems

Project within Sustainable Production - FFI
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FFI Fordonsstrategisk Forskning och Innovation
VINNOVA Energimyndigheten TRAFIKVERKET FKG VOLVO SCANIA VOLVO

# Content



FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which about €40 is governmental funding.

Currently there are five collaboration programs: Electronics, Software and Communication, Energy and Environment, Traffic Safety and Automated Vehicles, Sustainable Production, Efficient and Connected Transport systems.

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# 1. Summary

Sustainable industrial digitalization is fast-growing research area but still in its infancy. Despite the positive outlook of digital technologies in manufacturing, they also present the risk of accelerating our linear economy with faster and more efficient production of goods and services, thereby further trespassing planetary boundaries already exceeded. It is critical to align the goals of sustainable development and industrial development so they reinforce each other. The FREED pre-study focuses on data-informed environmental improvements in manufacturing.

In response to the need for sustainable action, this pre-study is composed to two activities:

**WP1. State-of-the-art review:** Investigate how digitalization can enhance the environmental sustainability of production systems by reviewing empirical studies demonstrating a broad range of environmental solutions for more sustainable manufacturing. Identify industrial challenges and propose ways in which digitalization should support sustainable production to overcome these challenges. Use published industrial cases of sustainable digitalization to create a good practice typology to organise information around data-informed environmental improvements and support learning/dissemination of good practices. Collect and analyse examples at the partners' manufacturing sites to check alignment with current knowledge sharing practices.

**WP2. Maturity assessments:** Develop an assessment model to evaluate the maturity of current environmental approaches and supporting data management systems in manufacturing companies. Identify areas of strengths on which promising sustainability initiatives can be built, as well as potential areas of improvements which should be prioritised to achieve significant environmental benefits. Create pilot specifications to test data-informed approaches for environmental assessment, reporting and improvement (integrate environmental information in performance management via robust data management system).

Ultimately, the project aims to ease the process for collecting, analysing and communicating environmental information so more focus can be placed on systematically integrating this information in decision-making processes and continuous improvement activities.

## 2. Background

With growing environmental pressures and incentivized by international treaties like the Paris Agreement and the European Green Deal, many companies are setting ambitious targets to meet sustainability goals, such as becoming climate neutral by 2050. This is evident with the uptake of the UN Sustainable Development Goals in many companies' strategies and annual reporting. However, there is an enduring consensus that industry is still operating in a largely linear and unsustainable manner. Leaders and decision makers need to address environmental issues more systematically using the knowledge and science-based information available.

Sustainable manufacturing as a research topic and set of industrial practices has progressively developed over the last half-century (Sarkis and Zhu 2018). Numerous tools and methods have been developed to support more ethical and responsible production (e.g. Finnveden and Moberg 2005; Kristensen and Mosgaard 2020). Furthermore, digital technologies are changing the way companies capture value in ever-more complex and connected systems, creating new opportunities for sustainable production (Kiel et al. 2017).

On the one hand, sustainable manufacturing increasingly relies on these technological advances (Núñez-Merino et al. 2020; Ren et al. 2019). On the other hand, digitalization does not automatically align with sustainability (Machado et al. 2020; Strozzi et al. 2017). The trends in manufacturing research focusing on sustainability are encouraging not keeping up with the technological developments under the broad umbrella of Industry 4.0 (Figure 1).

