SUSTAINABILITY AND CIRCULAR ECONOMY ACTIONS WITHIN THE PROJECT PORTFOLIO OF THE PRODUKTION2030 STRATEGIC INNOVATION PROGRAMME

Sustainability in Produktion2030

ARPITA CHARI
EMMA LINDAHL
ERIK SUNDIN
BJÖRN JOHANSSON
JOHAN STAHRE
JOHAN VOGT DUBERG
PATRIK WILLIAM-OLSSON
MAGNUS WIKTORSSON
CECILIA WARROL

PRODUKTION2030

Executive Summary

Global manufacturing industry is undergoing tremendous transformation towards increased sustainability. This vital, industrial sector is rapidly enhancing its capability for resource efficient, circular, and climate neutral processes and business models. Industry is also rapidly recognizing sustainability and resilience measures as competitive advantages and unique selling points. Companies are being both nudged and forced into sustainable, resource-efficient businesses to comply with new demands and regulations from for example the European Commission's Green Deal and global policy like the United Nations' Sustainable Development Goals (SDGs).

Customer needs as well as government policies and regulations are enforced through e.g. economic bonus and penalty systems, accelerating transformation. This change process is complex, requiring new knowledge and innovation. Therefore, Industrial sustainability is at the core of Produktion2030, the national Swedish Strategic Innovation Programme for manufacturing industry.

The vision of Produktion2030 is to enable a competitive and sustainable Swedish manufacturing industry. Produktion2030 is putting strong efforts into acceleration of the green transformation, creating crossdisciplinary and multi-stakeholder collaboration, increasing national innovation capacity and agility, and driving competence development as well as workforce upskilling. In 2020, the Produktion2030 Programme Office and Supervisory Group commissioned a study to map sustainability achievements within the programme's total product portfolio.

A national group of sustainability experts from Chalmers University of Technology, Linköping University, Royal Institute of Technology, and the institute RISE were invited to analyse all past and present Produktion2030 projects, from sustainability and circular economy perspectives.

This report presents the results from the study, highlighting a selection of contributions to industrial sustainability achieved by Produktion2030 during the programme's first six years. Data for the study was gathered during the spring of 2020. Representatives from all ongoing and finalised projects within the Produktion2030 programme were invited to an online survey. The objective was to investigate specific project impacts in terms of sustainability and implementation of a circular economy.

Results showed that all Produktion2030 projects had applied at least one dimension of sustainability, economic. Further, 71% of the projects also covered the environmental dimension. Several projects applied sustainability trade-offs, where an improvement within one sustainability dimension affected other dimensions negatively. The UN Sustainable Development Goals #8, #9 and #12, were considered most relevant by the projects. Implementation or inclusion of circular economy was also common (45%) among the projects. Projects adapted circular economy concepts differently, according to their self-defined project scope and system boundaries. Finally, 65 % of the projects implemented Industry 4.0 concepts and digital solutions, to increase and accelerate the sustainability impact. In conclusion, the study of sustainability efforts within the complete portfolio of Produktion2030 projects by 2020 showed that the programme is strongly contributing to the transformation of manufacturing industry in Sweden towards sustainability.

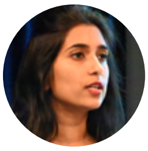
Produktion2030 has a deep, strategic commitment to address the challenges of the UN Sustainable Development Goals. This study shows that Produktion2030 also has an excellent transformational capability to deliver research, innovation, and education results that influences sustainability factors. The results strongly support the manufacturing community in Sweden, allowing industry, academia, and institutes to act towards a more sustainable, resilient, and circular society.

GLOSSARY OF TERMS

AHP	– Analytical Hierarchy Process
AI	– Artificial Intelligence
AR	– Augmented Reality
CAD	– Computer Aided Design
CE	– Circular Economy
CPS	– Cyber-Physical Systems
FEM	– Finite Element Method
GRI	– Global Reporting Initiative
I4.0	– Industry 4.0
IoT	– Internet of Things
KPI	– Key Performance Indicator
LCA	– Life-Cycle Assessment
LCC	– Life-Cycle Costing
ML	– Machine Learning
OEE	– Overall Equipment Efficiency
PdM	– Predictive Maintenance
PLM	– Product Lifecycle Management
PSS	– Product-Service System
RPA	– Rapid Plant Assessment
SAVE	– Sustainability Assessment and Value Evaluation
SDG	– Sustainable Development Goals
SI	– Sustainability Index
SME	– Small and Medium-sized Enterprise
SVSM	– Sustainable Value-Stream Mapping
TBL	– Triple Bottom Line
UN	– United Nations
UNSDG	– United Nations Sustainable Development Goals
VSM	– Value-Stream Mapping

AUTHORS

Björn Johansson
Professor
Chalmers University of Technology
bjorn.johansson@chalmers.se



Arpita Chari
PhD Student
Chalmers University of Technology
arpitac@chalmers.se

Johan Vogt Duberg
Research Assistant
Linköping University
johan.vogt.duberg@liu.se

Emma Lindahl, PhD Student
Royal Institute of Technology
emlindah@kth.se

Patrik William-Olsson
Senior Researcher, RISE
patrik.william-olsson@ri.se

Erik Sundin
Professor
Linköping University
erik.sundin@liu.se

Magnus Wiktorsson
Professor
Royal Institute of Technology
magwik@kth.se

Johan Stahre
Professor, Programme Co-Director Produktion2030
Chalmers University of Technology
johan.stahre@produktion2030.se

Cecilia Warrol
Programme Director Produktion2030
Teknikföretagen
cecilia.warrol@produktion2030.se

TABLE OF CONTENTS

FOREWORD

Perhaps the most crucial challenges faced by humanity right now is how to cope with climate change. Science is very clear, we all need to change radically into a more climate-friendly behaviour very quickly.

The rapidly growing industry has been one of the major causes of climate effects. Paradoxically, industry also holds major tools for change towards long-term sustainability. The quicker we can adjust industrial processes and the way we make food, things, energy etc., the quicker we can do something about the climate threats. Manufacturing industry operates at the core of production and consumption. Therefore it has strong leveraging factor on the impact of sustainability actions. Sustainability also has two other important dimensions, social and economic sustainability, which should be addressed together with climate impact.

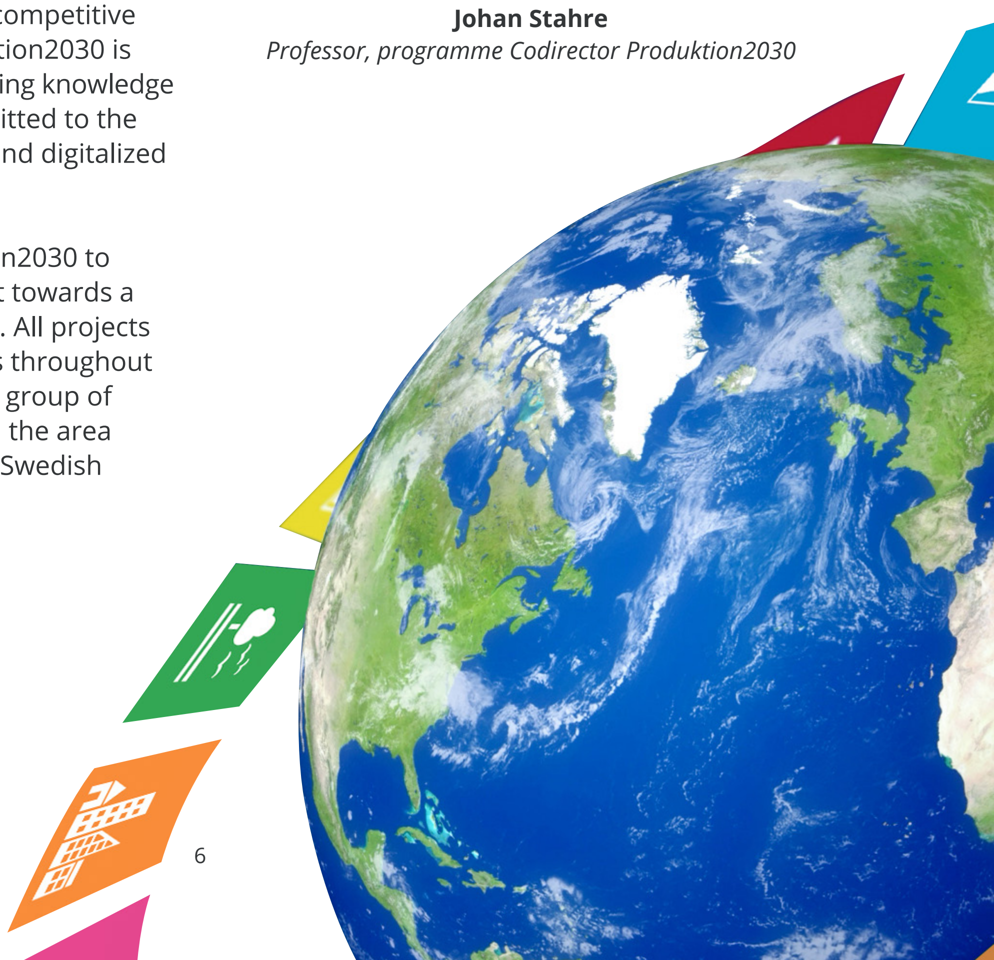
The Swedish Strategic Innovation Programme Produktion2030 is a Government-funded, national effort towards sustainable and competitive manu- facturing in Sweden. Produktion2030 is providing industry with new, leveraging knowledge and tools. The programme is committed to the ongoing dual transition to a green and digitalized manufacturing industry in Sweden.

This report is an effort by Produktion2030 to evaluate the effort and engagement towards a sustainable manufacturing industry. All projects funded by Produktion2030 partners throughout its lifetime have been analysed by a group of internationally renowned experts in the area of sustainable production, active at Swedish universities and institutes.

We are delighted by the results, showing a deep sustainability involvement among the partners and within the projects. The results show that Produktion2030's projects are well-positioned with respect to sustainability and it shows that Sweden is heading in the right direction. The report is an important indication that Strategic Innovation Programmes such as Produktion2030 are well equipped to handle complex challenges such as sustainability. It also shows that the Swedish research and innovation community is committed and able to address sustainability questions, and to translate knowledge into impact in industry. On behalf of the Produktion2030 Steering Group and Management team we are grateful to the project managers and the evaluation experts for making this report possible.

August, 2021
Cecilia Warrol
Programme Director Produktion2030

Johan Stahre
Professor, programme Codirector Produktion2030



1 Introduction

Achieving sustainability and long-term resilience against climate threats is undoubtedly one of the most important challenges for the 21st century society. Without major efforts to reduce harmful human impact on global ecological systems, society will not reach the temperature reduction goals suggested by e.g. the IPCC[1]. We will likely face rapidly increasing threats to our society and infrastructure in just a few decades.

Major efforts are ongoing, e.g., the United Nations' Sustainable Development Goals (SDGs)[2]. The European New Green Deal aims at reaching climate neutrality in 2050[3]. The EU Commission is also promoting the Industry 5.0[4] concept, focusing on Sustainability, Resilience, and Human-centredness. Regional climate initiatives are being launched across the globe. The Swedish Government has committed to Agenda 2030, the Paris Agreement and to high climate ambitions. The Swedish intentions are mirrored in initiatives by Swedish Government agencies like Vinnova, the Swedish Innovation Agency, as well as the Swedish Energy Agency. Special climate resilience efforts are provided by Sweden's seventeen strategic innovation programmes.

