Fraunhofer ISI

Industry 4.0 in the European Iron and Steel Industry: Towards an Overview of Implementations and Perspectives

Working document

Authors: Christoph Neef, Simon Hirzel, Marlene Arens

Karlsruhe, 05. September 2018

Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Strasse 48
76139 Karlsruhe, Germany

Contact: Dr. Christoph Neef
Phone: 0721 / 6809-350
E-Mail: christoph.neef@isi.fraunhofer.de

Acknowledgements

The authors would like to express their gratitude to all the experts sharing their insights on Industry 4.0 in the iron and steel industry. These include the participants who dedicated their time to the interviews, but also those taking part in the survey.

This investigation was carried out within the strategic initial research program of Fraunhofer ISI.

Table of contents

Executive Summary

The concept of Industry 4.0 is intensively discussed as a means to strengthen the international competitiveness of the European iron and steel industry. While the digitalization of process chains in discrete manufacturing is subject to intense research, only a few studies explore the current implementation and future expectations of Industry 4.0 in energy-intensive process industries like iron and steel. The **aim of this study is to investigate the current activities and expectations concerning Industry 4.0 in the European iron and steel industry**. A mixed methods approach was used that includes a systematic review of the publicly funded projects related to Industry 4.0, patent analysis, a series of expert interviews and a qualitative survey of academics and practitioners dealing with iron and steel making.

The main results of this investigation can be summarized as follows:

- **What is the current status of Industry 4.0 implementation in companies of the European iron and steel industry?**

The results of the project analysis and the interviews indicate that **all major actors of the European iron and steel industry are engaged** in digitalization. Among the various European funding lines, the Research Fund for Coal and Steel stands out regarding R&D projects for digitalizing the European steel industry. It covers about 145 R&D projects and has an average budget of 1.7 million euros.

A considerable share of the projects deal mainly with digitalization. Yet the interviews suggest a divergence between researchers and practitioners in terms of their understanding of what Industry 4.0 entails. Depending on the specific definition and operationalization of the concept, **about 30 to 50 R&D projects are "strongly" focused on Industry 4.0 beyond digitalization**.

In terms of implementation, the **implemented projects are mainly prototype applications and demonstrations.** There are only a few strongly commercially-oriented applications.

- **What are the experiences from these past and present activities?**

Due to the focus on demonstration and limited-scope projects, **practical experiences of the benefits of Industry 4.0 seem limited** in the European iron and steel industry. Many projects **labelled Industry 4.0 deal mainly with automation**, e.g. add sensors or data-driven process control. However, publicly shared information is limited when it comes to practical experience, especially concerning the economic benefits of realized projects.

The discussion of Industry 4.0 does **not focus on solving technical problems alone,** although this is an important component. A major concern is **to frame the topic from an organizational perspective**. Both the interviews and the survey indicate that transforming the organizational structure of a company remains an open challenge. According to the interviews, experience also reveals further **challenges related to updating legacy equipment** (which makes up a substantial part of the current European iron and steel production infrastructure), **understanding how to exploit the collected data** and **the economic situation** of some European steel producers. Yet the survey results also indicate that Industry 4.0 **implementations are required to provide economic benefits and make a strategic contribution** to the development of a company.

- **What role is expected for Industry 4.0 in the future?**

The analysis shows that, despite the uncertainties related to the topic, the **core idea of Industry 4.0 is perceived as a very important topic** for the future of the steel industry (not limited to Europe). Major **improvements are expected in terms of process efficiency and** the ability to develop

new business models. Among others, Industry 4.0 is seen as a means to enhance effectiveness because the associated technology promises **to provide intelligent support systems** for the workforce. There are diverging opinions about the future business models of steel companies. While the survey results suggest that steel manufacturers will not become mainly service providers as is the case, for example, for today's 3d-print shops, the interviewees mentioned this as a more tangible path of evolution.

When looking in more detail at the processes that Industry 4.0 will affect, it can be concluded that **"downstream" production areas like rolling and coating/finishing in the technical domain and the interaction with customers in the organizational domain** are expected to be most affected by Industry 4.0.

- **What are current barriers to and driving forces for implementing Industry 4.0?**

According to the interviews, the **main challenges** facing the European iron and steel industry on the way towards Industry 4.0 are related to **legacy equipment, uncertainty about the impact on jobs and issues of data protection/safety.** In line with this, the survey results suggest that technical barriers are considered less important than organizational issues. The **lack of qualified personnel** was a recurring issue during the interviews and was also rated as very relevant in the survey. Another barrier is related to **short payback requirements,** which might affect implementation since Industry 4.0 projects are often expected to yield both economic benefits and contribute to company strategy.

According to the survey results, **internal management is usually the driving force for the implementation of Industry 4.0 projects** while technology and production are also important but less crucial. This might be explained by the cross-cutting nature of Industry 4.0, which is not limited to technological issues alone. The interview results also indicate that **technological innovations tend to be driven by external parties**. This is in line with the survey results that steel manufacturers tend to rely on external expertise and cooperating with external partners when implementing Industry 4.0 solutions.

1 Introduction

Currently, the topic of Industry 4.0 is being intensively discussed for many industries. This discussion also concerns the iron and steel industry. Industry 4.0 was coined as a term in 2011 in the German High Tech 2020 Strategy (European Commission 2017). The closely related underlying idea of digitalization dates back even further. While Industry 4.0 is hotly debated, its implications for the iron and steel industry are still unclear.

Several initiatives that deal with digitalization and/or Industry 4.0 indicate the topic's relevance for the European steel industry. These include the ESTEP (European Steel Technology Platform) Working Group *Integrated Intelligent Manufacturing (I^2M)* founded in 2008 and the Working Group *Industrie 4.0* of Steelinstitute VDEh from 2014 (Peters 2016). While the latter consists of steelmakers[1] from German speaking countries and the research institution of the Steelinstitute VDEh, the ESTEP working group covers a broader range of stakeholders. It includes European and multinational steelmakers as well as plant manufacturers and several European universities and R&D institutions.[2]

While such activities underline the interest in the topic, specific literature on the actual implementation of Industry 4.0 in the European steel industry remains limited. Material is available in presentations by Peters (e.g. Peters 2016; Peters 2017) and Sube (2017). A report by Steelinstitute VDEh (BFI 2017) provides a more general overview of the implications of Industry 4.0

To complement these analyses, the aim of this study is to investigate the current activities and expectations concerning Industry 4.0 in the European iron and steel industry. The following questions are addressed:

- What is the current status of Industry 4.0 implementation in companies of the European iron and steel industry?
- What are the experiences from these past and present activities?
- What role is expected for Industry 4.0 in the future?
- What are current barriers to and driving forces for implementing Industry 4.0?

To answer these questions, a mixed-methods approach was chosen, including a systematic review of publicly funded projects related to Industry 4.0, patent analysis, expert interviews and a qualitative survey among academics and practitioners concerned with iron and steel making.

This report consists of three main sections: The following section 2 describes the chosen approach. Section 3 provides an overview of the main results, while section 4 provides a summary of the implementation and perception of Industry 4.0 in the iron and steel industry.

---

1 ThyssenKrupp Steel Europe, Salzgitter Flachstahl, Hüttenwerke Krupp Mannesmann, Arcelor Mittal Ruhrort & Bremen, Dillinger, Voestalpine, Stahlwerke Thüringen, Stahlinstitut VDEh, VDEh-Betriebsforschungsinstitut BFI

2 Arcelor Mittal, Tata Steel, ThyssenKrupp Steel Europe, Voestalpine, Ilva, Primetals, Danieli, VDEh-Betriebsfoschungsinstitut BFI, Centro Sviluppo Materiali, Centre d'Excellence en Technologies de l'Information et de la Communication, Scuela Superiore Sant Anna, Lulea University

2 Methodology and data

Industry 4.0 is a complex topic that is still being explored by researchers and practitioners. To provide a broad picture of the topic and its implementation in the European iron and steel industry, a mixed-methods approach was chosen. This combines a review of current R&D projects related to Industry 4.0 in the iron and steel industry, a patent analysis to review other R&D activities, a series of in-depth expert interviews and a broader survey on Industry 4.0. Further details are given below.

2.1 Analysis of R&D projects

Due to the lack of publications on the implementation of Industry 4.0 in the European iron and steel industry, information on publicly funded R&D projects can serve as a proxy to gain insights into current research and development activities in the industry. Thus, project databases on public funding activities offer a good source of information. Therefore, the abstracts and titles of previous and ongoing research projects were scanned with regard to their relevance to Industry 4.0 by matching certain keywords related to Industry 4.0. These covered terms relating to software development, big data, process modelling, predictiveness, human-machine interaction, horizontal and vertical integration, sensors and automation. The list obtained also includes projects that deal with preparatory activities because there is no clear definition of Industry 4.0 so far and there are difficulties discerning Industry 4.0 from less far-reaching digitalization projects. This means that the results presented here also include digitalization and advanced automation projects, e.g. those that use new IT-developments such as advanced sensors or measurements that could be applied (in the future) for real-time (online) data monitoring and response in the context of Industry 4.0.

Table 1: Databases for information about publicly funded R&D projects.

Source	Full title	Period	Source	Literature
RFCS	Research Fund for Coal and Steel	2003-2014 2015-2016	Summaries of RFCS Projects: 2003-2014 Synopsis of the RFCS projects 2015-2016	RFCS 2003-2014 RFCS 2015-2016
FP7	European Union Framework Programme 7	2003-2014	Community Research and Development Information Service (CORDIS database)	European Commission 2018c
H2020	European Union Horizon 2020	2015-2020	Community Research and Development Information Service, CORDIS database	European Commission 2018c
EUREKA	EUREKA	1985-2018	EUREKA projects	Eureka 2018b
SPIRE	Sustainable Process Industry through Resource and Energy efficiency	2015-2020	Community Research and Development Information Service (CORDIS database)	European Commission 2018c

In Europe, typically either national[3] or European research programmes provide public funding for R&D projects in the iron and steel industry. This investigation focuses on the latter. These include the Research Fund for Coal and Steel (RFCS), which is a key funding institution for the industry with an annual budget of about 55 million euros (RFCS 2018). The European Commission also has a general research and innovation funding programme. In the period from 2007 to 2013, this was referred to as the Seventh Framework Programme (FP7) and its successor, Horizon 2020 (H2020), is now in place for the period from 2014 to 2020 (European Commission 2018a). Another European initiative is

[3] Examples include support schemes by the German Ministry of Education and Research, the Dutch Ministerie van Economische Zaken, and the Swedish Innovation Agency Vinnova.