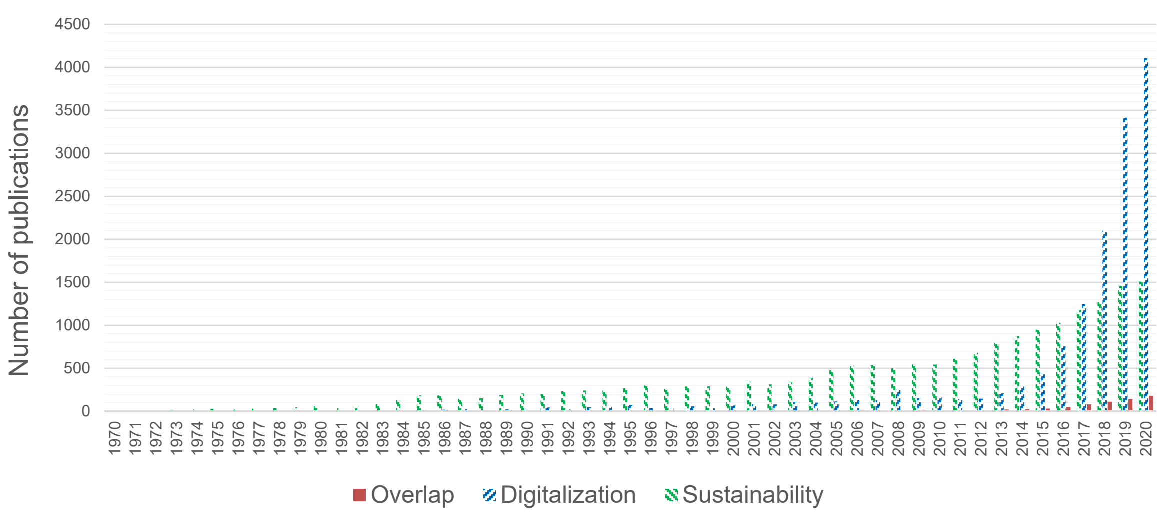


Figure 1. Growth of the academic literature on sustainable and digitalized manufacturing.

Bar chart visualizing Scopus search results for the following queries limited to Engineering subject area:

- Sustainability = (sustainab* OR environment*) W/1 (manufacturing OR production);
- Digitalization = ((smart OR intelligent OR digital*) W/1 (manufacturing OR production)) OR "industr* 4.0"

# 3. Purpose, research questions and method

Sustainable industrial digitalization is fast-growing research area but still in its infancy. Despite the positive outlook of digital technologies in manufacturing, they also present the risk of accelerating our linear economy with faster and more efficient production of goods and services, thereby further trespassing planetary boundaries already exceeded during the previous industrial revolutions (Desing et al. 2020). It is critical to align the goals of *sustainable development* and *industrial development* so they reinforce each other (rather than compete or conflict with one another). In other words, the adoption of digital technologies should support more sustainable industrial performance, and sustainability challenges should act as a driver for innovation and technological advances.

The purpose of this pre-study is to investigate how digitalization is currently being used to enhance the environmental sustainability of manufacturing systems. Accordingly, the research questions (RQ) are:

RQ1. What are the existing environmental solutions available to manufacturing companies and what are the implementation challenges encountered?
RQ2. How can digitalization support the systematic implementation of these solutions?

The project activities were organised in two work packages using the following methods:

**WP1. State-of-the-art review**

- Review empirical studies demonstrating a broad range of environmental solutions for more sustainable manufacturing (practices, measures, tools and methods used to assess, manage and improve the environmental performance of manufacturing systems).
- Gain insights into the *industrial challenges* encountered when implementing environmental solutions.
- Propose ways in which *digitalization should support sustainable production* to overcome these challenges.
- Identify research trends (and gaps) to define *research themes* for further work within the production engineering and management community.
- Use published industrial cases of sustainable digitalization to create a *good practice typology* to organise information for data-informed environmental improvements and support learning/dissemination of good practices.
- Collect and analyse examples at the partners' manufacturing sites to check alignment with current knowledge sharing practices.

**WP2. Maturity assessments**

- Develop an *assessment model to evaluate the maturity* of current environmental approaches and supporting data management systems in manufacturing companies.

- Identify *areas of strengths* on which promising sustainability initiatives can be built, as well as *potential areas of improvements* which should be prioritised to achieve significant environmental benefits.
- Create *pilot specifications* to test data-informed approaches for environmental assessment, reporting and improvement (integrate environmental information in performance management via robust data management system).