From a national Swedish perspective, Produktion2030[5], the national strategic innovation programme for the manufacturing industry, has the main role to catalyse innovation and applied research in Swedish industry. The programme vision is a competitive and sustainable industry, enabled by massive digitalisation for future production in Sweden. Produktion2030 focuses on six industrial challenge areas. If Swedish manufacturing companies can sustain high competitiveness within the following six areas, without demoting sustainability, industry can sustain its status as a strong industrial nation with extensive export and high standards of living:

1. Resource-efficient production
2. Flexible production
3. Virtual production development
4. Humans in the production system
5. Circular production systems and maintenance
6. Integrated product and production development

The Produktion2030 programme has been in operation since 2013 and was successfully evaluated in 2019. The programme is planned to continue until 2025. Sustainability and competitiveness was part of Produktion2030's original vision and increasing sustainability impact is expected from the programme. At half-time in the programme time-line the programme office and the Produktion2030 Supervisory Group decided that sustainability outcome and impact of the programme should be assessed, including aspects of circular economy. Sustainability should include economic, environmental, and social aspects. Circular Economy (CE) is covered by the larger umbrella of sustainability, with the aim of extending the value of products and operations in a product's life cycle. This report presents the results from an online survey in 2020 targeting all projects in the Produktion2030 to assess each projects' sustainability and circular economy implementation. This study is the result of a project financed by the Produktion2030 programmed. It was performed as a collaborative project between Chalmers University of Technology, Linköping University, Royal Institute of Technology, and RISE research institute.

1 The Intergovernmental Panel on Climate Change (IPCC) – https://www.ipcc.ch/
2 https://sdgs.un.org/goals
3 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu_en
4 https://ec.europa.eu/info/research-and-innovation/research-area/industrial-research-and-innovation/industry-50_en
5 Produktion2030 – National Swedish Innovation Programme for Manufacturing https://produktion2030.se/

2 Objectives

The objective of this study is to map projects within Produktion2030 in relation to their respective handling, methods of coping with, or contribution to Sustainability and Circular Economy impact in industry and society. The project aims to collect and analyse developments from all Produktion2030 projects. The results provide a databased assessment of how the research and innovation programme Produktion2030 has contributed to sustainability; its present position in this context, and a prediction about future needs for the programme to cope with emerging climate legislation expected within just a few years.

3 Methodology

3.1 SURVEY DEVELOPMENT

To review Produktion2030's project portfolio from a sustainability perspective, an online questionnaire was developed, based on the Google Forms platform. The questionnaire consisted of a total of 14 questions with multiple questions broken into sub-questions. The full list of questions are in Appendix A of this report.

Within the Produktion2030 research programme, a similar investigation on the topics Artificial Intelligence (AI) and Machine Learning (ML) was conducted during 2019. Experiences from that investigation was used for planning and performing the study on sustainability.

The project group involved a number of nationally leading experts in the field of Manufacturing sustainability. Survey questions were based on literature and academic expertise in sustainability and manufacturing to ensure that all objectives of the project were covered.

Before sending the questionnaire to all respondents, it was usability-tested with six sample projects. Their projectmanagers were asked to share their perception of the questionnaire in terms of clarity, relevance, and how well the questions captured the sustainability impact from the projects. The feedback received was used to further develop and finalise the questionnaire.

The questionnaire was then sent to the managers of the projects, whose details are publicly available on Produktion2030's website. The project managers were given an option to forward the questionnaire to other participants within the project with had sufficient knowledge to answer the questionnaire. The project managers could also answer the questionnaire via a videoconference call. After 2 weeks, the first reminders were sent out followed by a second reminder one month later.

4 Results and Discussion

4.1 RESPONSE EVALUATION

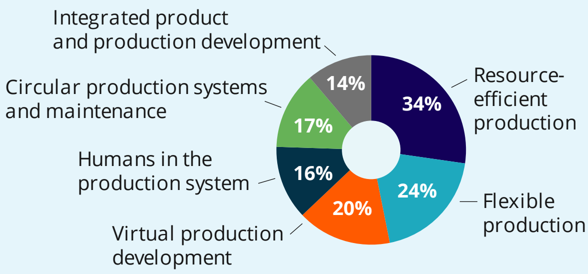
The questionnaire was sent to 113 Produktion2030 projects, both ongoing and finalised. Of these, seven project managers could not be reached due to outdated contact details, making the available number of projects to 106. In total, 78 responses were received. This corresponds to a response rate of 74% of the available number of respondents. The response rate of the questionnaire is presented in Table 1. The list of projects that responded to the questionnaire is presented in Appendix B.

TABLE 1
Trend of questionnaire responses. Frequencies correspond to the percentage of total number of responses (78). The response rate corresponds to the percentage of the total number of available respondents (106).

Question	Responses	Frequency	Response rate
1	78	100%	74%
2	78	100%	74%
3.1	78	100%	74%
3.2	2	3%	2%
3.3	45	58%	42%
4	76	97%	72%
5	8	100%	74%
5.1	64	82%	60%
6.1	65	83%	61%
7	76	97%	72%
8	78	100%	74%
8.1	48	62%	45%
8.2	78	100%	74%
9	53	68%	50%
9.1	23	29%	22%
9.2	52	67%	49%
10	62	79%	58%
11	59	76%	56%
12	76	97%	72%
12.1	51	65%	48%
13	57	73%	54%
14	75	96%	71%

The projects had varying timelines, budgets, and areas of strength. The start date of the projects was between 2013 and 2020 with an earliest end date of 2016. Furthermore, the majority of the projects had a planned end date of 2020 or earlier with a planned duration of the projects was between one and four years. **Figure 1** represents the distribution of the areas of strengths among the different projects. The total percentage in the figure sums to more than 100, indicating that more than one area was possible per project.

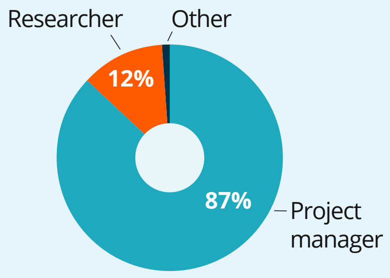
FIGURE 1
Distribution of the areas of strengths among the Produktion2030 projects. Percentages are based on the total number of projects with a specific challenge area.



For this data, 87% of the respondents were project managers and 12% were researchers, as depicted in **Figure 2**. Whether the project managers were also researchers or held another position in the project was not investigated. One of the respondents stated that they were not a researcher, but a colleague of the project manager.

The findings from the questionnaire are presented in the following sections. The first few sections showcase how the projects align with the Triple Bottom Line (TBL) of sustainability, the UN Sustainable Development Goals (UNSDGs) and the Circular Economy (CE). The following sections then describe how the projects measure and manage sustainability, what the immediate and long-term impact of the projects are on sustainability, and finally, the sustainability trade-offs within projects.

FIGURE 2
Respondents' roles in the questionnaire



4.2 SUSTAINABILITY WITHIN THE PROJECTS

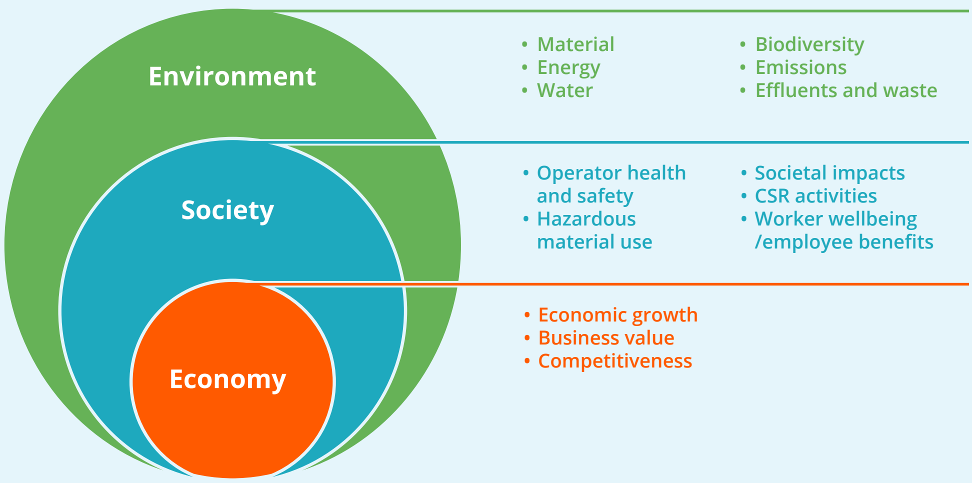
The term 'sustainability' in this project, was based on the definition of sustainable development by the Brundtland commission [1]:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

As part of this definition, sustainability is divided into three dimensions: environment, society, and economy. When all three dimensions are considered and fulfilled in a coherent manner, sustainability is achieved.

For the questionnaire, respondents could select which sustainability dimension was included in their project by selecting the sustainability aspects presented in **Figure 3.** Selecting an aspect such as Biodiversity, meant that a specific project had considered environmental sustainability. Projects could select multiple aspects, thus including several sustainability dimensions.

FIGURE 3
Classification of sustainability aspects into the three sustainability dimensions, environment, society and economy (adapted and recreated from Elkington [2])



All of the respondents (78) selected an aspect within the economic dimension, as depicted in **Figure 4**. For the other two dimensions, 55 (71%) respondents selected the environmental dimension and 47 (60%) selected the social dimension. These numbers show that the economic aspect is of high value for the projects, followed by environment and society.

A large majority (71) of the respondents selected two (40) or all three (31) sustainability dimensions. Every project that included more than one dimension in their project considered the economic dimension and combined it either with society or environment. The sustainability sub-dimensions that the respondents could select are presented in **Figure 5** together with the number of selections for each sub-dimension.

FIGURE 4
The number of respondents that selected each of the sustainability dimensions (environment, society and economy) and the number of respondents that selected each of the dimensions

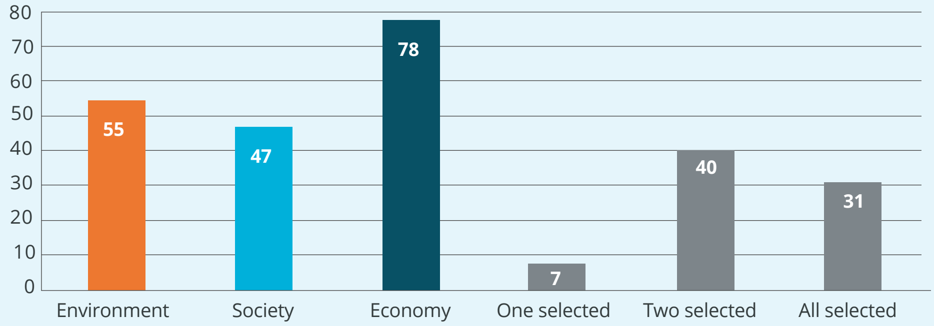


FIGURE 5
The number of respondents that selected the sustainability subdimensions

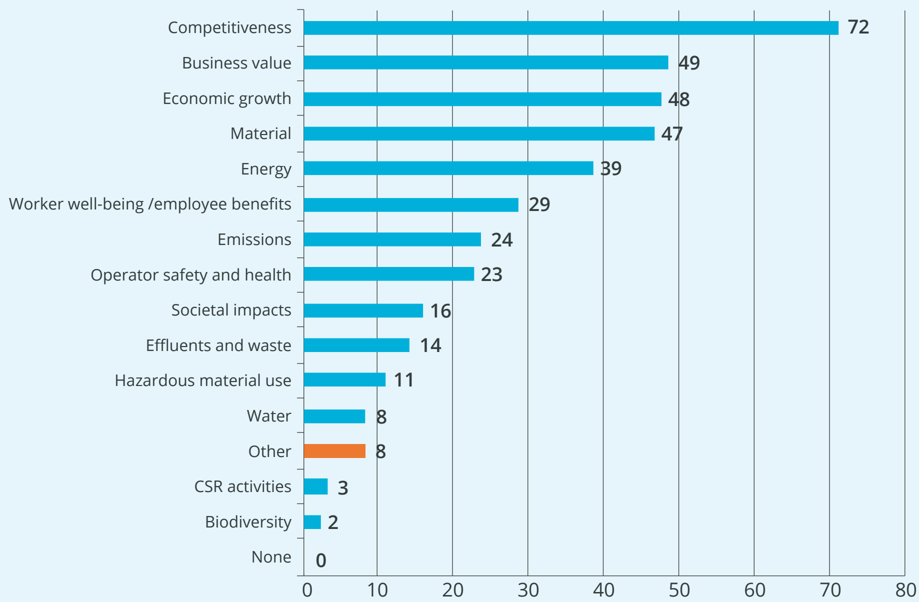
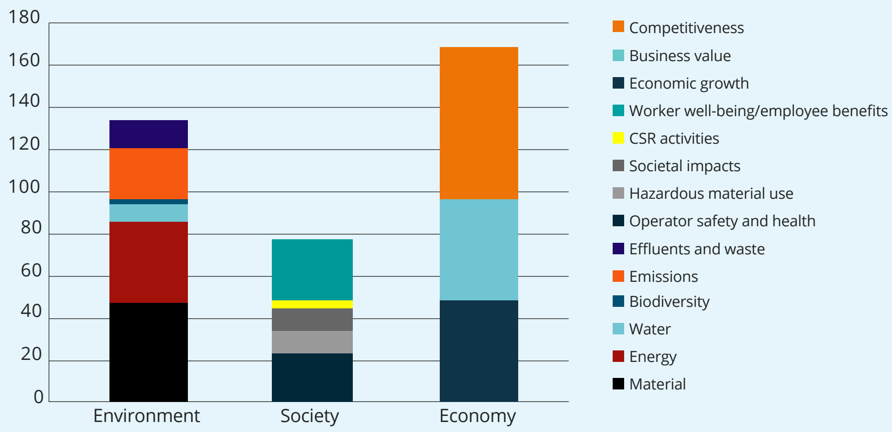


FIGURE 6
Aggregation of the selected sustainability aspects into the three sustainability dimensions environment, society and economy



In total, eight of the respondents selected the option Other and provided an additional answer. Six of these used the field to explain why these aspects were selected. For example, one respondent stated value logic and serviceability to be part of their project focus, they therefore chose societal impacts, economic growth, business value, and competitiveness as the sustainability targets of the project.