EUREKA, a pan-European network for market-oriented, industrial R&D (Eureka 2018a). Finally, SPIRE (Sustainable Process Industry through Resource and Energy Efficiency) is a public-private-partnership under H2020 for the most important European process industries including the iron and steel industry (European Commission 2018b). Databases for these R&D programmes (Table 1) were scanned for relevant projects.

2.2 Patent analysis

A patent analysis was carried out to complement the review of publicly funded projects and to provide insights into research results or concepts that are judged commercially valuable, independent of public funding. Since no patent classification for Industry 4.0 exists, the search strategy combined keywords and classification codes. The keywords describing Industry 4.0-relevance and the patent classifications (CPC codes) to narrow down the results to the production and processing of iron and steel are given in Table 2.

Table 2: Keywords and CPC codes used for the patent analysis.

Item	Operationalization
Keywords related to Industry 4.0 and digitalization aspects (also similar words)	machine learning, intelligent, smart, tracking, Internet of Things, artificial intelligence, customer integration, vertical integration, horizontal integration, cloud, big data, massive data, machine communication, RFID, autonomous, embedded system, predictive, deterministic, data driven, data handling, wireless, database, cyber, cognitive, logistics.
CPC codes classifying iron and steel production, casting and rolling (sub-codes were also used)	B21B (Rolling of metal) B21C (Manufacture of metal sheets, wire, rods, tubes or profiles) B22D11 (Continuous casting of metals) C21B (Manufacture of iron and steel) C21C (Processing of pig iron) C21D8 (Modifying the physical properties by deformation combined with, or followed by, heat treatment, e.g. hot or cold rolling) C22B (Production and refining of metals)

The analysis was limited to applications to European patent offices or WO patents and patents with a priority date after 2011/01/01. The search strategy was implemented using the STN International database (FIZ Karlsruhe). Patent abstracts were retrieved using the google patents database.

It should be noted that the search strategy based on keywords does not collect all Industry 4.0-relevant patents, since the basic concepts of digitalization, automation and process integration might be part of an invention, but not expressed in terms of typical keywords. Similarly, selecting patents by steel-related CPC codes neglects certain inventions that might be utilized for steel production processes, but have no exclusive reference to the procedure itself (e.g. sensors, algorithms).

In order to verify the results of this keyword and CPC-based search strategy, a manual screening of patents was then carried out for selected European steel producers. Since 2011, ArcelorMittal, ThyssenKrupp Steel, the European sections of TataSteel, Voestalpine, Salzgitter, Saarstahl and Dillinger submitted 230 applications to European patent offices or the WIPO, which were categorized using the CPC codes given above. To screen the R&D projects, the abstracts and descriptions of these 230 patent applications were then analysed manually. The Industry 4.0-relevance was assessed using the authors' expertise and the above-mentioned criteria. Compared to the semi-automated search strategy based on keywords, a similar number (±1) of Industry 4.0-relevant patents was found for each of the companies. It can therefore be concluded that the search strategy captures a valid order of magnitude for the relevant patents.

2.3 Interviews

In addition, several interviews were carried out with high-level stakeholders from major European and international steel producers, plant manufacturers and automation/component providers, industry associations and research institutes. The aim was to gain information about the general perception of Industry 4.0 in the European steel industry and to identify relevant drivers, barriers and priorities. In total, 14 semi-structured interviews were held from June to September 2017, either face-to-face or by telephone.

During the interviews, the stakeholders were asked for their perception of the following topics: the importance of Industry 4.0 for the steel production chain, new technologies (e.g. artificial intelligence, sensors, tracking), the benefits of and drivers for Industry 4.0, time-scales and financing of Industry 4.0 projects, management of knowledge and competences and their personal view regarding the future of steel production in Europe and Industry 4.0 in general. With regard to the development and implementation of new technologies and processes, an additional section addressed collaborative R&D projects on Industry 4.0 between research and industry, specifically the role allocation between the contributing partners and their methods for technology transfer.

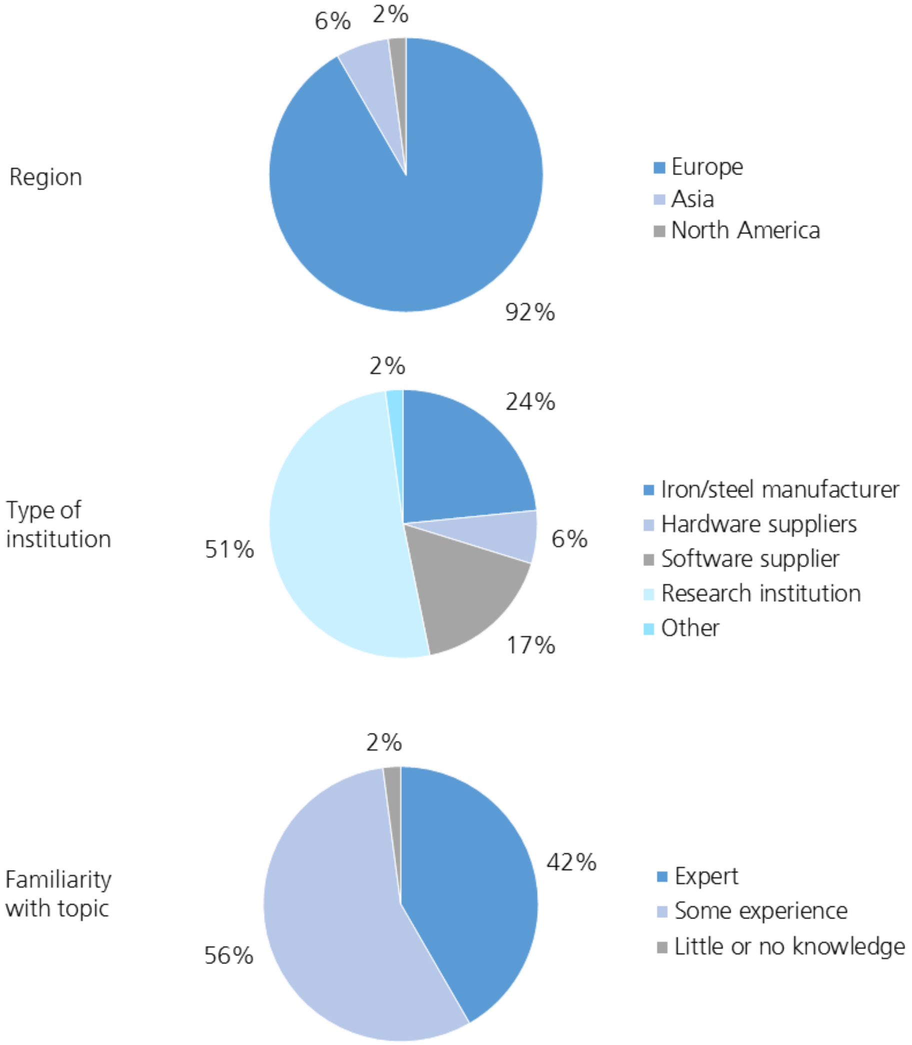
As well as yielding insights into the perception of Industry 4.0, the results of the interviews were also used as a basis for framing the questions and topics for a broader, subsequent survey.

2.4 Survey

The survey was carried out to complement the results from the previous steps. It was the last element of this investigation. After obtaining an overview of ongoing Industry 4.0 activities from the project reviews and patent analysis, the aim of this high-level survey was to obtain a broader view of the current perception and impact of Industry 4.0 on the European iron and steel industry until 2030. The survey took place in May/June 2018 directed at Industry 4.0 experts involved in the iron and steel industry. The participants were mainly chosen based on their participation in publicly funded research projects related to Industry 4.0 in the iron and steel industry, or their attendance at Industry 4.0-focused events. The target group included practitioners from the iron and steel industry (plant operators, suppliers, customers, developers and implementers of digitalization) as well as research staff from R&D departments and public institutions operating in the field. A total of 479 invitations were sent out via e-mail with a total of 48 completed questionnaires returned, corresponding to a response rate of almost exactly 10%. The survey consisted of 25 questions, some with additional sub-items, and typically took roughly 14 minutes to complete.

The large majority of participants (92%) operate mainly in Europe. About one half (51%) are employed in research institutions, while the rest (47%) work mainly for industrial companies, notably iron and steel manufacturers and software suppliers. Asked about their familiarity with the topic, 42% indicated that they consider themselves experts on Industry 4.0 in the iron and steel industry, while 56% said that they have some experience with the topic (Figure 1). The survey participants therefore represent both research and practice in nearly equal shares, they are experienced in the topic and have first-hand opinions of the European iron and steel industry. Nevertheless, it should be noted that this information is based on a self-assessment of the participants and that the survey is not necessarily representative.

Figure 1: Structure of the participants in the survey.



Questions:
a) Which region are you (as a person) mainly operating in? (N=48)
b) What type of institution are you mainly working for? (N=47)
c) How familiar are you with Industry 4.0 in the iron and steel industry? (N=48)

2.5 Methodological remarks and limits

Before proceeding to the results in the next section, some remarks are necessary: With regard to the overview of projects, it should be noted that this is based on public information only. This means that undisclosed R&D activities from organizations are not covered, even if the patent analysis indicates where institutions are relatively active besides the public funding of R&D activities. As pointed out earlier, it also has to be kept in mind that, since there is no clear and commonly accepted definition of Industry 4.0, this paper also covers activities in the field of digitalization. According to Peters (2017), digitalization is a pre-condition for Industry 4.0. Consequently, the paper features activities of which only a minor share might be considered Industry 4.0. For instance, we identified over 100

R&D projects in which the VDEh-Betriebsforschungsinstitut BFI is involved. From discussions with experts, we learnt that this institution is actually only participating in about 20 projects that it considers to be Industry 4.0 projects. One reason for this divergence is the lack of a clear definition of Industry 4.0. However, this exchange also indicates that our approach covers projects perceived as Industry 4.0 projects by key researchers. To distinguish projects that include digitalization aspects from Industry 4.0 projects, we would have to review the final reports of the projects, where available, and consult complementary experts. Both are beyond the scope of this study. Based on our analysis and the expert consultations, we estimate that a total of 30 to 50 RFCS-projects with a strong focus on Industry 4.0 were carried out up to 2017.