# 4. Preliminary results and deliverables

## 4.1 Literature review

**Summary of literature findings [journal submission on 20-Jul-2021]**

By analysing published literature on Industry 4.0 and sustainable manufacturing, a clear trend in digitalization was observed (see Figure 1 in Background section). While many researchers herald a positive future for Industry 4.0 to support more sustainable manufacturing systems, there are few published empirical studies. In addition, several challenges were identified in empirical studies demonstrating environmental solutions applied to manufacturing.

The most common methods to assess the environmental impacts of manufacturing activities are direct performance indicators (local impacts) and life cycle assessment (systemic/global impacts). Most of the life cycle studies reviewed were gate-to-gate analyses, excluding either upstream (material extraction and processing) or downstream activities (use and end-of-life phases). These studies recognised the need for a better coverage of the up- and downstream impacts to avoid unintended consequences and rebound effects. But such holistic solutions are currently limited due to data availability, data quality, skills and efforts requirements, and other methodological issues.

At a strategic level, sustainability decision making can be subjective. While various decision support methods exist (scenarios/prospective assessments, stakeholders' involvement and qualitative analysis), they can be difficult and time-consuming to use, thus hindering the abilities of companies to response quickly to sudden changes. Some studies also reported low motivation to invest time, efforts and resources in using environmental methods due to the absence of direct financial gains. Easy-to-use and reliable tools are needed to increase organizational resilience and the robustness of decision-making processes accounting for indirect and long-term economic, social and environmental impacts, and potential trade-offs between these different aspects.

Established operations management systems (e.g. Lean and Six Sigma) are preconditions for robust and effective environmental management systems. However, there can be conflicts between lean and green, productivity gains and sustainability, etc. Thus, Lean and other productivity methods need to be adjusted (e.g. include explicit environmental performance indicators) to ensure that they actually deliver sustainability benefits. Similarly, digital technologies and data-driven solutions can support sustainability improvements, but they must be carefully developed to do so as sustainability and digitalization do not always align automatically.

Regarding the role of production systems in CE, the literature does not cover the topic well with most of the research focused on linear, forward manufacturing systems. Closing loop through waste and end-of-life product recovery is critical. Circular scenarios should be explored to support companies in developing strategies for superior value delivery through servitization, dematerialisation, product durability and life extension, remanufacturing, recycling, etc.

To overcome the limitations and challenges identified, eight propositions (Figure 2) are made to guide the implementation of digitalization in line with the need for better approaches supporting environmentally sustainable manufacturing.

