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Dean Stroud · Antonius Johannes Schröder · Luca Antonazzo · Clara Behrend · Valentina Colla · Aitor Goti · Martin Weinel *Editors*

Industry 4.0 and the Road to Sustainable Steelmaking in Europe

Recasting the Future

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In memory of our colleague, Enrico Gibellieri (1947–2023)

Preface

This edited collection is a direct result of the activities of the ERASMUS+ funded project 'European Steel Skills Agenda' (ESSA), which aimed to develop a blueprint for a common European skills agenda of the steel sector. By investigating technological transformation, environmental challenges and developing understandings of the current skills profile of Europe's steel workforce, the ESSA project focused on developing a new sector skills strategy. The project brought together people working across the sector, including companies, training providers, representatives of industry associations and trade unions, as well as researchers and other stakeholders.

What has come out of ESSA goes beyond a simple exchange within the sector but comprises an overarching European education and economic endeavour that aims at a digital, green and prosperous Europe. In the course of the ESSA project the consortium and its ecosystem have gathered new knowledge, from which this book aims to present a rich cross-cutting overview of workforce development in the European steel industry. It represents various perspectives, topics, developments and solutions from ESSA and a range of other steel-focused projects to discuss the technical and social challenges of the twin transition towards digital and green production.

Overall, this volume employs the steel industry as a lens through which to provide an international perspective of sector transformation and transition and it is likely to be of interest to academic scholars in the areas of engineering, technology studies, human resources, labour process theory, employment relations, and skills formation. Based on original and cutting-edge research, the book is informed directly by sector-specific projects and offers a distinct sector analysis of Industry 4.0, digital technologies, decarbonisation, robotics, skills and workforce development and human resources that is also likely to attract interest from a range of industry stakeholders, from both within and outside the steel sector, including employers, trade unions and associated federations and business organisations.

The editorial team includes highly published engineering and social science researchers and scholars of the steel industry from across Europe—Antonius Johannes Schröder, Clara Behrend and Martin Weinel from Germany, Luca Antonazzo and Valentina Colla from Italy, Aitor Goti from Spain and Dean Stroud from the UK—who have pulled together a range of contributors with the aim of providing an informed and European perspective on recent and future developments across the sector. This is particularly as the latter applies to the industry's workforce and the skill implications of the twin challenges of digitalisation and decarbonisation, towards building a sustainable steel industry in Europe.

Cardiff, UK — Dean Stroud
Dortmund, Germany — Antonius Johannes Schröder
Prague, Czech Republic — Luca Antonazzo
Dortmund, Germany — Clara Behrend
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The publication of this research has been co-financed by the UD-Santander 2021 Research Award within the framework of the ESSA project. The editors further would like to thank the Technical University Dortmund, Cardiff University, the Scuola Superiore Sant’Anna and Deusto University for their financing of open access of the chapters in this book.

Finally, many thanks to the contributors to this volume for providing their insights on the direction the steel industry is taking. In particular, we thank our industrial partners and their contributions on what it takes to deliver a more sustainable and competitive European steel industry informed by the latest technologies and made possible by the efforts of a dedicated and highly skilled workforce. We pay special thanks and remembrance to Enrico Gibellieri who dedicated his career to the advancement of the European steel industry, and who sadly passed away the summer of 2023.

Contents

Editors and Contributors

About the Editors

Dean Stroud is a reader at Cardiff University School of Social Sciences teaching and researching on skills and workforce development, particularly in relation to the European steel industry, on which he has numerous publications. He has led and participated in numerous projects funded from a range of sources, mostly European, which have focused on skills needs, technological innovation, greening, equality and diversity, and, more generally, the 'human factors' of steel production. Currently, he is co-coordinator of the Erasmus+ European Steel Skills Agenda (ESSA) project and was a sector expert, with Antonius Johannes Schröder and Enrico Gibellieri, to the EASME-COSME funded Steel Sector Careers project.

Antonius Johannes Schröder is senior researcher and member of management board of Sozialforschungsstelle (sfs) (Social Research Centre, Faculty of Social Sciences at the TU University Dortmund), responsible for international research. He has worked in and managed several European projects, recently co-ordinating two EU Erasmus+ funded sectoral European Skills Alliances (ESSA and SPIRE-SAIS). He is Chairman of the Focus Group People within the European Steel Technology Platform ESTEP, the chair of the Task Force Non-technological and Social Innovation within Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) and Chair of the senate of the German Professional Association of Social Scientists (BDS).

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Aitor Goti is associate professor at the University of Deusto. Prior to that, and among others, he was the director of the Deusto Digital Industry Chair, Operations Deputy Director of an industrial multinational included at the Spanish trading market, and responsible for a research line at the University of Mondragon. Aitor has published over 100 articles, over 40 of them in journals with impact in the Journal Citation Reports and/or the Scimago Journal Rank. As a consequence of his activity, Aitor has made about 40 transfer projects financed by companies, resulting in the training and formation of 50 interns or hired personnel.