The results from the interviews and the survey are also subject to limitations. First, the selection of interview partners and survey participants was limited to those who are interested in the topic, willing to participate and allowed to do so. Requests for interviews were, for example, declined on the grounds of strict information-sharing policies. Furthermore, there are common issues with interviews and surveys related to the socially-desired answers problem, i.e. people might say what they think is expected rather than giving unbiased views. It also has to be noted that the survey was designed as an open, anonymous survey with no sampling or quotation of participants. Finally, it must be kept in mind that the future is impossible to predict and that answers related to future developments are obviously subject to uncertainty.

To sum up, this study aims at providing an overview of the expectations and current implementations of Industry 4.0 in the European iron and steel industry, but it takes an external perspective and only relies on publicly shared information.

3 Results concerning the current implementations and expectations

3.1 Projects related to Industry 4.0 in the European iron and steel industry

The presentation of results concerning R&D activities is structured in three sub-sections: First, projects funded within the RFCS will be discussed as this is the most important programme for R&D in the iron and steel industry. This is followed by projects within other European programmes.[4]

3.1.1 Projects funded by the Research Fund for Coal and Steel

The Research Fund for Coal and Steel is the most important funding scheme for technology development in the European iron and steel industry and thus also for its digitalization. An overview of projects funded within the RFCS is given in two documents; the first for the period from 2003 to 2014 and the second for the period from 2015 to 2017 (RFCS 2003-2014, RFCS 2015-2017). These project overviews contain information on the project names, budgets, start and expected finish dates, abstracts and project participants. In addition, the projects are grouped and listed by process steps (e.g. ore agglomeration and ironmaking, steelmaking process, casting, factory-wide control). While the titles and abstracts give insights into the projects' objectives and the technologies (including digital ones) chosen to achieve them, the assessment of their content using the term "Industry 4.0" depends heavily on definitions.

A total of 145 RFCS-projects were found that cover aspects of digitalization and Industry 4.0, e.g. adaptive online control, through-process optimization, through-process synchronization of data, zero-defect manufacturing, traceability, intelligent and integrated manufacturing. The total budget of the identified projects amounts to 250.1 million euros, resulting in an average budget per project of 1.7 million euros (Table 3).

Table 3: Overview of R&D projects funded by the RFCS

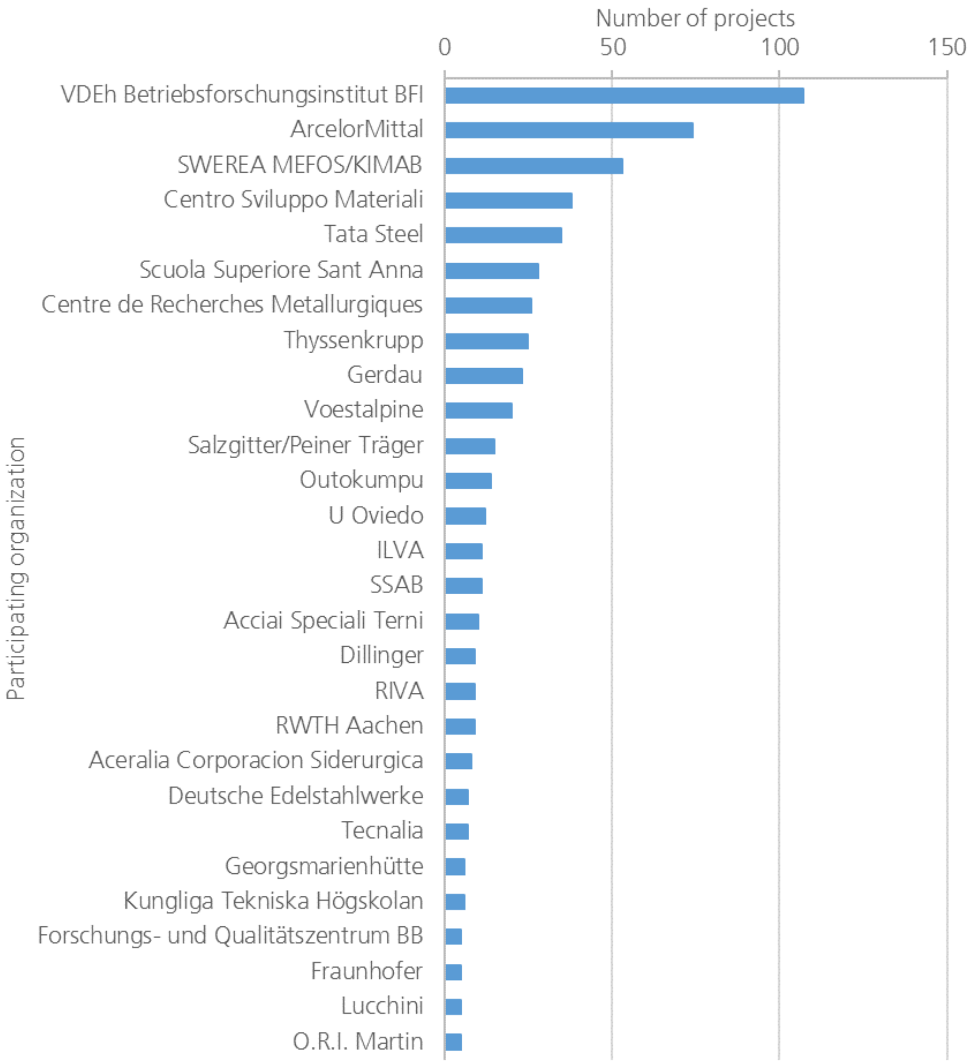
Indicator	Value
Number of identified projects	145
Period	2003 – 2017
Total amount of mentioned budget	250.1 million euros
Average budget by project	1.7 million euros

Projects funded by the RFCS can feature as many as ten project partners. Indeed, there is an extensive number of research institutions, steel producing companies and plant manufacturers or IT-providers. In total, more than 170 organizations were involved in the identified projects, of which 90 participate in only one project, while 47 participate in two or three projects. Two organizations stand out (Figure 2): the VDEh-Betriebsforschungsinstitut BFI (in short: BFI), a German-based research institution with close ties to the Steelinstitute VDEh, which is involved in 73.8 % of the identified projects. The European branch of ArcelorMittal, part of the world's largest steel company (Worldsteel 2017), is also involved in every second project. A group of four research institutions and four steelmaking companies follow: The former are Swerea MEFOS and Swera KIMAB that belong to Swerea, the Swedish Research Institute for Industrial Renewal and Sustainable Growth, as well as the Centro Sviluppo

4 The appendix shows an overview of the acronyms of the identified RFCS projects (Table 5) and projects from other funding schemes (Table 6).

Materiali (now part of RINA SPA) and the Scuola Superiore Sant'Anna di Studi Universitari e di Perfezionamento, both based in Italy, and the CRM Group (Centre de Recherches Metallurgiques) in Belgium. Four steel companies, namely ThyssenKrupp Steel, Tata Steel, Sidenor (formerly Gerdau Investigacion y Desarrollo Europa SA) and Voestalpine, complement the top ten.

Figure 2: Number of RFCS-funded projects by participating organization (2003-2016).



Interestingly, plant manufacturers or IT-providers seem to play only a minor role in RFCS projects concerned with digitalizing the steel industry. When comparing the results of this analysis with the members of the ESTEP Working Group on *Integrated Intelligent Manufacturing*, we find that both groups have large overlaps, with the exception of Swerea MEFOS / KIMAB as well as the CRM Group, which are not part of the ESTEP Working Group.

3.1.2 Projects funded by other European schemes

In addition to the projects funded by the RFCS, sixteen projects were found in other European funding schemes on digitalizing the steel industry, i.e. FP7, H2020, Eureka and SPIRE. These projects have a total budget of 85.9 million euros, resulting in an average budget of 5.1 million euros per project compared to 1.7 million euros in the RFCS-funded projects (Table 4). Some of these projects are not restricted to the steel industry, but have a broader scope. The Recoba project under the H2020 framework, for instance, also covers the chemical industry.

Two thirds of these projects started between 2014 and 2017. Interestingly, we also identified three projects that started in the early 1990s that already cover aspects of digitalizing the steel industry, all funded by EUREKA (OREXPRESS, BRICK, and TAM). These findings support the statement by Hecht (2017) that digitalizing the steel industry started long before these activities were called Industry 4.0.

Analysing the actors in these projects, we find that only five companies are involved in two or more projects. Interestingly, ArcelorMittal again has a leading position in this group of funded projects. It is the only company involved in four projects, while the other four companies each only participate in two projects. ThyssenKrupp and Tata Steel are two steelmaking companies that frequently collaborate in RFCS projects as well as these other projects.

Table 4: Overview of R&D projects funded by other European programmes

Indicator	Value
Number of identified projects	16
EUREKA	7
FP7	1
H2020	6
SPIRE	3
Period	1990 - 2016
Total amount of mentioned budget	85.9 million euros
Average budget per project	5.1 million euros

Besides the formalized research projects on a European level, there are additional activities outside these funding programmes. Due to the lack of public funding, information on these projects is often incomplete. The search identified 31 activities related to digitalizing the European steel industry. These cover a broad range of activities and include research projects funded by national ministries or innovation agencies, one-time events related to Industry 4.0 (e.g. Hack4Steel Belgium) or announcements about advanced steel plants (i.e. Kapfenberg by Voestalpine).