The remaining two respondents stated "Compliance to different environment, sustainability, and safety related regulations and standards" and "more sustainable modification and operation of production system", giving an indication of a sustainability project focus, however, in the latter it is not fully specified how.

4.2.1 Sustainability drivers

The respondents were given a multiple choice option and choose 'drivers' for including sustainability aspects within their projects. These are presented in **Table 2**. Seven selected the option Other and provided an additional answer to the question. Of these, one respondent described that one of the drivers was to reduce the amount of lead in their material which also leads to improved long-term competitiveness and this also complies with the new guidelines for environmental regulations and standards in Sweden. Another explained that the drivers were to improve worker health and performance. The remaining five described their drivers as: reducing the negative impact from production on the environment, for ecological/biological reasons, improved image of the company, exploit new opportunities based on interdisciplinary collaboration, and to achieve sustainability through resource efficiency of the forest.

TABLE 2
List of drivers to include sustainability within projects
(Note: More than one selection was possible by each project)

Drivers	Number of projects
Improve long-term competitiveness	72
Reduce costs	54
Improve environmental image of company or product	18
Meet new market or customer demands	33
Comply with environmental regulations and standards	16
Other	7

4.2.2 Sustainable development goals

The United Nations (UN) describes the Sustainable Development Goals (UNSDGs) [3] as follows:

> *"The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests."*

The SDGs are used as a framework for addressing the sustainability impact of Produktion2030. An illustration of the 17 goals is presented in **Figure 7** below.

FIGURE 7
The 17 SDGs set by the UN and its member states [4]

Most projects (70) considered between one and three SDGs as depicted in **Figure 8**. The top three SDGs chosen were SDG 9 Industry, innovation and infrastructure, SDG 12 Responsible consumption and production and SDG 8 Decent work and economic growth with 71, 42 and 19 selections respectively. These three SDGs are further described in the following subsection, where the relevancy to the project is presented. **Figure 9** gives an overview of all the projects and the respective SDGs chosen.

FIGURE 8
Overview of the how many SDGs that were selected by the respondents. For example, 30 projects selected two SDGs

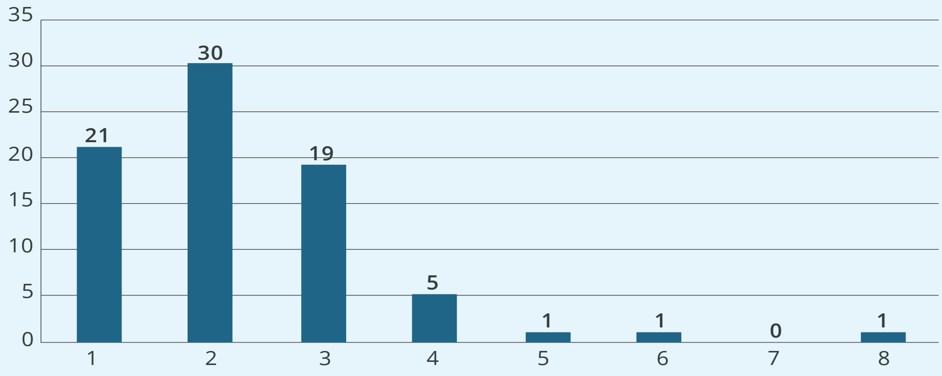
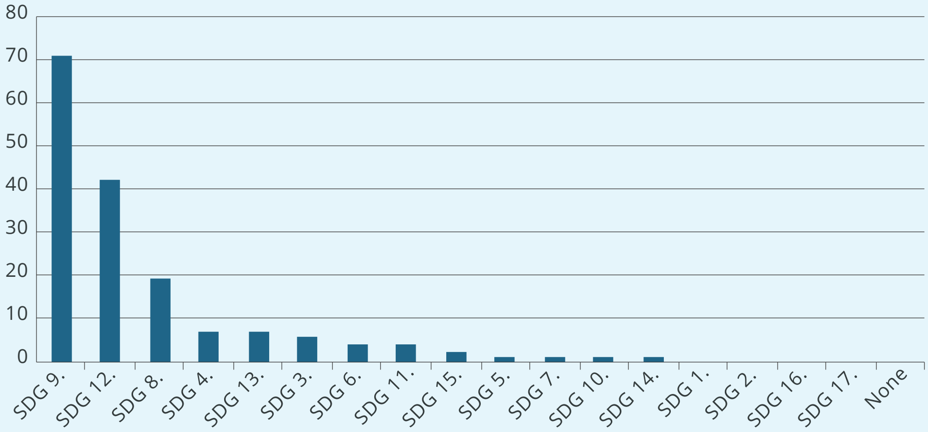


FIGURE 9
The number of respondents per SDGs



4.2.3 SDG 9 – Industry, innovation and infrastructure

The projects targeted the SDG 9 in several ways. One project aimed to support Small and Medium-sized Enterprises (SMEs) to cope with digital transformation, while some other projects introduced technology that would have an impact on industry and the way value chains work. Examples of such are implementation of robots in industry as well as simulation models that allow for virtual testing and planning, thus reducing both the use of energy and material consumption in production. Such solutions for sustainability can also improve the quality of a production process, which results in reduced amount of wastes and elimination of non-value adding activities. Simulation was also stated as a tool to assess circular business models and to set the direction for positive sustainability effects.

Four respondents specifically stated that they contributed to SDG 9 by increasing the capacity or utilisation in industrial processes for production systems and by implementing new innovative ideas. Of these, one project succeeded by introducing AI in industry. Another focused on improving the competitiveness of their renewable and sustainable material by reducing wastes in terms of energy and manpower.

If successful, it could lead to a wider use of the material and provide a positive environmental impact. Innovativeness was also aimed to be achieved through upgrading digital infrastructure, digitalisation and Internet of Things (IoT). Digitalisation was stated to increase the competitiveness of small-scale industries and allow them to enter new markets through a digital platform.

Other contributions were: improving the reliability of long-life products, creating more engagement and action for environmental improvements for the SDG goal, reducing scrap and improving efficiency in production. SDG 9 was also relevant in introducing a modernised maintenance function which could support the ease of upgrading production infrastructure, stimulate innovation within maintenance area and ensure the long-term well-being of the manufacturing industry.

4.2.4 SDG 12 – Responsible consumption and production

Six respondents selected SDG 12 and described how they promoted, implemented or developed value-retaining operations such as remanufacturing, reuse and recycling. Remanufacturing contributes to responsible consumption and production by its environmental benefits, compared to new manufacturing. It uses less resources, enables new work opportunities and gives a broader customer segment access to new technology, from high-end brands to a reduced price. The operations increase material utilisation, as material is used several times in a circular resource flow before final disposal. Reduction in waste generation results in less emissions released to air, water and soil. This has positive impact on human health and environment.

Resource efficiency through various methods, such as applying lifecycle design, maintenance, agile production, and additive manufacturing were stated by the projects. Digitalisation reduces material waste through either the value-retaining operations, or through the use of additive manufacturing. Additive manufacturing enables new design opportunities that use less material and results in less waste material during production. Such savings were also reported to be achieved by the use of simulation. Projects also targeted the SDG by implementing practices that use less chemicals, emit lower emissions and reduce packaging waste.

4.2.5 SDG 8 – Decent work and economic growth

One of the respondents pointed out that their consideration of the importance of caring for the employees or other people being influenced by a company as an important contribution to the SDG. Two other respondents gave instances of where heavy, stressful and perceived meaningless tasks were reduced from their production activities. Less heavy lifting and stressful tasks will contribute to better operator health and at the same time increase productivity, making local Swedish companies more competitive towards low-wage countries. One project investigated how the work environment in industry could be improved by creating a digital copy of the production which provided an overview of the workers' feeling of engagement, control and importance. Another project aimed to increase innovation capability of industry by including all employees in the problem-solving activities. Yet another project investigated safe human-machine collaborations, further exemplifying that more and more industries are considering the overall safety and wellbeing of their employees.

4.2.6 Produktion2030 sustainability aspects and their relation to UNSDG targets

Several connections were identified between the earlier mentioned sustainability aspects, project boundaries and the top three SDGs selected (8, 9 and 12) along with their individual target goals. The connections have been mapped in detail in Appendix C and explained briefly on the following page:

Target 8.2
"Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors"
– If the research and development of technologies is done with the inclusion of competitiveness, business value and/or economic growth sustainability aspects then it is likely that an aspect of this development includes economic productivity (increased value of output per value of input). This is because productivity is important for increasing economic growth, competitiveness and business value. It was seen from the projects that competitiveness was the most important driver together with the sustainability work. For example, recycling or remanufacturing Figure 11 in combination with economic sustainability aspect Figure 4.

Target 8.4
"Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead"
– The research and development of technologies that is done with the inclusion of recycling, remanufacturing or reuse technologies does include an aspect of economic decoupling. This is the case since all projects reported simultaneously working with economic sustainability see Figure 4 (competitiveness, business value and/or economic growth). Reducing impacts while increasing economic output requires a certain level of increased decoupling.

Target 8.5
"By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value"
– The research and development of technologies that is done with the inclusion of worker wellbeing, employee benefits and/or operation safety will aim to increase safe work. See Figure 5.

Target 8.8
"Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment"
– The research and development of technologies that is done with the inclusion of worker wellbeing, operation safety and health. See Figure 5.

Target 9.4
"By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities."
– The research and development of technologies that is done with the development of recycling, remanufacturing or repair technologies aim to increase resource use efficiency. See Figure 11.

Target 12.2
"By 2030, achieve the sustainable management and efficient use of natural resources"
– The research and development of technologies that is done with regards to recycling, remanufacturing or repair promote efficient use of natural resources does aim to achieve a more efficient use of natural resources. See Figure 11.

Target 12.4
"By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment"
– Projects were considering contamination of hazardous substances in product recycling systems. It was pointed out as challenging in comparison to a production-consumption-disposal system where chemicals are treated not to enter the system again.

Target 12.5
"By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse"
– Projects had a high level of understanding in the matter of prioritisation in the waste hierarchy. Some projects mentioned minimize waste whilst others preferred optimization of resources.

4.3 CIRCULAR ECONOMY WITHIN THE PROJECTS

The concept of Circular Economy (CE), has evolved from a dissatisfaction of the ‘take-make-dispose’ linear flow of materials and energy, resulting from several decades of resource exploitation of the natural environment. By encouraging a reuse of resources in a profitable way, retaining value and decoupling material use from economic growth CE has gained traction over the past years in the manufacturing as well as academic context.