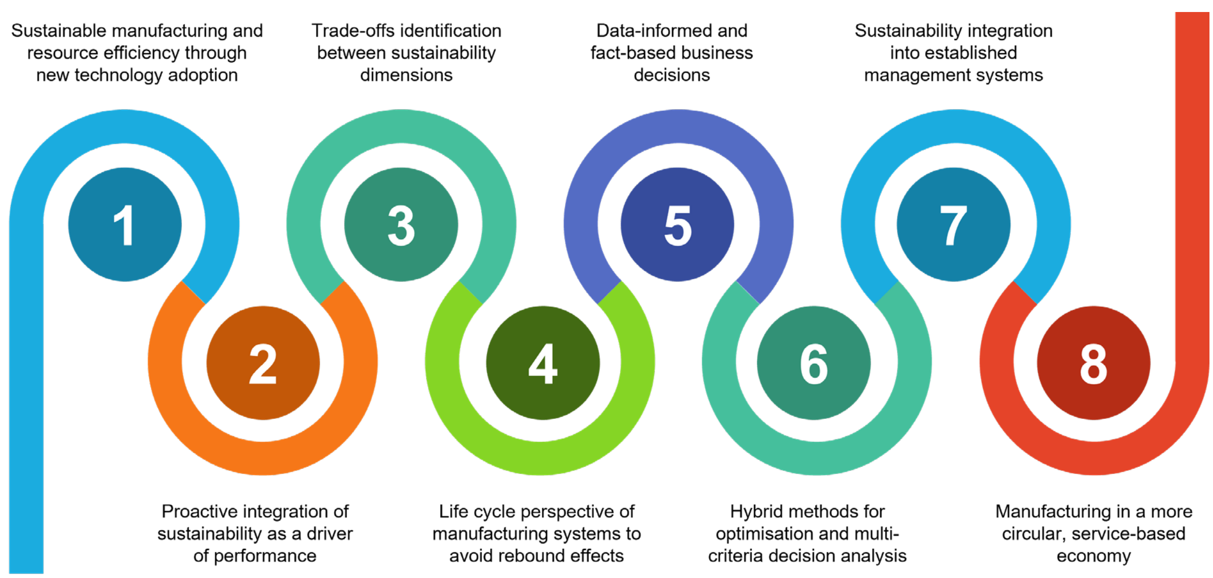


Figure 2. Eight propositions about how digitalization can support sustainable manufacturing.

## 4.2 Good practice typology

As identified in the literature review, there are few real-world applications demonstrating how digitalization enhanced the sustainability of manufacturing systems. To support the more systematic use of digital solutions and the data available, we proposed a typology to document and share best/good practices for data-informed environmental improvements in manufacturing.

The **good practice typology** aims to identify what information is needed to document and share data-informed environmental improvements with the purpose to disseminate and replicate success stories (as opposed to pure reporting purpose). The typology is composed to three **types of improvement** and information related to **means of improvement**.

**Types of improvement** in three areas:

- Process design
- Production planning
- Process controls

**Means of improvement** split into three groups of factors:

- Operational factors – data needed
    - Physical resources – material, energy, water, chemicals, etc. (inputs, outputs)
    - Manufacturing process – description of the process
    - Infrastructure – supporting systems (IT, buildings, ….)
    - Performance indicators – metrics and targets
    - Methods – e.g. standard, Lean tool, etc.
- Organizational factors – who will be involved and what skills are required
    - Roles & responsibilities – access and ownership of the data and information; authority in making decision; control in taking action
    - Skills/competencies
- Other factors: Frequency – how often does the best practice require an action

## 4.3 Maturity assessment model

Combining prior work on sustainability maturity models and ongoing research on data-driven solutions, a maturity model and assessment process (Figure 3) are proposed.