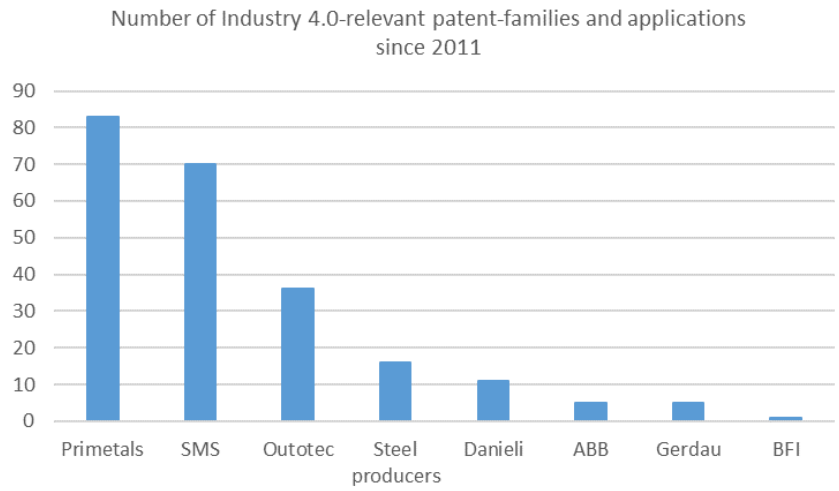
3.2 Results of the patent analysis

The analysis of patents can give insights into the technological but also economic importance attributed to Industry 4.0. Compared to R&D projects, patents are one step further towards the commercialization of new technologies and the intellectual property is either considered to be economically valuable in terms of licensing opportunities or applicants intend to gain competitive advantages by securing the developed methods and products for their own use.

Following the strategy described in the method’s section yields more than 600 Industry 4.0-relevant patent applications (grouped by families) with priority dates in or after 2011 (340 applied for by organizations registered in Europe). The collected data shows no significant increase in patenting activities over time, underlining that - in contrast to the emergence of "Industry 4.0" or "smart production" as umbrella terms - the use of digital methods in iron and steel production has already been pursued for several years.

Figure 3 shows the number of patent applications (grouped by families) since 2011 by organization. Only organizations with four or more applications or organizations appearing in the R&D projects are shown. Two organizations dominate, namely Primetals Technologies and the SMS Group, in terms of both applications and granted patents. Taking into account their predecessors or sub organizations (Siemens VAI, SMS Siemag, SMS Meer), they account for about one third of the patents applied for by organizations registered in Europe.

Figure 3: Number of Industry 4.0-relevant patents (grouped by families) by organization. Only shows organizations with more than four patents and organizations appearing in public R&D projects.[5]



Other plant manufacturers are also represented, but they play a smaller role. The focus of Industry 4.0 patents by plant manufacturers lies in the fields of material tracking, transport and handling and the use of predictive methods in process control.

Compared to the plant manufacturers, European steel producers are much less active in patenting Industry 4.0-relevant inventions. They account for only about 5 % of the identified applications. Among the steel producers, ThyssenKrupp Steel Europe has the highest share. Compared to the elevator division of ThyssenKrupp, the patenting activities of the steel division in the field of Industry 4.0 are much less pronounced. The Industry 4.0 patents by steel producers focus mainly on process control by image processing, human-machine interaction and safety aspects of shared workspaces of humans and machines as well as tracking metal products throughout the steel mill.

The patent landscape shows a certain contrast to the composition of publicly funded R&D consortia and budget allocation. Steel manufacturers and R&D-organizations only hold a comparably small number of patents. However, both types of organizations have a strong presence in RFCS and other funding programmes.

To some extent, this might reflect the pre-competitive character of many of the analysed R&D projects. On the other hand, the large share of intellectual property patented by plant manufacturers might indicate that Industry 4.0 solutions are typically not developed by steel producers themselves.

In practice, the smart linkage of systems and devices or equipping production facilities with digital interfaces and sensors will be at the core of Industry 4.0 implementation. The development of data-

[5] Primetals Technologies including Siemens Vai Metals, SMS Group including SMS Siemag and SMS Meer, Outotec Finland Oy, Steel producers with at least one respective patent (European branch of ArcelorMittal, Thyssenkrupp Steel and TK System engineering, Tata Steel Europe, Salzgitter Flachstahl, Voestalpine), Danieli & COM, ABB, Sidenor (Gerdau Investigacion y Desarrollo) and VDEH-Betriebsforschungsinstitut (BFI).

driven process control strategies, which are then able to utilize the generated information, is often not within the scope and expertise of steel manufacturers, since specialized algorithms and software are needed. Hence, inventions are expected to be generated by second or third parties.

3.3 Results of the expert interviews

In general, the interviewees agreed that Industry 4.0 is a highly relevant topic for the European steel industry and the competitiveness of local producers. They also confirmed that Industry 4.0 is evolving from an R&D subject into a high priority topic for management and that it is moving towards concrete implementation projects.

Nevertheless, it has to be noted that interviewees perceived the term "Industry 4.0" quite heterogeneously. With respect to steel mills, for example, the focus of "Industry 4.0"-projects as seen by practitioners is often on the modernization of IT-infrastructure and the implementation of (commercially available) state-of-the-art equipment and technologies. Researchers, on the contrary, tended to have a different understanding of Industry 4.0. For them, Industry 4.0 is used to describe the utilization of cutting-edge-technologies like artificial intelligence for pattern recognition or prediction in process control, which have scarcely been implemented so far, or for which only a few commercial solutions are currently available (see section 3.1).

Interviewees mentioned that, within mixed consortia of steel producers and research organizations, the implementation of Industry 4.0 is often driven by the latter and new technologies are often developed by players from outside the steel industry. Understandably, steel producers exhibit a certain scepticism when asked to provide their production infrastructure as a test bed for disruptive technologies that are associated with the risk of failure. In practice however, Industry 4.0 projects do not often deal with the implementation of new hardware, but rather with the exchange of existing data and a more intelligent linkage of process steps and organizational units or customer and supplier integration.

The current status of Industry 4.0 implementation projects can be characterized as between demonstration and piloting (utilization of new technologies) and large-scale roll-out (digitalization or modernization of digital infrastructure). Projects to do with digitalization or modernizing digital infrastructure are often a pre-condition for the implementation of more cutting edge Industry 4.0 approaches.

Besides the availability of technologies, it became apparent during the interviews that the training and availability of skilled workers is an issue that the industry will have to deal with. As a branch that is typically not associated with high technology, the steel industry is discussing how to become more attractive to younger people or experts from areas not classically attributed to steel production (e.g. ICT).

When asked about the specific situation of European steel producers, the interviewees pointed out the challenges due to the industry having evolved locally over several decades. In contrast to many Asian steel mills, most European production facilities have not been established recently and use heterogeneous equipment and infrastructure. The extensive utilization of data thus necessitates large investments into harmonizing and standardizing production systems. This can be prohibitive, given the economic situation of some European producers and fierce international competition.

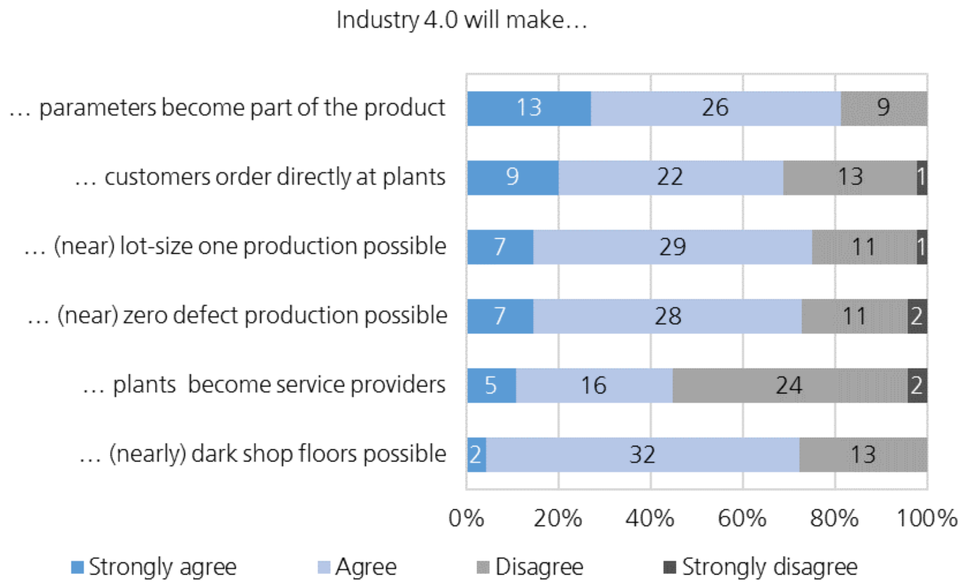
3.4 Results of the survey

This section gives an overview of the survey results. Please note that the sum of usable answers per item may vary, because missing answers were not included to improve the comparability of results. The number of answers per question is indicated below the respective figures.

3.4.1 Expectations concerning the role of Industry 4.0 in 2030

As a starting point, participants in the survey were asked about their expectations concerning Industry 4.0 for the European iron and steel industry in 2030 (Figure 4). The majority (81 %) agrees or strongly agrees that production and/or process parameters will become part of the product. In addition to the product parameters, customers are expected to obtain access to information on the production process that is currently only available to steel manufacturers. Lot-size one production (75 %) and zero defect production (73 %) are also considered feasible options for 2030.

Figure 4: Expectations concerning the European iron and steel industry in 2030.