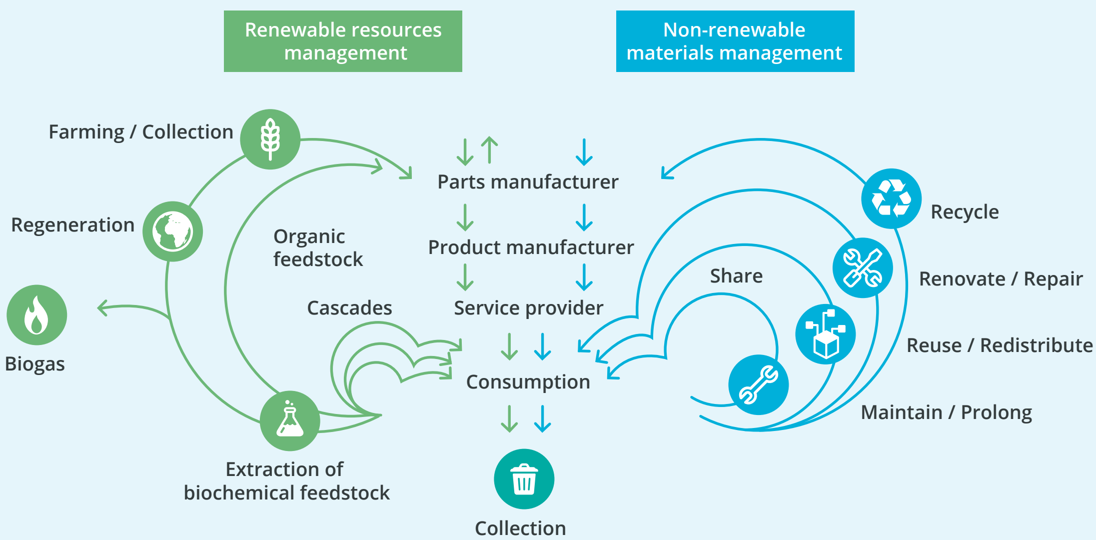
CE has been characterised as “as an economy that is restorative and regenerative by design and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles” [5] p.10. In this report, the interpretation of CE is limited to the butterfly diagram from the Ellen MacArthur Foundation [6], which is often used within business contexts. See Figure 10. The figure shows desirable circular flows in two separate systems, the technical cycle and the biological cycle. However, the concept is wide in its definition, facing limitations and overlaps with already existing closed loop-systems.

Of the 78 projects, 35 described that they worked with CE in some way. For example projects mentioned the reduction of waste and time, usage of new technology, additive manufacturing to be able to remanufacture scrap, as well as improved maintenance for prolonging product life time. Some of the CE concepts mentioned by the respondents also appeared in the sustainability aspects column. In order to evaluate the degree

of circularity each project managed to fulfil, a systems perspective was added in the CE section. The projects were allowed to choose system boundary categories, which helped in the further investigation of how they approached a systems thinking and societal interconnectivity, a crucial part of the circular economy concept.

The results showed that the interpretation and commitment of CE concepts varied between the projects. For example, some projects only considered a certain product whilst others covered the full value chain and considered actors as part of a wider production system.

FIGURE 10
Representation of the CE with technical and biological material flows in a product life cycle [6]

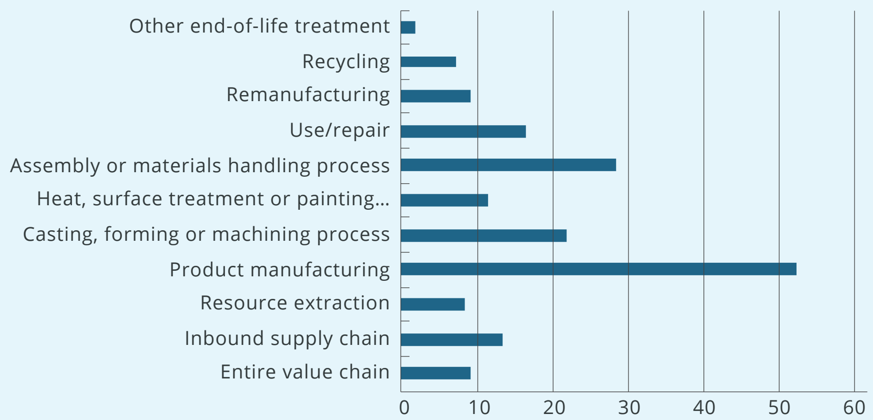


4.3.1 Scope of the projects (system boundaries)

Respondents were given a list of choices that would help define the boundary of their respective projects. These are highlighted in **Figure 11**. Boundary aspects were formulated in the most common terms found in literature while defining the project boundary. For example Cradle-to-gate, Gate-to-gate, Cradle-to-cradle, or Cradle-to-grave.

From the data analysis it was seen that a majority of the projects were oriented to product manufacturing, followed by assembly or materials handling process, and lastly by casting, forming or machining process.

FIGURE 11
Project boundaries chosen by the respondents



The commonly defined boundary for a product life-cycle was the cradle-to-gate system. In total 18 projects categorized themselves into this category. This group of projects cover material extraction and power generation, part manu-facturing and product manufacturing. The cradle-to-cradle/ cradle-to-grave system were not as common as the cradle-to-gate system. A greater systems perspective was found in projects that considered the factory, eight projects, as well as the entire value chain, nine projects (Table 3). In this latter group of projects, actors alongside the value chain were encountered as suppliers, customers, legislators etc.

Of the 35 projects that considered CE economy aspects, some used well-established CE concepts such as prolonging loops, prioritizing towards the waste hierarchy, reverse supply chain in their projects, while others interpreted CE in their own words. For example CE was described as optimization of material handling, efficient assembly, intelligent materials etc. The categorisation of the different projects under these three categories has been given in Table 3.

Based on the CE aspects chosen by the projects, the answers were categorised into three overarching levels:

- Product/Process
- Factory
- Value chain

TABLE 3
Total number of projects working with CE divided in project scope definitions

Level	Number of projects	Well-established CE concepts	Self-interpreted CE concepts
Product/Process	18	9	9
Factory	8	4	4
Value chain	9	7	2

4.3.2 CE at the product/process level

The ‘product/process’ level was chosen the most, and projects within this category used tools such as Life Cycle Assessment and other descriptions of circular flows connected to the manufacturing of a product or the manufacturing process to achieve CE. Common concepts were at the product/process level were:

- Down-cycling, contamination of material in circular metal flows
- Improving remanufacturing processes
- Measuring number of times a product is used
- Digitalisation increases reuse of resources by ensuring traceability of materials for safety as well as supply certainty
- Efficient assembly, remanufacturing
- Less rejects
- Reuse of metal powder, good quality
- Component reuse and improved maintenance
- Remanufacturing instead of linear flows

4.3.3 CE at the factory level

The second largest identified category included the full production site, enlarging the scope to a wider system at a factory level, in a total of eight projects. Commonly used CE concepts at the factory level were:

- Use of technology to assist CE
- Down-cycling, refurbishing, sales to after-markets
- Additive manufacturing allows new techniques for restore and repair
- Information systems needed in order to meet customer demands and new markets, closing information loops
- Intellectual properties, new business collaboration methods
- Prolonging material loops, improved maintenance activities
- Optimisation of material handling by additive manufacturing
- Identified the “Avoid” step in the waste hierarchy
- Improved maintenance throughout the production system
- Less waste in the production system

4.3.4 CE at the value chain level

The last group consisting of nine projects, stated that they covered the entire value chain and also incorporated improved business models towards product-service-systems in their project scope. Several projects identified difficulties with resource circularity within greater systems perspective.

Aspects mentioned in the projects pertaining to this level were:

- Material passport, digital platform that collects and maintain information for value chain distribution
- Servitisation of products within a value chain
- Optimisation of logistics and transports within value chain
- CE business models (ex: gas turbines as service)
- Material contamination in recycling systems
- Need for collaborative standards, regulation and better controlled procurement

4.4 SUSTAINABILITY PERFORMANCE MANAGEMENT

Sustainability assessment measures provide decision-makers with the necessary information to holistically understand the present state of the manufacturing system and take appropriate actions to maintain the sustainability strategy of the organisation. Previous research in the manufacturing domain has explored several methods [7–10] and Key Performance Indicators (KPIs) [11–14] to measure industries' sustainability performance effectively by considering all the three dimensions of sustainability. KPIs that industries commonly use have been reported to be from the Global Reporting Initiative (GRI), Dow Jones Sustainability Index (SI), international labour organisation, etc [14]. According to sustainability assessment studies in the manufacturing industry, the methodologies that are used most often are life cycle-based assessments, Sustainable Value Stream Mapping (SVSM), fuzzy-based or Analytical Hierarchy Process (AHP)-based multi criteria approaches, Sustainability Assessment and Value Evaluation (SAVE) approach, process-based evaluations, among others [7].

The sustainability KPIs, assessment methods as well as the influence of technology on sustainability, as seen from the projects, are described in the following sections.

4.4.1 KPIs and methods used in the projects

34 of the 78 projects used sustainability KPIs to measure their performance. Some of the KPIs used were:

1. OEE (Overall Equipment Efficiency)
2. Resource efficiency (material and energy consumption)
3. Combination of economic and environmental factors (cost and carbon footprint reduction)
4. Defect and rework rates
5. Social aspects of sustainability (involving users from needs inventory to evaluation of ideas)
6. Prioritisation of critical raw materials for recycling and recovery
7. CE/circularity indicators

Of the 16 projects that used sustainability assessment methods to evaluate their sustainability performance, eight combined KPIs along with the specific sustainability methods. Some of the most commonly cited ones were:

1. LCA (Life Cycle Assessment) and simplified LCA (sLCA)
2. Climate Impact Analysis
3. Qualitative value assessment
4. LCC (Life Cycle Costing)
5. VSM (Value Stream Mapping)
6. RPA (Rapid Plant Assessment)
7. Novel tool development: 'SAVE', a tool that systematically breaks down high level expectations and links to product and process parameters can be impacted through engineering and innovation studies. This allows comparative studies and is good for multi-level decision making.

It can be seen that the KPIs and methods used in the projects are similar to what was found from literature, showing relevance of these methods in industrial practices even today.

In one of the projects, ergonomics and productivity were measured with respect to material consumption and energy. Apart from ergonomics, projects also considered the involvement of the 'user' throughout the project process, which is another important social dimension of sustainability. The users' ideas (and their connection to the project's focus on sustainability) were evaluated through qualitative interviews with the users.

What was also interesting was that life-cycle oriented methods were used for service-based offerings such as Product-Service Systems (PSS) and product remanufacturing in the CE. VSM techniques helped achieve leaner manufacturing methods by efficient lead times.

As some projects were pre-studies or feasibility studies, they did not necessarily use sustainability assessment methods or KPIs, but clearly stated that they intended to use methods like LCA and LCC as part of the next phase in the projects. It was encouraging to see that this initiation of collaboration of SMEs with academia could improve the incorporation of these methods as part of their project planning process.