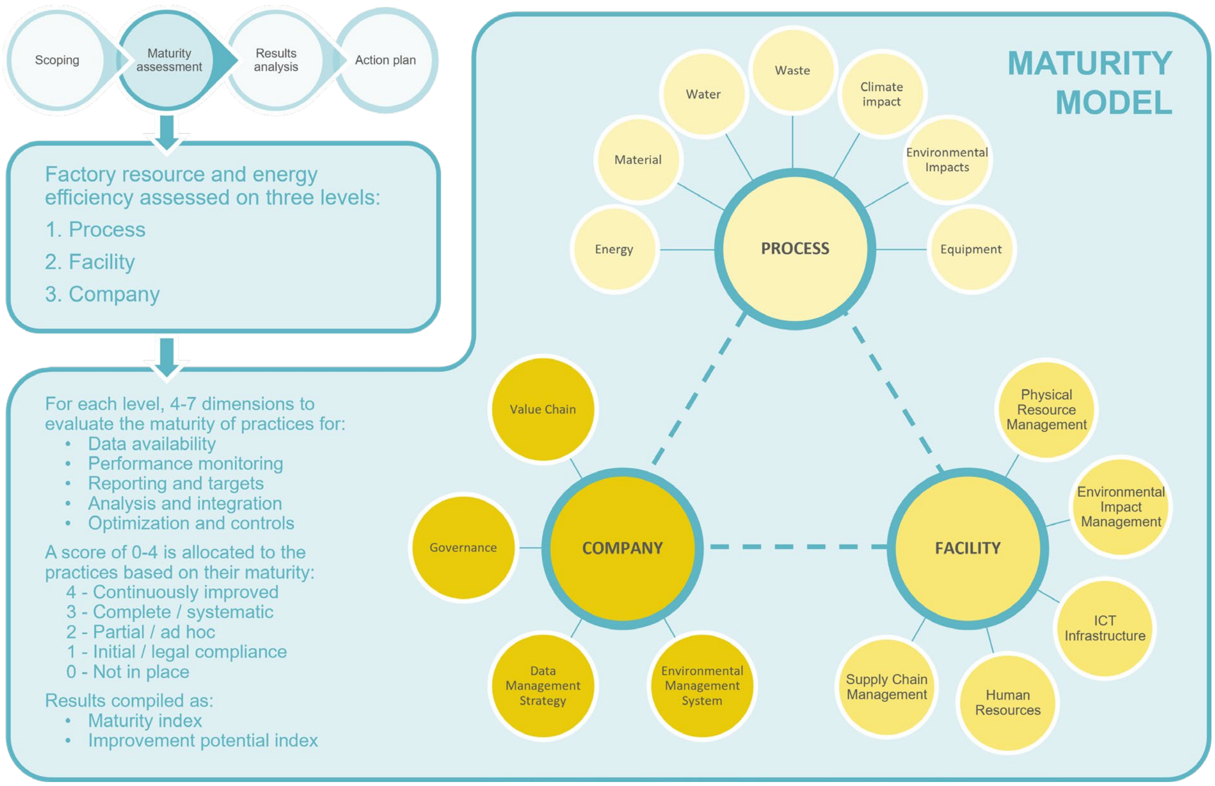


Figure 3. Maturity model and assessment process.

The maturity assessment at COMPANY level captures strategic aspects of environmental sustainability. The FACILITY level focuses on the infrastructure and management systems for a manufacturing site. Finally, the PROCESS level focuses on operational issues around resource efficiency and the related information for data-supported improvements.

The results of the assessment can be used as a basis to define new projects for environmental performance improvement, for example:

- Focus on low maturity areas to elevate performance to a minimum level;
- Focus on high maturity areas to push performance further (environmental leadership);
- Combine areas with different maturity scores to close the gap between low and high performing areas and enable intra-company learning.

The maturity assessment process overall is designed to support continuous improvement activities by identify areas of strength to build upon and priority areas where large opportunities exist for superior environmental performance.

# 5. Dissemination and publications

## 5.1 Dissemination

| How are the project results planned to be used and disseminated? | Mark with X | Comment |
|---|---|---|
| Increase knowledge in the field | X | Focus on knowledge to develop robust data management systems supporting environmental performance improvements |
| Be passed on to other advanced technological development projects | | |
| Be passed on to product development projects | | |
| Introduced on the market | | |
| Used in investigations / regulatory / licensing / political decisions | | |

## 5.2 Publications


Despeisse, M., Chari, A., González Chávez, C. A., Monteiro, H., Machado, C. G., Johansson, B. (2021). Enabling sustainable manufacturing through digitalization: a systematic review of empirical studies and a research framework. *[submitted 20-July-2021]*

Syu, F. S., Vasudevan, A., Gonçalves, M. M., Estrela, M. A., Chari, A., Turanoglu Bekar, E., & Despeisse, M. (2021). Usability and Usefulness of Circularity Indicators for Manufacturing Performance Management. *[submitted 15-September-2021 to the CIRP conference on Life Cycle Engineering, LCE2022]*

# 6. Participating parties and contact persons

| | | |
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| Autoliv Saving More Lives | Autoliv Development AB | Cecilia Sunnevång, Vice President Research |

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Strozzi, F., C. Colicchia, A. Creazza, and C. Noè. 2017. "Literature Review on the 'Smart Factory' Concept Using Bibliometric Tools." International Journal of Production Research 55 (22). https://doi.org/10.1080/00207543.2017.1326643.