Questions: With regard to the European iron and steel industry in 2030, do you agree that Industry 4.0 will …

a) … lead to detailed process/production parameters becoming part of the final product? (E.g. customers will be able to review data that is currently only known to producers in addition to product properties) (N=48),

b) … broadly enable final customers to order their products directly at iron and steel plants? (I.e. intermediaries are not needed even for small orders) (N=45),

c) … enable (near) lot-size one production? (E.g. each individual coil is tailor-made according to the customer's requirements) (N=48),

d) … enable (near) zero defect production? (E.g. there are no faulty products due to improved process control, automatic rerouting or remanufacturing) (N=48),

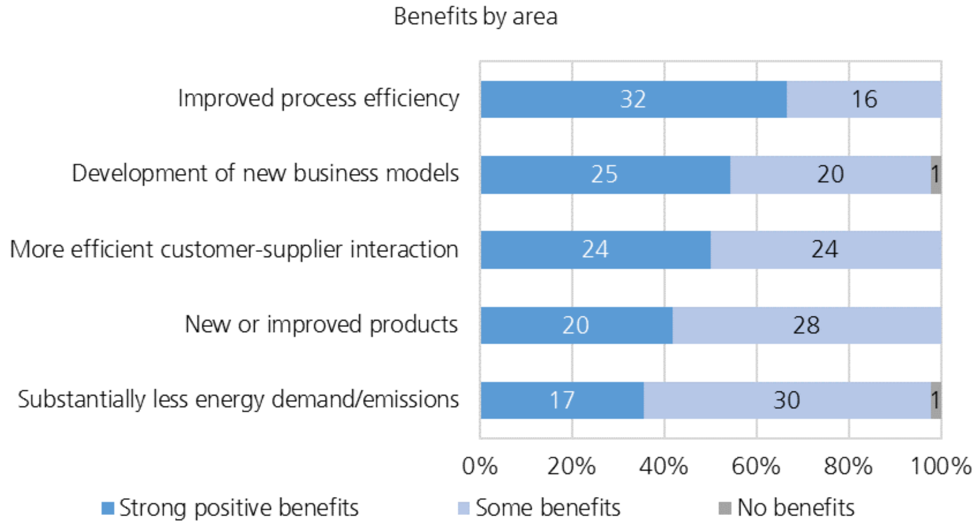
e) … make iron and steel plants largely become on-demand service providers? (I.e. process control data and related knowledge will become public and no longer remain a competitive advantage with plants operating similar to today's 3D-print shops) (N=47),

f) … enable (nearly) dark shop floors? (e.g. production is controlled by intelligent software and process specialists via software/apps mainly from a distance) (N=47).

Approximately two-thirds (69 %) also agree that customers will place their orders directly at steel plants even for smaller orders, eliminating the need for intermediaries. However, fewer participants (45 %) expect steel plants to become mainly on-demand service providers like today's "print shops" for 3D models. More (72 %) expect shop floors to become "darker" in the future, i.e. that production is mainly controlled from a distance.

Industry 4.0 is expected to trigger various benefits for the European iron and steel industry in 2030. More than half the participants (67 %) expect Industry 4.0 to have a strong positive effect on process efficiency. 54 % believe that it will open up opportunities to develop new business models, and 50 % that it will lead to more efficient interaction between customers and suppliers. Product improvements are also expected (42 %), but are less pronounced than improvements in process efficiency. Substantial reductions in energy demand or related emissions are also expected, but fewer of the participants (35 %) expect strong benefits here (Figure 5).

Figure 5: Expected benefits by area for 2030.



Question: What kind of benefits from Industry 4.0 do you expect for the European iron and steel industry in 2030 in the following areas?

a) Improved process efficiency (e.g. smaller workforce, less scrap, fewer resources/energy, less downtime) (N=48)
b) Development of new business models (e.g. digital services, trading platforms, product-service-combinations) (N=46)
c) More efficient customer-supplier interaction (e.g. new B2C channels, customized products, faster order to delivery, advanced product tracking, reduced storage and logistics costs) (N=48)
d) New or improved products (e.g. customized/specialized products, improved product quality) (N=48)
e) Substantially less energy demand/reduced carbon dioxide emissions (due to e.g. improved process control, less scrap, improved planning) (N=48)

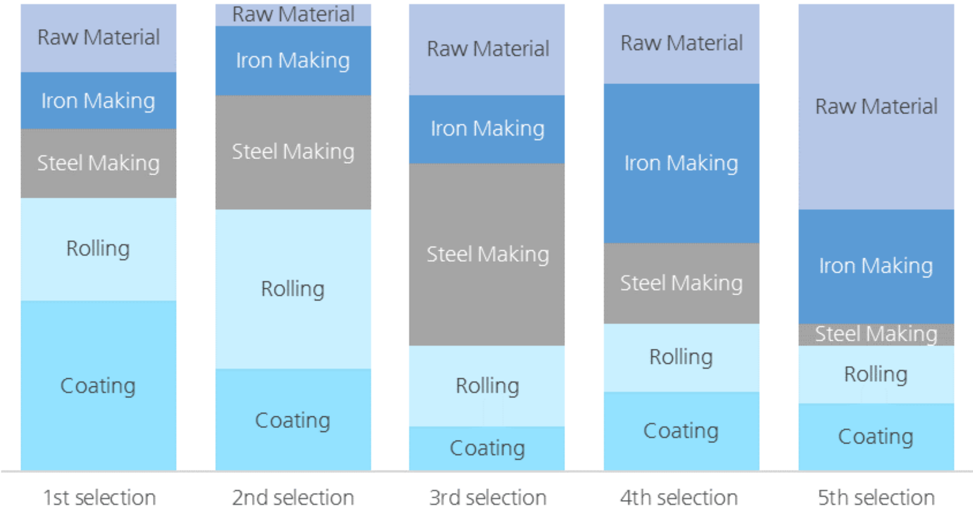
Other benefits mentioned by individual participants include improvements in operational risk management and problem solving strategies, less need for an experienced workforce as systems are expected to help resolve issues and problems, improved product value for final customers and closer relationships with customers.

3.4.2 Evolution towards 2030

Realizing these potential benefits requires changes to the European iron and steel industry. These concern both production and organizational areas. To better understand which areas are most affected, the participants were asked to rank them by the expected degree of change until 2030 from the biggest to the smallest.

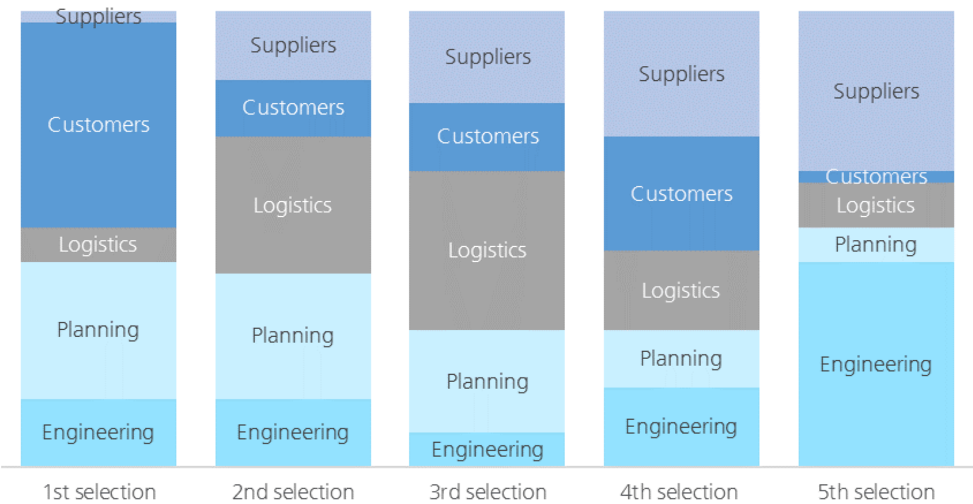
Asked about the biggest changes in production, most participants selected the "downstream" areas "rolling" as well as "coating and finishing". Steel making itself tends to be in the middle, whereas "raw material processing" and "iron making" as "upstream" areas tend to be less affected by future changes (Figure 6).

Figure 6: Areas of production ranked by degree of expected change until 2030 (largest =1 to smallest = 5 change)



Question: Which areas of production in the European iron and steel industry will undergo the biggest changes until 2030? First select the area with the biggest changes, then the second, etc. (N=41)

Figure 7: Organizational areas ranked by degree of expected change until 2030 (largest =1 to smallest = 5 change)

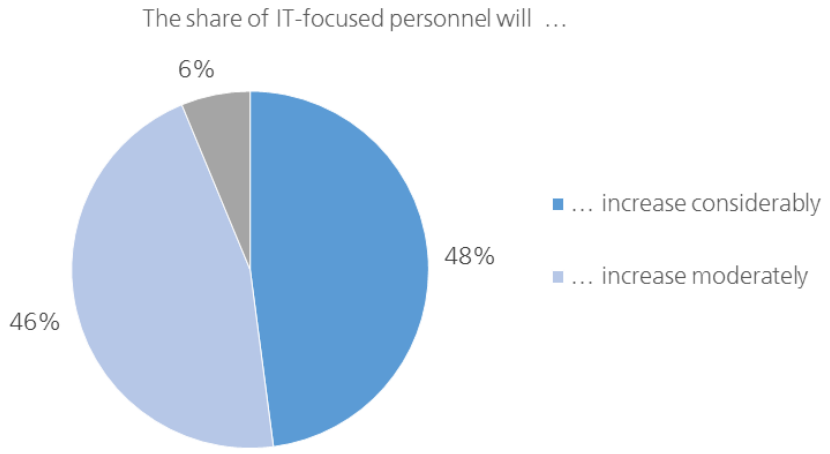


Question: Which organizational areas in the European iron and steel industry will undergo the biggest changes until 2030? First select the area with the biggest changes, then the second, etc. (N=40)

The same question about the organizational area shows a trend that is not as clear as for production: In general, many participants expect major changes in the "interaction with customers", while the "interaction with suppliers" is expected to be less affected. Changes in "internal and external logistics" is often ranked in the middle. The aggregate of "production planning and control" and "plant and equipment engineering" shows no clear trend, though planning tends to be ranked higher and engineering is often seen as the least affected area (Figure 8).

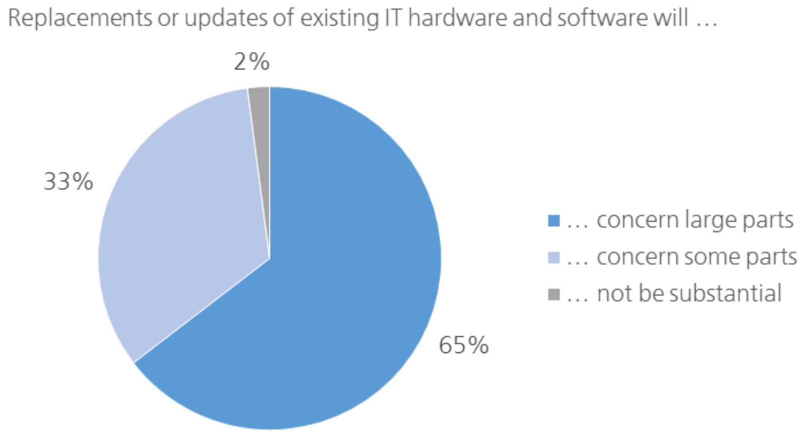
In terms of changes to the workforce, nearly all the participants (94 %) expect changes with regard to the share of IT-focused personnel. Almost half (48 %) expect considerable changes. Yet there are no further indications whether this is due to a general reduction of the workforce in the wake of automation or an absolute increase in IT-focused personnel (Figure 8).