4.4.2 Influence of technology on sustainability assessment

In the present study, 34 out of 78 projects conducted their sustainability assessments manually, while 17 out of 78 projects used technology or other methods to carry out this process. The manual processes included the methods or KPIs previously mentioned, while the technologies/ sources used varied depending on the technology readiness level of the project. Some of these were:

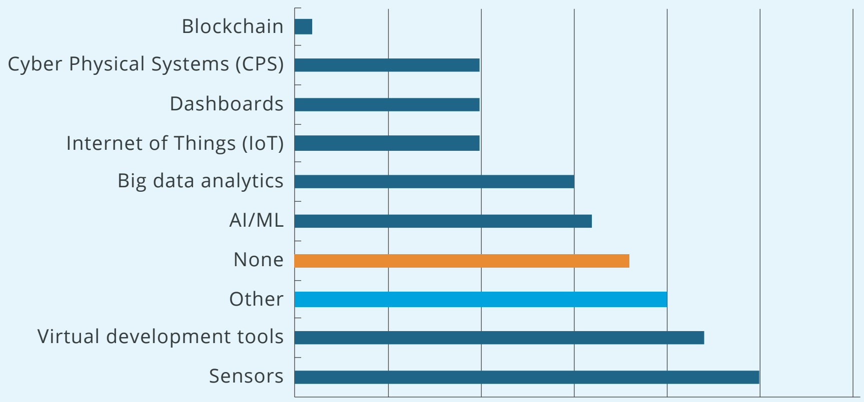
1. Predictive Maintenance (PdM) algorithms: predict future maintenance needs based on multiple data streams across multiple machines utilising AI and ML technology. It enables manufacturing organisations having installed sensors to fully exploit the availability of tremendous amounts of data with respect to the implementation of a PdM strategy
2. Commercial LCA software (e.g. SimaPro 7.1 combined with for example eco-indicator 99 impact assessment method used to assess CO2 estimation, energy consumption, water consumption, material consumption)
3. Tracking and tracing technologies: deliver information used for further calculations, the simulation in the digital twin allows an optimised or better reality-oriented visualisation
4. To measure economic and environmental sustainability a computer-based advance simulation and modelling tool was used. The tool was developed combining Agent and Discrete Event based modelling techniques as the model combined different stages of the value chain such as design, supply chain, use and maintenance etc.
5. Digital wellbeing assessment devices: assess wellbeing of operators in real time.
6. Production monitoring system already used in the companies
7. Use of smart workwear for evaluation of social aspects of sustainability
8. Finite element simulations

Some projects considered the indirect effect of the technological developments on sustainability. For instance, the efficiency and effectiveness of a simulation process, or the use of virtual methods. With the implementation of these technologies, the efficiency and effectiveness of the overall process can be increased as well as reduce the overall time for implementation as the amount of testing is replaced with virtual testing. The measurement of the effects of smart maintenance on maintenance performance was another indirect effect on sustainability.

In addition to the technologies used for sustainability assessment, 58 projects stated that a technology in general had been implemented. Moreover, not all these technologies were linked to sustainability, as all the projects did not have a sustainability focus. 51 projects (65%) had either an environmental and/or social sustainability focus. The respondents could select multiple choices among a list of Industry 4.0 (I4.0) technologies. As seen in **Figure 12**, sensors were the most commonly implemented technology followed by virtual development tools.

Literature has shown the advantages of implementing technologies, especially those in the I4.0 area to increase competitiveness, enable

FIGURE 12
Results of the multiple-choice question 12. Has there been a technology implementation in the project? The choice Other represents the number of free-text answers



sustainable value creation [15,16], and contribute towards the CE [17,18]. Some of the characteristics of these technologies with regards to sustainability and the CE are [15,19-22]: the use of functions or services instead of products, increase in productivity, reduction in resource use and wastes, increased use of recycled and remanufactured products, among many other advantages.

The data indicated that some projects' newly developed technologies can help improve sustainability through new practices for efficient production and reduction of waste. Other projects used techniques such as simulation, AI, and ML to evaluate the impact of new solutions on the environment. One pointed out that the knowledge from the project could improve sustainability by "[...] efficient and safe cooperation between humans and robots as means to generate resource efficient industrial operations, such as knowledge about several different levels of 'cooperation', safety methods, the importance of wording ('assistants' rather than 'robots'), choice of colours ('warm' colours), choice of surfaces (soft surfaces), avoidance of 'jerky' movements, etc." It represents a futuristic scenario where the steps taken towards more sustainable and high-technological solutions within production are beneficial for both workers and efficiency of processes.

In addition to AI and ML, technologies that could be linked with the I4.0 area were also implemented, such as:

1. Digital twins
2. Computer based advance simulation and modelling tools
3. Edge computing
4. Industrial robots with e.g. sensors and grippers
5. Augmented Reality (AR)
6. Smart workwear
7. Additive manufacturing
8. Digital platforms
9. Simulation models

Other technologies that were developed are presented in the following list. Most of them are computer-based technologies that in various ways can enable new solutions within the production area.

1. Data transfer
2. Computer vision
3. Mathematical modelling and optimisation
4. Finite Element Method (FEM)
5. PC-based software in production planning
6. Survey instruments for smart maintenance, maintenance performance and productivity
7. Wave guides
8. Computer aided design (CAD) and Product Lifecycle Management (PLM) software packages
9. Collaborative robot applications

4.4.3 Application of performance assessment tools developed

The Green Performance Map (GPM) developed by the 'Kostnadsdriven Grön Kaizen' project is currently being used by several companies in their daily businesses, and its development is continuing in ongoing projects. The logical methods developed by the Logik inom tillverkning (LiM) project are now adapted in subsequent projects and for other product and system scopes. Some project managers expressed that if the projects had been implemented on a larger scale or incorporated specific technological aspects, then there could have been an even larger positive impact on sustainability.

4.5 IMMEDIATE SUSTAINABILITY IMPACTS

Several impacts on sustainability were seen as a result of the project activities. Some projects had a direct impact (and immediate effects) while some others had indirect impacts on sustainability (effects not immediately seen). As some projects had just commenced or were in the ideation phase, immediate impacts were not seen, but were planned for the scale-up/next phase of project development (perhaps long-term impacts can be seen). These have been categorised into different themes that emerged from the analysis of the data and have been described below.

4.5.1 The Triple Bottom Line of sustainability

Considering the immediate direct impacts on the TBL of sustainability, many projects focused their efforts on resource efficiency of their production processes, that in turn affects cost and time efficiency. Indirect impacts on the social aspects as a result of the improved deviation handling and increased process stability such as improved working environments for employees were also mentioned. Reduced production disturbances was seen as a key contributor to affecting all three dimensions of sustainability; reduction in energy consumption, lower costs and safer workplaces.

Considering the benefits that arise due to sustainability, implementation of business models that approach the principle of doing more with less (eco-efficiency) are increasing in manufacturing firms. Due to the cleaner energy systems present in Sweden, production here acts as a precondition for sustainable industrialisation and scale-up process vs other countries.

4.5.2 Circular Economy

Value capture opportunities and innovative approaches are increasingly being explored. One finding revealed that three companies who were part of the same project, co-developed circular offerings using component reuse and improved maintenance. Reduction of CO2 emissions was also considered in one of the projects by switching to circular business models.

Another project had better control of their materials, components and products, thus enabling reuse, remanufacture and recycling. By adopting CE strategies, the project supported compliance to different regulations and standards in the long-term. Incorporating value logic in participating companies' operations in the supply chain provided conditions for more circular offerings.

4.5.3 Performance

Reduced production disturbances will result in increased productivity. High maintenance performance was seen as a result of production activities allowing lower energy consumption, less wastes and emissions. Overall increase in competitiveness was also seen as a direct result of increased sustainable activities.

4.5.4 Technology and digitalisation

Due to the increased availability of analytic systems, giving rise to more transparent and visible information, more accurate decision making can take place, both in the short and long-term that can lead to short term sustainability effects such as less waste, fewer transports, higher utilisation of resources, etc. Virtualisation increased the effectiveness of the development process, reducing errors in the early stages. New agile forms of data collection also helped in reducing waste/scrap. AI techniques could help save costs, increase production yield and prolong product life.

There could be resistance to implement technologies such as additive manufacturing, as the technology is fairly new and there is too much risk/uncertainty involved, for industries to safely invest and find potential in its use. Another project used the potential of digitalisation to optimise information flow between suppliers and sub-suppliers in the value chain to implement circular production systems.

4.5.5 Education

The level of company engagement was seen to have increased due to the dissemination of project results in the form of handbooks, workshops and availability of the data on the web. This allowed SMEs and other companies who were interested to be engaged, to use the findings to different extents and positively impact sustainability.

4.6 LONG-TERM SUSTAINABILITY IMPACTS

Many projects were not scaled-up to production level and did preliminary investigations of the potential of implementing sustainability criteria in their production processes and had a vision for increasing their future sustainability impact and competitiveness as a result of their innovative production processes.

4.6.1 TBL of sustainability

An investigation of a new casting technique had the potential of reducing energy consumption and handling waste scraps in the steel foundry industry. A project in the gas turbine industry looked into offering 'gas turbine as-a-service'. By investigating this potential, several benefits were envisioned such as improved business model creation and subsequent increase in market share, establishing competitive pricing strategies, moving closer towards CE product and production systems, better control over assets enabling reusability and the ability to remanufacture products, increase in resource conservation (materials including chemicals, energy and value added services) and reduction of emissions, waste parts and products. Another objective of one of the projects was to better align supply and demand, which led to less raw material consumption and less transportation.

4.6.2 Circular economy

Projects also looked at increasing the lifespan of their products/machines, thus contributing to the CE. New business models and processes based on collaboration between stakeholders, and coordinated information in a circular value chain using resources in a more sustainable manner could give rise to long-term sustainability impacts.

4.6.3 Maintenance

One project mentioned that the long-term effect of their maintenance activities could attract talented workers (increased social sustainability and competence) and this could further drive the industrial digitalisation process.

4.6.4 Technology and digitalisation

One of the projects described the value of human involvement in this era of digitalization, by contributing to a future where humans are not replaced by machines, but rather can augment their capacity by using methods to efficiently cooperate with machines.

When production logistics information is made more visible, it can enable a change in logistics flows leading to major sustainability effects concerning circularity of material and products, sourcing decisions, location decisions, system resilience, etc.

Investigations are ongoing with regards to the improvements in flexible manufacturing processes related to copper-based products thus improving overall sustainability impacts. This is being done as use of electrical power is increasing in all sectors, giving rise to increasing use of copper.

With increasing awareness among customers and manufacturers, projects are making more long-term decisions with regards to the type of technology that needs to be developed, which in turn need to be designed with increasing number of sustainability parameters. Through transparent sharing of digital data and information between actors in the value chain, the information will be used in the production planning processes, hopefully leading to less waste, improved processes and business relations over time. Implementing error source prediction models enables Swedish companies to maintain competitiveness, thereby improving their sustainability performance.

4.6.5 Education

Some projects used test beds to increase awareness of the technology through educative platforms. The long-term impact of this effort was seen to be on the SDGs 4, 8, 9, and 12. Other projects helped in the development of tools and methods for large scale implementation to increase the sustainability of industrial resource extraction. Yet another generated knowledge about how employees' motivation can be increased among employees through various solutions that visualise production (and how they themselves contribute to the whole) as well as ideas about solutions with technology that are sustainable in an industrial environment. Future performance measurement systems including the use of KPIs that target sustainable manufacturing can be benefitted by the use of educational, project result handbooks.

4.7 SUSTAINABILITY TRADE-OFFS

In production, the operations frontier can be used to describe the occurrence of trade-offs [23]. The frontier contains the set of all possible combinations of for example two categories that are prioritised. It is not possible to maximise several completely different categories simultaneously, hence the reason trade-offs occur.

There were 38 respondents that stated that they had experienced sustainability trade-offs, and of these, 26 stated clear trade-offs. The remaining twelve respondents described either a win-win situation or it could not in another way be interpreted as a trade-off. For the projects that did not state any trade-offs, there could be several reasons why. The scope of many projects was not sustainability per se, which could be a reason why sustainability trade-offs has not been reported by them. It could also be because the sustainability focus was low in the project, making it a redundant factor, or because the steps taken in the project was towards the operations frontier and thus prioritisation due to sustainability trade-offs was not yet necessary.

4.7.1 Trade-offs between the environment and economy

The most common trade-off among twelve respondents that answered this question, was the economy versus environment. Four respondents stated directly without any explanation that the trade-offs were between environment and economy. The others had varied explanations of how the trade-offs occurred, and no common denominator could be found for the projects. The trade-offs were in some instances positive economic effects and in other positive environmental. One project had to sacrifice resource efficiency to achieve cost reduction within the project, while another had successfully achieved positive environmental gains in a pilot, but suffered a negative short-term economic impact.

Value-retaining operations within a CE were considered as environmental beneficial. Two projects had a remanufacturing focus, whose environmental benefits were limited by economic factors. Instead of retaining value from used products in Europe, a project mentioned that it could be cheaper to buy low-quality copies from China, thus reducing the attractiveness of remanufacturing. In another case, remanufacturing was not identified as economically beneficial, instead material recycling had to be prioritised in exchange for less environmental benefits. A third project with a CE focus, whose solution would increase circularity at SMEs, had a trade-off where it was not always feasible to implement the solution.