Figure 8: Expected changes to the structure of the workforce until 2030



Question: What changes to the structure of the workforce will occur in European iron and steel plants until 2030? (N=48)

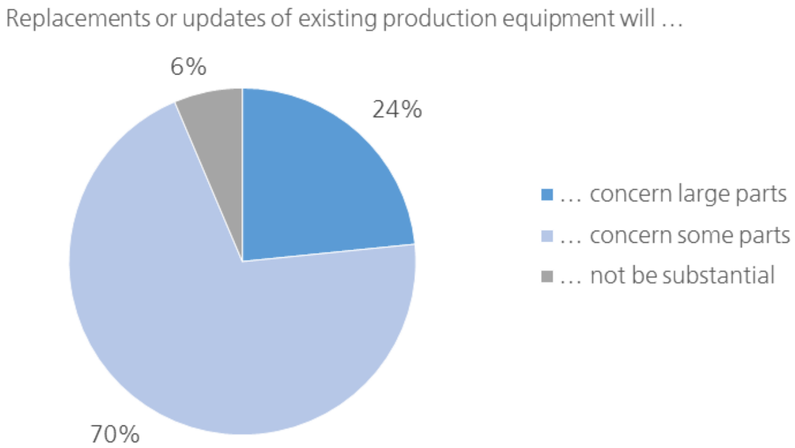
Figure 9: Expected changes to the IT infrastructure until 2030



Question: What changes to the IT infrastructure will have to happen to fully implement Industry 4.0 in European iron and steel plants until 2030? (N=48)

To fully implement Industry 4.0, nearly two out of three participants (65 %) expect that large parts of the existing IT infrastructure, i.e. hard- and software, will have to be replaced or updated (Figure 9). Nearly all the remaining participants (33 %) see the need to modify at least some parts of it. This view of the IT infrastructure can be contrasted with expectations concerning replacements or updates of existing production equipment (Figure 10). There, only roughly one in four participants (24 %) expects changes in large parts, while the majority (70 %) expect some changes. In sum, the IT infrastructure is expected to undergo more extensive changes than production equipment.

Figure 10: Expected changes to production equipment until 2030



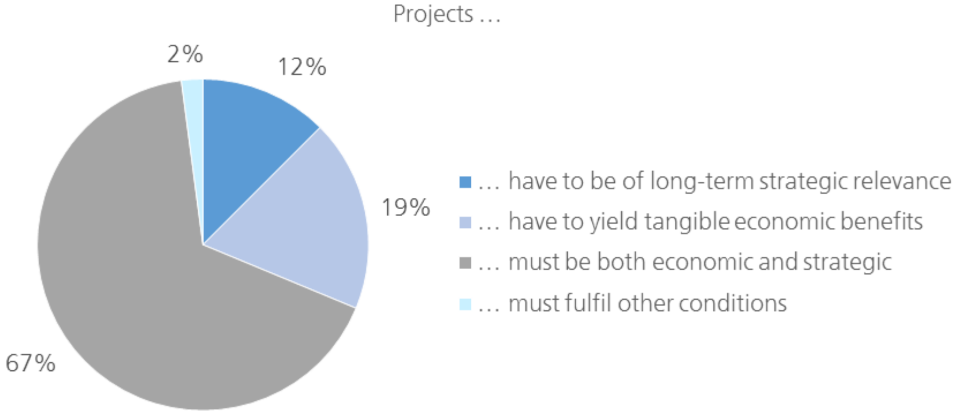
Question: What changes to the production equipment will have to happen to fully implement Industry 4.0 in European iron and steel plants until 2030? (N=47)

3.4.3 Current and future engagement

To implement these changes via Industry 4.0-projects, companies of the European iron and steel industry can follow different strategies. Two thirds (67 %) of the participants indicate that it is important for Industry 4.0 projects to be both economically viable and strategically relevant for a company. Only a fraction of participants (12 %) indicate that the strategic long-term relevance of Industry 4.0 is sufficient on its own, while a slightly higher share point out that tangible economic benefits (19 %) will suffice (Figure 11).

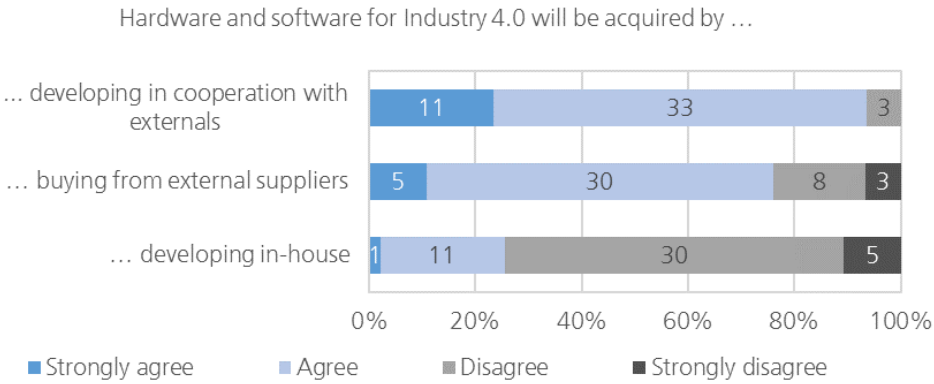
With regard to hardware and software development, the majority agree or strongly agree (94 %) that the European iron and steel industry will focus mainly on development models based on cooperation with external companies and R&D institutions, or that they will purchase these from external suppliers (76 %). Only roughly a quarter (26 %) see in-house developments as a way to acquire new hardware and software. This underlines the importance of the availability of external knowledge for further enhancements (Figure 12).

Figure 11: Conditions for implementing Industry 4.0 projects in European companies



Question: Which conditions for Industry 4.0 projects are most important for their implementation in companies of the European iron and steel industry? (N=48)

Figure 12: Acquisition of hardware and software for the transformation towards 2030



Question: How will the European iron and steel industry acquire hardware and software for Industry 4.0 on its way towards 2030?

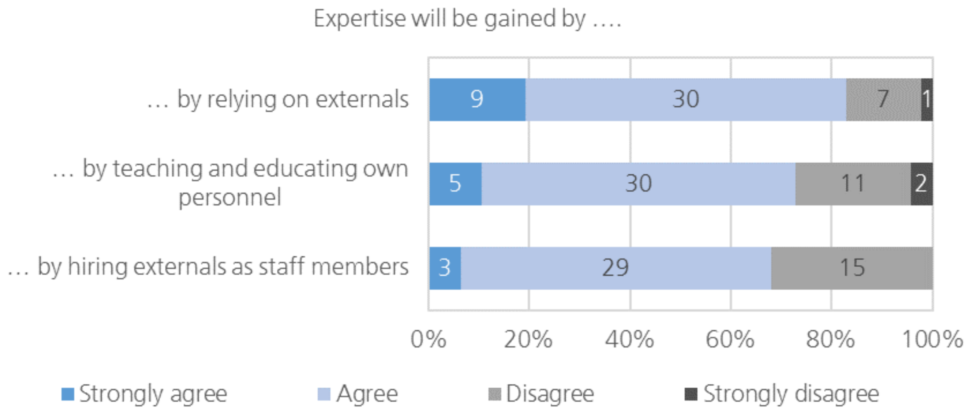
a) Industry will develop new hardware and/or software in cooperation with external companies and R&D institutions (i.e. the iron and steel industry will develop customized solutions in cooperation with hardware and software suppliers). (N=47)

b) Industry will buy complete hardware and/or software from external suppliers (i.e. off-the-shelf software and hardware will be acquired from external sources which will be customized by adjusting default values). (N=46)

c) Industry will develop new hardware and/or software in-house (i.e. internal R&D departments will have resources and experts to cover all necessary areas). (N=47)

With regard to obtaining the expertise for the transition, the results indicate that there is a slight tendency to rely on external specialists, suppliers and consultants (83 % of participants agree or strongly agree). However, there was also broad agreement for educating and training own personnel (73 %) as well as hiring external specialists as new staff members (68 %) (Figure 13).

Figure 13: Acquisition of expertise for the transformation towards 2030



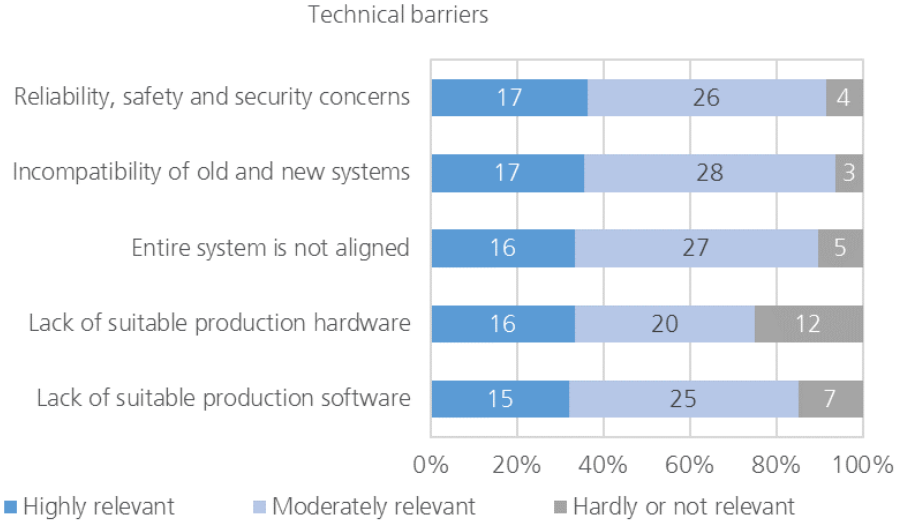
Question: How will the European iron and steel industry gain its expertise on Industry 4.0 on its way towards 2030?
a) Industry will rely on external specialists, suppliers and consultants. (N=47)
b) Industry will teach and educate their own personnel to become specialists. (N=48)
c) Industry will hire externally trained specialists and make them staff members. (N=47)

3.4.4 Current barriers to and drivers for the implementation

Implementing Industry 4.0 can be subject to various barriers. Participants were asked to judge the current relevance of barriers to the implementation of Industry 4.0 in the European iron and steel industry. The answers indicate that different barriers prevail and that the different technical barriers are of nearly equal importance (32% to 36% of participants see them as highly relevant). These include concerns about reliability, safe and security, about technical compatibility and the alignment of entire systems and about the availability of suitable production hardware and software. Note that the lack of suitable production hardware is considered as relevant slightly less often when compared to software, but the results might be influenced by the comparatively large number of hardware suppliers (Figure 14).

Compared to technical barriers, organizational barriers are considered more relevant. The lack of qualified personnel is considered especially relevant (74 % of all answers), but short payback requirements are also considered by many (61 %) to be important. The majority (51 %) also consider uncertainty or missing information about the economic benefits of Industry 4.0 to be highly relevant. The classical split-incentive problem is less relevant, i.e. costs and benefits that are attributed to different departments or organizational units (Figure 15).

Figure 14: Current technical barriers to the implementation of Industry 4.0



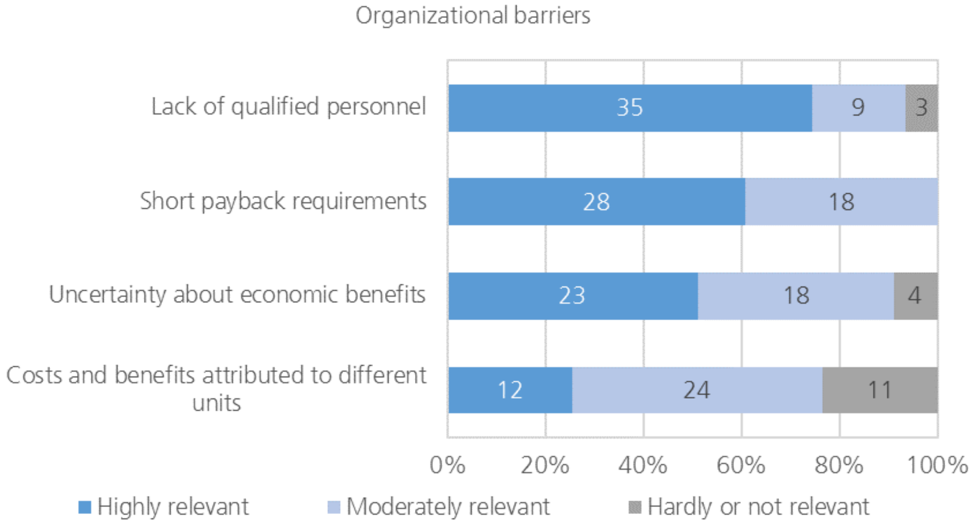
Question: How relevant are the following technical barriers currently to the implementation of Industry 4.0 in the European iron and steel industry?

a) Reliability, safety and security concerns (e.g. process data safety, security risks, fear of process disruptions) (N=47)
b) Incompatibility of old production systems and new hardware, software and control systems (N=48)
c) Industry 4.0 projects cannot yield their full benefits as the entire system is not aligned accordingly (N=48)
d) Lack of available and suitable production hardware (e.g. hardware with integrated sensors, measuring systems, big data storage systems) (N=48)
e) Lack of available and suitable production software (e.g. algorithms, artificial intelligence, tools) (N=47)

Again, individual participants described additional barriers they believe to be important. These included the following: a) It is difficult to ensure a match between the skills of the workforce and new systems and business models; b) There is a tendency to preserve the status quo rather than to innovate and proper change management is missing; c) Data validation has yet not been sufficiently recognized as vital; d) A clear vision of the potential benefits of Industry 4.0 is missing beyond just collecting all kinds of data; and e) Competition and anti-trust laws prevent the necessary collaborations.

In the context of barriers to Industry 4.0, it is also interesting to identify the groups that are actually driving the implementation of Industry 4.0. The participants were asked whether they perceive internal management, technology and production or external suppliers of hardware and software as drivers for Industry 4.0. The results underline that all these groups are relevant, but internal management is considered the main driver by 79 % of participants. Technological departments (45 %) and external suppliers (38 %) play a less important but still relevant role (Figure 16).

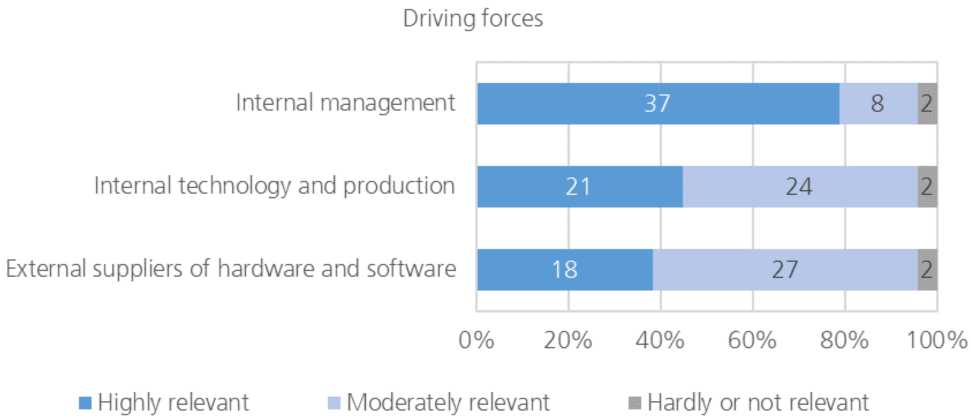
Figure 15: Current organizational barriers to the implementation of Industry 4.0



Question: How relevant are the following organizational barriers currently to the implementation of Industry 4.0 in the European iron and steel industry?

a) Lack of qualified personnel (N=47)
b) Short payback requirements are in contradiction with the long-term benefits of investments in Industry 4.0 (e.g. projects are only started if they pay off within few years) (N=46)
c) Uncertainty or missing information about the economic benefits of Industry 4.0 implementations (N=45)
d) The costs and benefits of Industry 4.0 projects are attributed to different departments/division/organizational units (e.g. by internal accounting rules) (N=47)

Figure 16: Relevance of groups as driving forces for Industry 4.0?



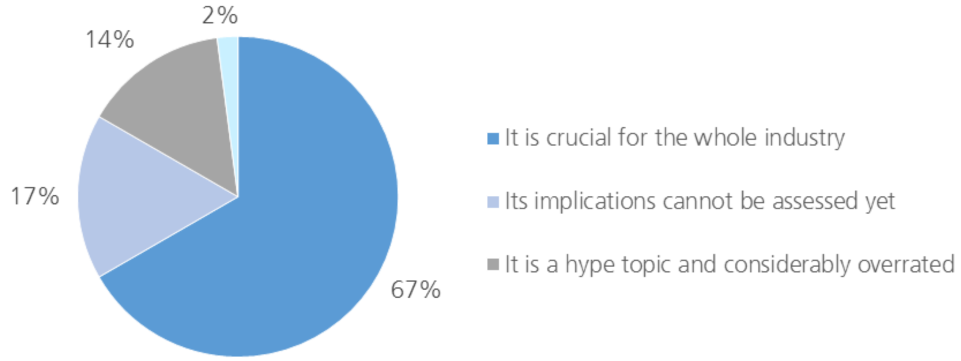
Question: How relevant are the following groups currently as driving forces for Industry 4.0 in the European iron and steel industry?

a) Internal management (e.g. CEO, CIO, middle and lower management) (N=47)
b) Internal technology and production (e.g. research division, developers, IT specialists) (N=47)
c) External suppliers of hardware and software (N=47)

3.4.5 General perception of Industry 4.0

The survey concluded by confronting the participants with four statements about Industry 4.0 and asking them to choose the statement that best matches their perception of its relevance for the iron and steel industry. The majority of participants (67 %) stated that they see the topic as crucial for the iron and steel industry worldwide. A smaller proportion (17 %) think that the implications of Industry 4.0 cannot be assessed yet, while a similar share (14 %) perceive Industry 4.0 as a hype and considerably overrated (Figure 17).

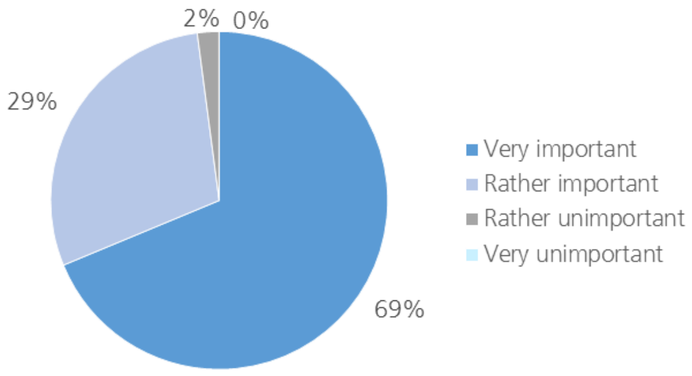
Figure 17: Perception of the relevance of Industry 4.0 for the iron and steel industry (not limited to Europe).



Question: Which statement matches best your perception of Industry 4.0 in the iron and steel industry in general (not limited to Europe)? (N=48)

Nevertheless, nearly all the participants (98 %) see Industry 4.0 as rather or very important for the competitiveness of the European iron and steel industry (Figure 18). The above mentioned limitations about the representativeness of the survey should be taken into consideration here. It is likely that the participants represent those particularly interested in the topic.

Figure 18: Perception of the importance of Industry 4.0 for the competitiveness of the European iron and steel industry.