Implementing new solutions or technologies can also have unwanted affects depending on what country it is implemented in. A new efficient cleaning technology that works in Sweden, or other countries with sufficient water supply, would not be usable in countries where there is a shortage of water, since it uses twice the amount of water compared to traditional cleaning methods. Another respondent identified that new innovative products and methods could result in new wastes that must be handled. Lastly, a project suffered from high cost used finite resources to implement instruments and equipment, by replacing human labour.

4.7.2 Sustainability considered as a general trade-off

Sustainability was considered as a general trade-off term for six projects. It is likely that these projects had at least the environmental dimension in mind as sustainability and environmentally friendliness are commonly interchangeable words. All these projects had a clear view of how they were affected by the trade-offs.

One stated that individualised production through additive manufacturing provides advantages from a sustainability point of view, similar to how large-scale and small series production have different priorities. A similar comparison was also emphasised by a project with a high production logistics focus. That project's aim was also to make sustainability aspects more visible in decision-making. The business value and cost for digitalisation were also considered as trade-offs with sustainability, as was achieving sustainability through increased maintenance performance in exchange for higher costs.

One respondent stated that it had sustainability trade-offs as a specific aim, while another had balancing between sustainability and resource efficiency. One of them developed technology to reduce the trade-offs, which could mean that the operations frontier is pushed, allowing for further beneficial combinations that enables higher competitiveness and sustainable production practices. The other project developed a performance measurement system, a framework, which considered all sustainability dimensions. But even a sustainability framework can have trade-offs, and it was stated that time spent using the framework must be balanced with the sustainable value given.

4.7.3 Other trade-off factors

Only two respondents reported a trade-off that could be directly linked to the social dimension of sustainability by stating "reduced time and cost, but increased quality and health" and "gender equality in industry". Some projects had indirect effects, by reducing the amount of human labour in production. Reduction of manual labour could be a positive effect for social sustainability if, for example, these jobs were in unhealthy environments, had poor ergonomic conditions or affected the health of the worker. However, the actual effect from these projects on this dimension is unclear.

The remaining projects stated the following trade-offs:

- Low cost and high quality
- Cost and performance
- Handling short- and long-term disturbances in production
- Production availability, technical efficiency and cost
- Flexibility in product design and 'quality and performance'
- Time spent on strategic decisions and do-nothing
- Less material usage and higher energy consumption

5 Future Outlook

The results from the project show that the Produktion2030 projects are well-positioned with respect to sustainability and it shows that Sweden is heading in the right direction.

5.1 LIMITATIONS AND FUTURE WORK

Projects that involved multiple case studies, developed case specific KPIs, and detailed information about these could not be retrieved. Follow-up interviews would be required to gather more details.

5.2 DISSEMINATION OF KNOWLEDGE

The knowledge gained from the Produktion2030 projects that can be passed on to future projects to improve sustainability is high and varied. From improved efficiency in production, to new technology implementation for sustainability and investigations of environmentally friendly manufacturing processes, the advantages are many. As one of the respondents mentioned, "Awareness of sustainability aspects must come before change of business processes", it is important to be aware of potential sustainability improvement areas first before finding solutions. This is something that all projects should consider to be able to tackle the challenges of the future.

5.3 FUTURE SUSTAINABILITY IMPROVEMENT POTENTIAL

22 out of 78 respondents (28%) mentioned that they would like to include sustainability aspects to a higher degree if the projects were to be conducted again. Respondents were asked to explain what they would have changed if the project were conducted again. The answers have been summarised in **Table 4** from a TBL standpoint. Observe that some projects chose more than one dimension of sustainability. 44 out of 78 respondents (56%) had some sort of sustainability competence within the project. This shows potential for the future, as an increasing number of projects are incorporating a sustainability focus as part of their project objectives.

TABLE 4
Future sustainability improvement focus.

Future desire to work more with...	... environmental sustainability	... social sustainability	... economic sustainability
Number of projects	12	7	5

5.4 EU POLICY REQUIREMENTS

The European commission recently passed the new Green Deal [24] which is a plan to tackle environmental challenges and achieve net zero carbon emissions in the EU by 2050. An extraordinary goal, this will require a major overhaul in almost every aspect of the European economy. The green deal will be especially significant for manufacturing and energy industries as they contribute significantly to EU greenhouse gas emissions [25]. Thus, the need for sustainability in industrial processes is increasing and will continue to grow in the coming years.

6 Conclusions

The sustainability analysis of Produktion2030's projects was made to identify the content and scale of the Produktion2030 programme's overall impact on industry's sustainability and circular economy. Manufacturing industry must urgently transform into sustainable and resource- efficient operations, complying with new demands and regulations from the European Commission's Green Deal. A sustainability assessment was made of 78 (out of 113 projects), using an online questionnaire with questions on how projects managed sustainability connected to the Tripple Bottom Line (TBL); United Nations's Sustainable Development Goals (SDGs); and Circular Economy factors (CE). Also, sustainability assessment methods and technology implemented by the projects were documented.

A majority of the projects showed high sustainability focus on TBL and SDGs. All projects contributed to the economic dimension, while more than half of the projects incorporated environmental aspects. Less than half the projects addressed social issues. The main sustainability driver among the 78 projects was cost reduction and improvement of longterm competitiveness.

The three SDGs primarily considered by the projects were: SDG 9 – Industry, Innovation and Infrastructure; SDG 12 _ Responsible Consumption and Production; and SDG 8 – Decent work and economic growth. Most projects considered one to three SDGs.

Projects approached SDG 9 in multiple ways, e.g. by supporting SMEs in digital transformation; developing new technology impacting the value chains; implementation of robots in industry; and development of simulation models. Other examples are introduction of AI in industry, digitalisation, IoT and renewable materials.

The SDG 12 was addressed through valueretaining operations, e.g. remanufacturing, reuse, and recycling. Recourse efficiency was achieved by methods, e.g. applying lifecycle design, maintenance, agile production, and additive manufacturing. For SDG 8, projects focused on the importance of caring for employees or people being influenced by the company. Issues like heavy, stressful and perceived meaningless tasks illustrated as examples, as well as human-machine collaboration and a focus on health issues. Many direct and indirect impacts on sustainability were linked to CE, performance, and technological implementation.

For instance, projects using AI described these techniques as prolonging product life, thus contributing to CE. One project used digitalisation to optimise information flow between suppliers and subsuppliers in the value chain, thus implementing circular production systems and contributing to CE. Increased sustainable activities, maintenance performance and competitiveness were seen as a result of implementing advanced data-driven disturbance handling procedures in a project.

Analysing the projects' approaches to CE, a systems perspective was investigated on each project. Projects were asked to categorise themselves on the scope of the project, later analysed and translated into three systems levels; i.e. product, factory, and value chain. Thus, a majority of the projects handled projects on a product level by using common terms linked to CE. Projects also used synonyms and their own interpretation of established CE concepts. In the factory and value chain categories, CE concepts link to logistics and supply or value chains. Servitization of products and new business models were emphasized in this category.

In pursuit towards sustainability, several projects explored tradeoffs, often between environment or general sustainability and an economic factor e.g. efficiency or cost reduction. Some tradeoffs were not environmentally friendly, but in general projects prioritised it.

A few cases had tradeoffs in the social dimension, but it was not the main focus for most projects. Sweden already poses strong protective systems for workers and regulations in favour of people. That may be a reason why projects did not present more social tradeoffs since such factors could be taken for granted. The investigation showed strong commitment and ambition among project partners to acknowledge and drive research efforts towards national and international sustainability goals. This will influence industries in Sweden to adopt increased awareness and ability to deal with forth-coming sustainability regulations and requirements.

In conclusion, this study of sustainability efforts within the total portfolio of Produktion2030 projects shows that the programme is strongly contributing to the transformation of manufacturing industry in Sweden towards sustainability, the UN SDGs, and a circular economy.

ACKNOWLEDGEMENTS

The authors would like to thank the respondents who took part in this study, without whom this project would not have been possible.
The project was funded through the strategic innovation programme Produktion2030, by Vinnova and Energimyndigheten.

REFERENCES

1. United Nations World Commission on Environment and Development. Report of the world commission on environment and development: Our common future; 1987.

2. Elkington, J. Cannibals with forks: The triple bottom line of 21st century business; Stony Creek, CT :New Society Publishers: Gabriola Island, BC, 1998.

3. UN DESA. The 17 goals | sustainable development goals. Available online: (accessed on 29 June 2020)

4. UN. Communications materials | sustainable development goals. Available online: https://www.un.org/sustainabledevelopment/news/communications-material/ (accessed on 29 June 2020)

5. Ellen MacArthur Foundation. Intelligent assets unlocking the circular economy potential; 2016.

6. Ellen MacArthur Foundation. Towards the circular economy; 2012.

7. Ahmad, S.; Wong, K.Y. Sustainability assessment in the manufacturing industry: A review of recent studies. Benchmarking: An International Journal 2018, 25, 3162–3179, doi:10.1108/bij-08-2017-0214.

8. Gadenne, D.; Mia, L.; Sands, J.; Winata, L.; Hooi, G. The influence of sustainability performance management practices on organisational sustainability performance. Journal of Accounting & Organizational Change 2012, 8, 210–235, doi:10.1108/18325911211230380.

9. Gasparatos, A.; Scolobig, A. Choosing the most appropriate sustainability assessment tool. Ecological Economics 2012, 80, 1–7, doi:10.1016/j.ecolecon.2012.05.005.

10. Hasna, A.M. A review of sustainability assessment methods in engineering. The International Journal of Environmental, Cultural, Economic, and Social Sustainability: Annual Review 2009, 5, 161–176, doi:10.18848/1832-2077/CGP/v05i01/54552.

11. Azapagic, A.; Perdan, S. Indicators of sustainable development for industry. Process Safety and Environmental Protection 2000, 78, 243-261, doi:10.1205/095758200530763.

12. Winroth, M.; Almström, P.; Andersson, C. Sustainable production indicators at factory level. Journal of Manufacturing Technology Management 2016, 27, 842-873, doi:10.1108/jmtm-04-2016-0054.

13. Zackrisson, M.; Kurdve, M.; Shahbazi, S.; Wiktorsson, M.; Winroth, M.; Landström, A.; Almström, P.; Andersson, C.; Windmark, C.; Öberg, A.E., et al. Sustainability performance indicators at shop floor level in large manufacturing companies. Procedia CIRP 2017, 61, 457-462, doi:10.1016/j.procir.2016.11.199.

14. Ahmad, S.; Wong, K.Y.; Rajoo, S. Sustainability indicators for manufacturing sectors: A literature survey and maturity analysis from the triple-bottom line perspective. Journal of Manufacturing Technology Management 2019, 30, 312-334.

15. Bonilla, S.H.; Silva, H.R.O.; Da Silva, M.T.; Gonçalves, R.F.; Sacomano, J.B. Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. 2018, 10, doi:10.3390/su10103740.

16. Stock, T.; Obenaus, M.; Kunz, S.; Kohl, H. Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. 2018, 118, 254-267, doi:10.1016/j.psep.2018.06.026.

17. Bressanelli, G.; Adrodegari, F.; Perona, M.; Saccani, N. The role of digital technologies to overcome circular economy challenges in pss business models: An exploratory case study. 2018, 73, 216-221, doi:10.1016/j.procir.2018.03.322.

18. Rajput, S.; Singh, S.P. Connecting circular economy and industry 4.0. International Journal of Information Management 2019, 49, 98-113, doi:10.1016/j.ijinfomgt.2019.03.002.

19. Bag, S.; Telukdarie, A.; Pretorius, J.H.C.; Gupta, S. Industry 4.0 and supply chain sustainability: Framework and future research directions. 2018, 10.1108/BIJ-03-2018-0056, doi:10.1108/BIJ-03-2018-0056.

20. Bechtsis, D.; Tsolakis, N.; Vouzas, M.; Vlachos, D. Industry 4.0: Sustainable material handling processes in industrial environments. 2017, 40, 2281-2286, doi:10.1016/B978-0-444-63965-3.50382-2.

21. Berawi, M.A. The role of industry 4.0 in achieving sustainable development goals. 2019, 10, 644-647, doi:10.14716/ijtech.v10i4.3341.