Question: In sum: How important is Industry 4.0 for the competitiveness of the European iron and steel industry? (N=48)

4 Conclusions

The aim of this study was to investigate the current activities and expectations concerning Industry 4.0 in the European iron and steel industry. It was based on a review of publicly funded R&D projects, a patent analysis, a series of expert interviews and a survey. Although this investigation has limits, we found the following answers to the initial questions:

The main results of this investigation can be summarized as follows:

- **What is the current status of Industry 4.0 implementation in companies of the European iron and steel industry?**

The results of the project analysis and the interviews indicate that **all major actors of the European iron and steel industry are engaged** in digitalization. Among the various European funding lines, the Research Fund for Coal and Steel stands out regarding R&D projects for digitalizing the European steel industry. It covers about 145 R&D projects and has an average budget of 1.7 million euros.

A considerable share of these projects deal mainly with digitalization. Yet the interviews suggest a divergence between researchers and practitioners in terms of their understanding of what Industry 4.0 entails. Depending on the specific definition and operationalization of the concept, **about 30 to 50 R&D projects are "strongly" focused on Industry 4.0 beyond digitalization**.

In terms of implementation, the **implemented projects are mainly prototype applications and demonstrations.** There are only a few strongly commercially-oriented applications.

- **What are the experiences from these past and present activities?**

Due to the focus on demonstration and limited-scope projects, **practical experiences of the benefits of Industry 4.0 seem limited** in the European iron and steel industry. Many projects **labelled Industry 4.0 deal mainly with automation**, e.g. add sensors or data-driven process control. However, publicly shared information is limited when it comes to practical experience, especially concerning the economic benefits of realized projects.

The discussion of Industry 4.0 does **not focus on solving technical problems alone,** although this is an important component. A major concern is **to frame the topic from an organizational perspective**. Both the interviews and the survey indicate that transforming the organizational structure of a company remains an open challenge. According to the interviews, experience also reveals further **challenges related to updating legacy equipment** (which makes up a substantial part of the current European iron and steel production infrastructure), **understanding how to exploit the collected data** and **the economic situation** of some European steel producers. Yet the survey results also indicate that Industry 4.0 **implementations are required to provide economic benefits and make a strategic contribution** to the development of a company.

- **What role is expected for Industry 4.0 in the future?**

The analysis shows that, despite the uncertainties related to the topic, the **core idea of Industry 4.0 is perceived as a very important topic** for the future of the steel industry (not limited to Europe). Major **improvements are expected in terms of process efficiency and** the ability to develop **new business** models. Among others, Industry 4.0 is seen as a means to enhance effectiveness because the associated technology promises **to provide intelligent support systems** for the workforce. There are diverging opinions about the future business models of steel companies. While the survey results suggest that steel manufacturers will not become mainly service providers as is the case, for example, for today's 3d-print shops, the interviewees mentioned this as a more tangible path of evolution.

When looking in more detail at the processes that Industry 4.0 will affect, it can be concluded that **"downstream" production areas like rolling and coating/finishing in the technical domain and the interaction with customers in the organizational domain** are expected to be most affected by Industry 4.0.

- **What are current barriers to and driving forces for implementing Industry 4.0?**

According to the interviews, the **main challenges** facing the European iron and steel industry on the way towards Industry 4.0 are related to **legacy equipment, uncertainty about the impact on jobs and issues of data protection/safety.** In line with this, the survey results suggest that technical barriers are considered less important than organizational issues. The **lack of qualified personnel** was a recurring issue during the interviews and was also rated as very relevant in the survey. Another barrier is related to **short payback requirements,** which might affect implementation since Industry 4.0 projects are often expected to yield both economic benefits and contribute to company strategy.

According to the survey results, **internal management is usually the driving force for the implementation of Industry 4.0 projects** while technology and production are also important but less crucial. This might be explained by the cross-cutting nature of Industry 4.0, which is not limited to technological issues alone. The interview results also indicate that **technological innovations tend to be driven by external parties**. This is in line with the survey results that steel manufacturers tend to rely on external expertise and cooperating with external partners when implementing Industry 4.0 solutions.

Literature

BFI Betriebsforschungsinstitut des VDEh, 2017, "Stahl 4.0: Interpretation von Industrie 4.0 für die Stahlindustrie", Fachausschussbericht Nr. 5.063

European Commission, 2017, Germany: Industry 4.0, Digital Transformation Monitor, January 2017.

European Commission, 2018a, Research and Innovation funding 2014-2020, https://ec.europa.eu/research/fp7/index_en.cfm, accessed 2018-01-08.

European Commission, 2018b, Sustainable Process Industry, http://ec.europa.eu/research/industrial_technologies/sustainable-process-industry_en.html, accessed 2018-03-05.

European Commission, 2018c, Community Research and Development Information Service CORDIS, https://cordis.europa.eu/projects, accessed 2018-03-05.

Eureka, 2018a, What is Eureka? http://www.eureka.dlr.de/en/129.php, accessed 2018-01-08.

Eureka, 2018b, Eureka projects, http://www.eurekanetwork.org/eureka-projects, accessed 2018-01-08.

Hecht, M., 2017, Industrie 4.0 der Dillinger Weg, Stahl und Eisen 137 (4).

Peters, H., 2016, Application of Industry 4.0 concepts at steel production from an applied research perspective, Presentation at 17th IFAC Symposium on Control, Optimization, and Automation in Mining, Mineral and Metal Processing.

Peters, H., 2017, How could Industry 4.0 transform the Steel Industry? Presentation at Future Steel Forum, Warsaw, 14.-15.6.2017.

Research Fund for Coal and Steel, RFCS, 2003-2014, Summaries of RFCS Projects: 2003-2014, http://ec.europa.eu/research/industrial_technologies/pdf/rfcs/summaries-rfcs_en.pdf, accessed 2018-01-08.

Research Fund for Coal and Steel, RFCS, 2015-2016, Synopsis of the RFCS projects 2015-2016, http://ec.europa.eu/research/industrial_technologies/pdf/rfcs/synopsis_projects_2015-16.pdf, accessed: 2018-01-08.

Research Fund for Coal and Steel, RFCS, 2018, What is the Research for Coal and Steel Fund (RFCS)? http://ec.europa.eu/research/industrial_technologies/rfcs_about.html, accessed 2018-01-08.

Sube, G., 2017, Recipes for a successful digital transformation, Presentation May 09th, 2017, ThyssenKrupp Steel Europe.

World Steel, 2017, World Steel in Figures. https://www.worldsteel.org/en/dam/jcr:0474d208-9108-4927-ace8-4ac5445c5df8/World+Steel+in+Figures+2017.pdf, accessed: 2018-02-20.

Abbreviations

Abbr.	Abbreviation
CORDIS	Community Research and Development Information Service
CPC	Cooperative Patent Classification
ESTEP	European Steel Technology Platform
FP7	Seventh Framework Programme
H2020	Horizon 2020
I2M	Integrated Intelligent Manufacturing
ICT	Information and Communication Technologies
R&D	Research and Development
RFCS	Research Fund for Coal and Steel
RFID	Radio Frequency Identification
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
WIPO	World Intellectual Property Organization

Appendix

Table 5: List of acronyms of the identified projects within the RFCS

Acronyms				
AdaptEAF	EAFCAMERA	INNOSOLID	OPCONSTAINLESS	SensorControPilot
ADCTEC	EAFDYNCON	INTCLEANCON	OPTCOOLUB	SHAPEHPM
AlCirc	EDDYCAST	IPCDS	OptDeslag	SHELL-THICK
ANALCO	EDGECONTROL	IPRO	OPTHEAT	SimulEAF
AUTOADAPT	ENCOP	IPTINGOT	OPTIBLAFINS	SIMUSTEEL
Autocheck	EnergyDB	KNOWDEC	OPTILUB	Sinter efficiency
Autodiag	Enhanced BF Operations	Lacomore	OptiScrapManage	SISCON
BOFDEDUST	ERAMAC	LADTHERM	OPTISHAMP	SLACON
BOFdePhos	EvalHD	LAREFMON	OPTITUBE	SMARTFIRE
BOFDYN	FACTMON	LCS	ORSC	SOFTDETECT
CASTDESMON	FINALPLATEFLATN.	LINECOP	OSCANEAF	SoProd
CASTINCREM	Flat strip control	LOWCNEAF	OXYMON	SSSSS
CHATTER	FLEXCHARGE	MACO Pilot	PerMonLiSt	StackMonitor
CheckSIS	FLEXPROMUS	MASTERBILLET	Plant Temp	StImprove
CLOGGING	FLOWVIS	MeltCon	PLUGWATCH	SUPERCHARGEEAF
Cognitive Control	FOMTM	Memorace	Predinc	SUPSYSCC
CONOX	FOSUCOR	MICROCONTROL	PRESED	SURFQUALDEV
Consistent BF	GASNET	MicroControl-P.	PRESEG	SUSTAINTAP
Cyber-POS	GLOBALSHAPECONTR.	Modelcor	PUC	TECPLAN
DECFLAQ	Hearth efficiency	MONWIRE	RAMSCI	TOPOMETER
DEFFREE	HIGH-PICK	MULTISAVE	RAPCOAT	TotOptLis
Deprex	HIRODS	NDTCASTING	REFFIPLANT	TRACKOPT
DIRECT DEF.	I2MSteel	NDTSLAB	REMOCOAL	TUNDJUST
DOT Application	IConSys	NEXTEP	ROLLMARK	ULTRAFINE
DroMoSPlan	ICONTENS	Nox-RF	ROLLWITECH	VADPSHEETS
DUMICO	ILORA	O-Chess	Scale Control	VirtROLL
DYNAMO	IMGALVA	OFFGAS	SCRAP PROBE	WAVIMETER
DYNERGYSteel	INCLUSION	OMC	SELSA	WAVISURF
DynStir	INFOMAP	ONDECO	SensoCont	ZINCANA

Table 6: Acronyms of identified other EU-projects

EUREKA	FP7	H2020	SPIRE
Orexpress	FACTORY-ECOMATION	DECRON	DISIRE
TAM		I-ThERM	EPOS
BRICK		LoCO2Fe	
H2PREDICTOR		COCOP	
HOPLITES		Recoba	
MILLTECH		Intensified by Design	
TOP-RADAR			