22. Bressanelli, G.; Adrodegari, F.; Perona, M.; Saccani, N. Exploring how usage-focused business models enable circular economy through digital technologies. 2018, 10, doi:10.3390/su10030639.

23. Anupindi, R.; Chopra, S.; Deshmukh D., S.; Meighem, J.A.V.; Zemel, E. Managing business process flows: Principles of operations management, 3 ed.; Pearson: 2012.

24. Commission, E. Communication from the commission to the european parliament, the european council, the council, the european economic and social committee and the committee of the regions : The european green deal; Brussels, 2019.

25. Eurostat. Shedding light on energy in the eu - a guided tour of energy statistics. Available online: https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-4a.html (accessed on Aug 11 2020)

26. UN. Global indicator framework for the sustainable development goals and targets of the 2030 agenda for sustainable development. Available online: https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202020%20review_Eng.pdf (accessed on June 29 2020)

APPENDIX A:
Questionnaire

PRODUKTION2030

P2030 SUSTAINABILITY ASSESSMENT

Sustainability Analysis of Produktion2030's projects

Email address:

1. **Select your project**
   <See list of projects in Appendix A>

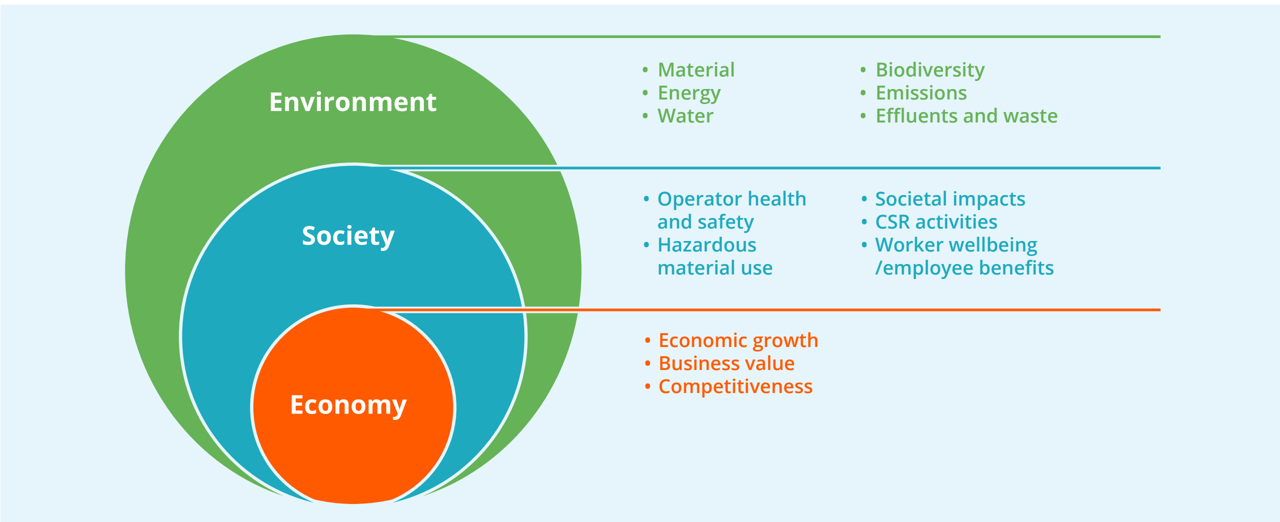
2. **What was your role in the project?**
   ☐ Project Manager
   ☐ Researcher
   ☐ Other:

3. **Sustainable development is "[... the] development that meets the need of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). Sustainability is met when all three pillars (environment, society and economy) are considered within the limitations of the planet's resources.**

3.1. Which aspects of sustainability were included in the project? Multiple choices possible.
☐ Material
☐ Energy
☐ Water
☐ Biodiversity
☐ Emissions
☐ Effluents and waste
☐ Operator safety and health
☐ Hazardous material use
☐ Societal impacts
☐ CSR activities
☐ Worker well-being/employee benefits
☐ Economic growth
☐ Business value
☐ Competitiveness
☐ None
☐ Other:

3.2. If none, why?

3.3. What further sustainability aspects would you consider if you were doing the project again?



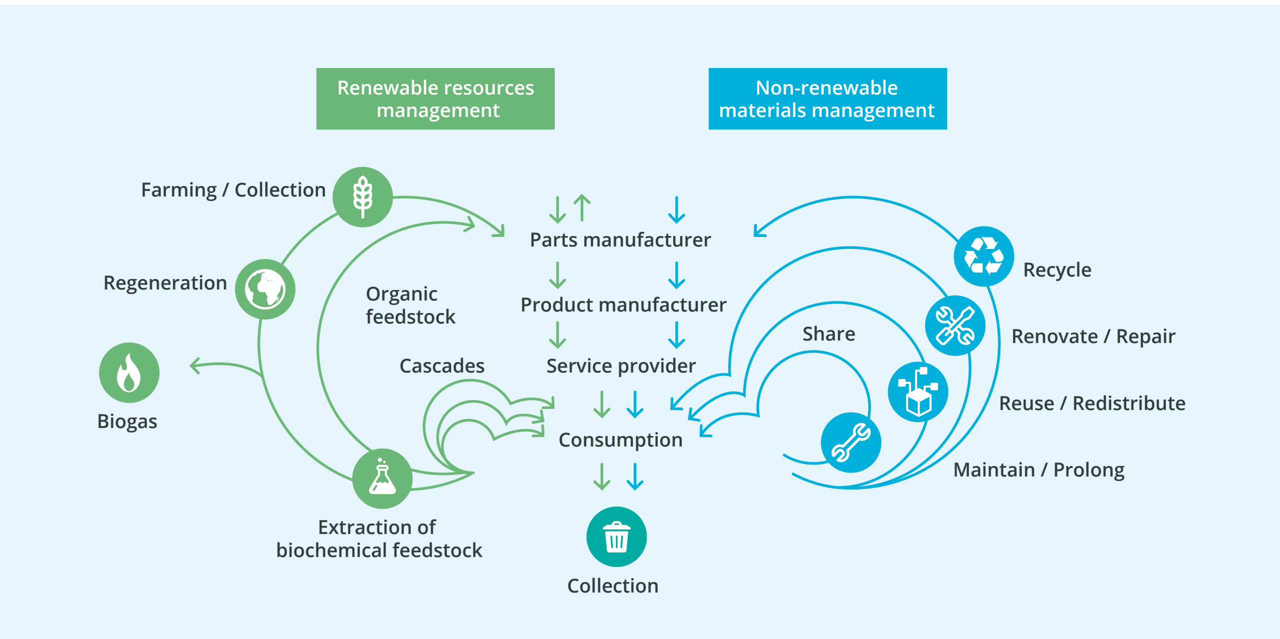
4. **What were the drivers to include/ not include sustainability?**
   - ☐ Improve long-term competitiveness
   - ☐ Reduce costs
   - ☐ Improve environmental image of company or product
   - ☐ Meet new market or customer demands
   - ☐ Comply with environmental regulations and standards
   - ☐ Other:

5. **Which UN Sustainability Development Goals (UNSDGs) were relevant for the project?**
   <Multiple choice list of UNSDGs>

   5.1. How were these UNSDGs relevant to the project?

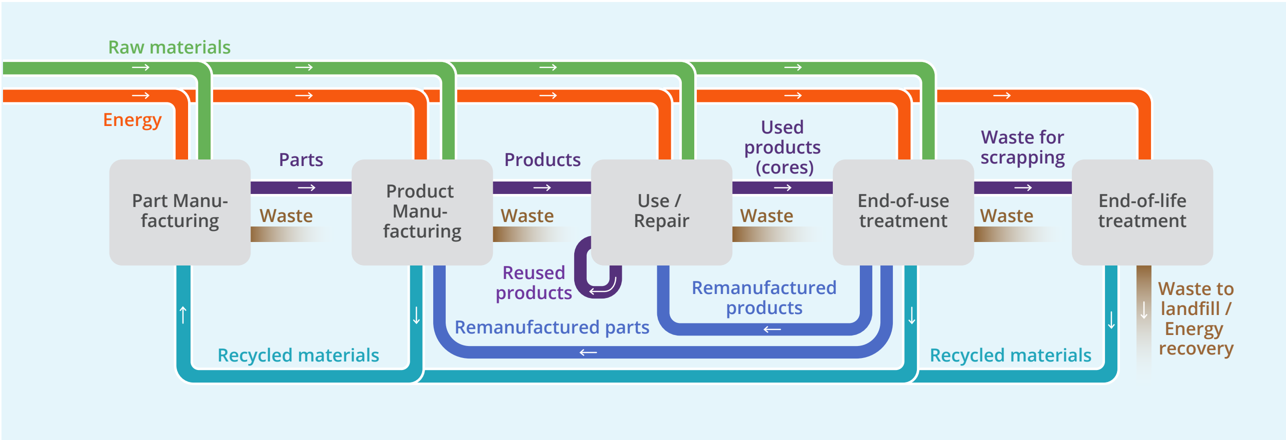
6. **Circular economy is “going beyond the current linear take-make-waste industrial model by decoupling economic activity from the consumption of finite resources, retaining the value of resources for as long as possible within the product’s life cycle and designing waste out of the system” (Ellen MacArthur Foundation 2015).**

   6.1. Does your project include aspects of a Circular Economy? If yes, please describe in detail.



7. **What were the physical boundaries of the project?**

☐ Entire value chain
☐ Inbound supply chain
☐ Resource extraction
☐ Product manufacturing
☐ Casting, forming or machining process
☐ Heat, surface treatment or painting process
☐ Assembly or materials handling process
☐ Use/repair
☐ Remanufacturing
☐ Recycling
☐ Other End-of-Life treatment
☐ Other:



8. **What did you use to measure sustainability of the project?**
☐ KPI
☐ Sustainability assessment method
☐ Other:

8.1. Please describe in detail the KPIs and methods used.
Example: KPIs such as carbon footprint, etc; Sustainability assessment methods such as Life cycle assessment (LCA), Life cycle cost (LCC), etc.

8.2. Why were these methods chosen?

9. **How was the sustainability assessment carried out?**
☐ Use of technology
☐ Other:

9.1. If technology was used for the assessment, please describe the technology, to what extent and how it was used.

9.2. Were there sufficient competencies and resources to achieve the set sustainability targets in the project?

10. **Does the project foresee any immediate and long-term impacts on sustainability from different areas of the project? Please describe.**

11. **What are the possible trade-offs for sustainability in the project? Please describe. E.g. reduced costs but decrease in quality and performance etc.**

12. **Has there been a technology implementation in the project?**
☐ Internet of Things (IoT)
☐ Sensors
☐ Cyber Physical Systems (CPS)
☐ Big data analytics
☐ Dashboards
☐ Virtual development tools
☐ Blockchain
☐ AI/ML
☐ None
☐ Other:

12.1. If yes, what potential benefit for sustainability was/is foreseen by the implementation of the technologies?

13. **What knowledge from this project can be used for other projects to increase their sustainability impact?**

14. **Would you be willing to participate in an interview to further assess sustain-ability of the project?**
☐ Yes
☐ No

APPENDIX B:
List of projects

Beslutsstöd utifrån layout-visualisering och ergonomi-simulering (3D-silver)

A digital twin to support sustainable and available production as a service

Adapted Chemical Composition of materials for Enhanced Laser welding (ACCEL)

Adaptive lifecycle design by applying digitalization and AI techniques to production (Adapt 2030)

Automation of Kitting, Transport and Assembly (AKTA)

Additivt tillverkade verktygsdelar för flexibel produktion och optimerade produktegenskaper (AMtoFlexs)

Automation in Repair and Re-manufacturing (ARR)

Automation solutions for production deviation management (ASPIRE)

Avancerade tjänster i tillverkningsindustrin (ATIT)

Augmenting Human Operators for the ERA of Automated Industry (A/HOPE/AI)

Automatiserad inspektion och andra möjligheter vid införandet av digitalröntgen i tillverkningsindustrin

Blyfria kopparlegeringar i produkter och komponenter

Circular Manufacturing in Energy Industry: An assessment of circular business model potential

Circularis

Data-driven disturbance handling (D3H)

Demonstrating and testing smart digitalisation for sustainable human-centered automation in production

Den tekniska innovationsfabriken

Design och implementering av cirkulära produktionsbaserade tjänsteaffärsmodeller

DIGitaliserat välbefInnande (DIG IN)

Digitaliseringskoncept för två-materialgjutning (Digicast)

Digitaliseringskoncept för lärande och kunskapsåteranvändande (DigiLean)

Digi-load

Digital and physical testbed for logistic operations in production (Digilog)

Digital infrastructure for smart manufacturing (DigIN)

Digital innovation for railway production value chains (makeITrail)

Digital Sågverkstvilling för effektiv produktion och underhåll (MillTwin)

Digital value chain for geometry data management (DigiGeo)

Digitala Värdekedjor I SkogsIndustrin, DiVISI

Digitalisering av fogningsberedning

Digitalization of steel production work-flows (DigSteel)

Digitisation of Factory In A Box Solutions (Digi-FBX)

Digitalization of metal production work-flows (DigMetal)

Digitalized Large Scale Additive Manufacturing (DiLAM)

Digitaliserad Prediktionsbaserad Produktionsoptimering (DiPP)

Demonstration of Infrastructure for Digitalization enabling industrialization of Additive Manufacturing (DiSAM)

Digitalization of Supply Chain in Swedish Additive Manufacturing (DiSAM)

Digitaliserade Värdekedjor I SkogsIndustrin (DiVISI)

Digital Weldability Test and Prototyping Platform (DWEL)

Dynamisk interaktion mellan människa och automation (DYNAMITE)

Efficient Automation for Customized products in Swedish Industry (e-Factory)

Effektivt cirkulationssystem för material i additiv tillverkning

Enabling Reuse, Remanufacturing and Recycling Within INDustrial systems (REWIND)

Enabling super quality electric steel through advanced use of data analytics in real time

Effektiv tillverkning av prepreg (ETAP)

FactORY on Demand (FORD)

Flexibel tillverkning av funktionella kopparbaserade produkter

Flexibla modeller för smart underhåll

Flexible Additive Manufacturing of Micrometer/Millimeter Wave Components

Från avlopp till resurs: Slutna vattenbalanser i industrin

Förbättrad metod för svetslagning av gjutjärnsgods

Giftfritt substitut för hårdkrom i volymtillämpningar

Hybrid Joining Testbed for Smart Production (HJT)

Human Perspective, Machine-Learning ERP-system1: Humble

Hållbart utnyttjande av metallpulver i pulverbäddsbaserad additiv tillverkning

In-line Measurement and Simulation Integration in Manufacturing (IMSIM)

Infrastructure for Digitalization enabling industrialization of Additive manufacturinG (IDAG)

Interaktivt verktyg för ökat kunskapsinnehåll i tidiga skeden av teknisk design

Karakuri IoT

Konceptstudie för Ny Innovativ motståndssvetsning (KNIW) (RSW)

Kostnadsdriven Grön Kaizen

Logik inom tillverkning (LiM)

Ljudorienterade fiber i kompositer (LOFiK)

Low volume high mix production in Sweden by flexible automation and mobile robots (LoHiSwedProd)

Production Logistics Visibility (LOVIS)

Ett system för automatisk kontroll av maskinhälsa (Maint-CPS)

Material Passport: A digital platform for manufacturing industry to implement Circular Production Systems (CEPort)

Materialflexibel produktion, utveckling av fysik och virtuell testbädd (MATFLEX)

Kommunikation, organisation och kompetens för framtidens arbetsplats (MEET)

Mentorskap i Mätnätverk (MIM)

Molnbaserat tillverknings variation kontrol

MObil och digiTal AutomatION (MOTION)

Nervsystem i industriella fixturer

Ny flexibel metod för att sammanfoga värmeväxlare

Ny matarteknology för ökad hållbarhet vid järn- och stålgjutning

Optimerad produktionsprocess för additiv tillverkning

Process Automation for Discrete Manufacturing Excellence (PADME)

Performance prediction of a biobased product

Prediktivt underhåll för tjänstebaserade & hållbara affärsmodeller i svensk industri (PMBM)

Positioning technology for the heavy manufacturing industry sector (POSTECH)

Predictive maintenance using Advanced Cluster Analysis (PACA)

Prediktering av gnissel och gnek för robust produkt och produktion

Produktionsinnovation

Produktionsspegeln – digital interaktion i industrimiljöer

Produktionsänglar – Ett innovativt koncept för industralisering och uppskalning Produktionsinnovation

Robust in-process joint finding (RobIn)

ROBust Optimisation in Design for Additive Manufacturing (ROBODAM)

Sensible Value Chain through Digitalised Planning, Material handling and Circular Economy (SCARCE II)

En säkerhetsmodell för samverkande robotar (Scor)

Secure Shortcut (SeeCut)

Sensible Value Chain: Material Flows, Roles and Circular Economy (SCARCE)

Servicearkitektur för produkt- och produktionstillgänglighet

New Application of AI for Services in Maintenance towards a Circular Economy (Simon)

Shape Inspection by Vision in Production (SIVPRO)

Skräddarsydda verktygsytor för robust och hållbar presshärdning

Sustainable Manufacturing by Automated Real-Time Performance management (SMART PM)

Smart teknik för hållbar produktion genom självutveckling

Smart Maintenance Assessment (SMASh)

Sustainable and Qlean Industry Demonstrator (SQID)

Storskalig produktion av produkter av mixade material

SUstainability, sMart Maintenance and factory desIgn Testbed (SUMMIT)

Sustainable Resource Efficient Business Performance Measurements Systems (SuRE BPMS)

Teknologimodellering av hållbara tillverkningsmetoder i elektronikindustrin (TechMO)

Teknologi för klimatvävar för ökad kontroll av klimatet i växthus med RFID

Time Data Management for Smart Factories

Virtual Commissioning of Vehicle Maintenance Operations (UNIFICATION)

Value creation by applying AI techniques in production and maintenance through lifecycle engineering (VALID LIFE)

Adaptive control of varying joint gap in LBW (VarGA)

Variation förutsägelse och källidentifiering för noll fel bearbetning linjen

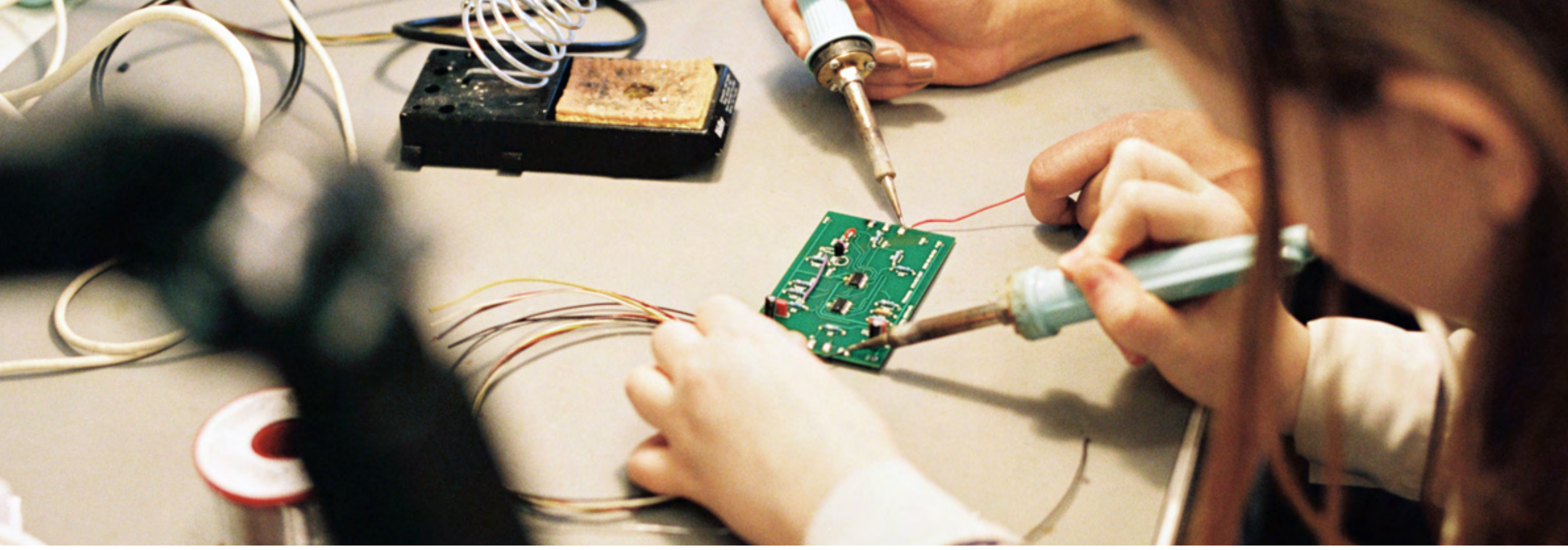
Verktygresursoptimering

Virtuella demonstratorer för parallell produkt- och produktionssystemutveckling

Automated quality inspection in assembly lines through low-cost vision system (VISION)

Vision Inspection Swedish Testbed (VIST)

Effektiv ÅTERtillverkning genom användning av lean-principer och PRODUKTlivscykeldata (ÅTER PRODUKT)



APPENDIX C:
SDGs and TBL correlation

The Appendix table presents a mapping of connections between the Produktion2030 projects and SDG targets. The targets are retrieved from [26]

8.1
Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries,
– *No direct correlation to any sustainability aspects*

9.1
Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
– *No direct correlation to any sustainability aspects*

12.1
Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
– *No direct correlation to any sustainability aspects*

8.2
Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors
– *Correlation to competitiveness*
– *Correlation to business value*
– *Correlation to economic growth*

9.2
Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries
– *No direct correlation to any sustainability aspects*

12.2
By 2030, achieve the sustainable management and efficient use of natural resources
– *Correlation to recycling, remanufacturing and repair*
Reasonable sustainability assessment method: LCA

8.3
Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services
– No direct correlation to any sustainability aspects

9.3
Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets
– No direct correlation to any sustainability aspects

12.3
By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses
– No direct correlation to any sustainability aspects

8.4
Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead
– Correlation to recycling, remanufacturing and repair
– Correlation to competitiveness, business value and economic growth
Reasonable sustainability assessment method: LCA

9.4
By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities
– Correlation to recycling, remanufacturing and repair
Reasonable sustainability assessment method: LCA

12.4
By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment
– Correlation to recycling, remanufacturing and repair
– Correlation to effluents and waste

8.5
By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value
– Correlation to worker wellbeing/employee benefits
– Correlation to operation safety and health

9.5
Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending
– No direct correlation to any sustainability aspects

12.5
By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
– Correlation to recycling, remanufacturing and repair

8.6
By 2020, substantially reduce the proportion of youth not in employment, education or training
– No direct correlation to any sustainability aspects

9.A
Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States
- No direct correlation to any sustainability aspects

12.6
Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle
– *No direct correlation to any sustainability aspects*

8.7
Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms
– *No direct correlation to any sustainability aspects*

9.B
Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities
– *No direct correlation to any sustainability aspects*

12.7
Promote public procurement practices that are sustainable, in accordance with national policies and priorities
– *No direct correlation to any sustainability aspects*

8.8
Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment
– *Correlation to worker wellbeing/employee benefits*
– *Correlation to operation safety and health*

9.C
Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020
– *No direct correlation to any sustainability aspects*

12.8
By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature
– *No direct correlation to any sustainability aspects*

8.9
By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products
– *No direct correlation to any sustainability aspects*

12.A
Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
– *No direct correlation to any sustainability aspects*

8.10
Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all
– *No direct correlation to any sustainability aspects*

12.B
Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products
– *No direct correlation to any driver*

8.A
Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries
– *No direct correlation to any sustainability aspects*

12.C
Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities
– *No direct correlation to any sustainability aspects*

8.B
By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization
– *No direct correlation to any sustainability aspects*

PRODUKTION2030

With support from
VINNOVA
Sveriges innovationsmyndighet
Energimyndigheten
FORMAS
Strategic innovation programmes