Martin Weinel is a researcher based at Cardiff University. His area of research includes the Sociology of Scientific Knowledge, in particular scientific controversies; generation and validation of scientific knowledge, studies in expertise and experience: classification of expertise, technical decision-making; relationship between technical and political decision-making. More recently his research has focused on steel and industrial contexts, and he has published extensively across all areas of his research interests.

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Abbreviations, Acronyms and Initialisations

ABSC	Activity-Based Standard Costing
AI	Artificial Intelligence
AIE	Alkaline Iron Electrolysis
AM	Additive Manufacturing
AR	Augmented Reality
BB	Building Blocks
BF	Blast Furnace
BI	Business Intelligence
BOF	Basic Oxygen Furnace
CC	Comparative Capitalism
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Usage
CCUS	Carbon capture, Utilisation and Storage
CDA	Carbon Direct Avoidance
CE	Circular Economy
CEN	Comité Européen de Normalisation/European Committee for Standardization
CEPIS	Council of European Professional Informatics Societies
CME	Coordinated Market Economy
CNC	Computer Numerical Control
CNN	Convolutional Neural Network
CPS	Cyber-Physical Systems
CPSoS	Cyber-Physical Systems of Systems
CSP	Clean Steel Partnership
DG	Directorates-General
DNN	Deep Neural Network
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EC	European Commission
ECSC	European Coal and Steel Community
EGD	European Green Deal

EIIs	Energy Intensive Industries
ERA	European Research Area
ERP	Enterprise Resource Planning
ESCO	Classification of European Skills, Competences, and Occupations
ESIR	Expert Group on the Economic and Societal Impact of Research and Innovation
ESSA	European Steel Skills Agenda
ESTEP	European Steel Technology Platform
EU	European Union
EUROFER	European Steel Association
EUWIN	European Workplace Innovation Network
EVP	Employer Value Proposition
GHG	Greenhouse Gas
H2-DR	Hydrogen-based Direct Reduction
HMI	Human-Machine Interface
HPSR	Hydrogen Plasma Smelting Reduction
HR	Human Resources
IBRSR	Iron Bath Reactor Smelting Reduction
ICT	Information and Communications Technology
IEA	International Energy Agency
IIoT	Industrial Internet of Things
ILO	International Labour Organisation
ISCO	International Standard Classification of Occupations
IoT	Internet of Things
KETs	Key Enabling Technologies
LME	Liberal Market Economy
M2M	Machine to Machine
MES	Manufacturing Execution System
ML	Machine Learning
MOE	Molten Oxide Electrolysis
NECP	National Energy and Climate Plan
OEM	Original Equipment Manufacturer
P4Planet	Processes4Planet
PI	Process Integration
PPP	Public Private Partnerships
R&D	Research &Development
RFCS	Research Fund for Coal and Steel
ROS	Robot Operating System
SBTC	Skill Biased Technological Change
SCU-CCU	Smart Carbon Usage—Carbon Capture & Utilisation
SCU-PI	Smart Carbon Usage Process Integration
SDGs	Sustainable Development Goals
SMEs	Small and Medium-sized Enterprises
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency

SPIRE-SAIS	Skills Alliance for Industrial Symbiosis
STEM	Science, Technology, Engineering, and Mathematics
UAV	Unmanned Aerial Vehicles
UGV	Unmanned Grounded Vehicles
UN	United Nations
VET	Vocational education and training
VoC	Varieties of Capitalism
VUCA	Volatility, Uncertainty, Complexity and Ambiguity
WIP	Work in Process

List of Figures

Aiming for Industry 4.0: The Case of the Czech Republic

The Cold Rolling Industry: Demographic Changes and Further Challenges—Impacts on the Workforce and Current Status of the KaWaGi Project

Preparing for a Digital Steel Industry: What Challenge for Skills Formation Systems?

List of Tables

Introduction: The Historic Importance and Continued Relevance of Steel-Making in Europe

Martin Weinel, Luca Antonazzo, Dean Stroud, Clara Behrend, Valentina Colla, Aitor Goti, and Antonius Johannes Schröder

1 Introduction

In some sense, the European steel industry is the most European of industries as it has been inextricably intertwined with the conception, establishment and development of a political, social, cultural and economic entity that is known today as the European Union (EU). Indeed, the emerging European project started out as the European Coal and Steel Community (ECSC) in 1952 (European Commission 2023a).

One of the key reasons for the prominence of steel and the steel industry in the emergence of the European project is its strategic importance. Since the late 1800s, steel has become one of the critical ingredients of most large-scale infrastructure developments, whether this concerns the rapid urbanisation where steel plays an

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important role in construction projects or the development of transport networks where steel is for example used to build railway lines or bridges. In the post-war era, however, steel was recognised as one of the critical resources that can fuel and decide wars as the material plays such an important role in the manufacturing of weapons of all kinds. One of the key purposes of the ECSC was to prevent yet another European war by creating a unified and jointly regulated market for coal and steel which was supposed to create economic growth, increase employment opportunities and improve living standards across the 6 original signatory states.

While the relative economic and political importance of the steel industry for the European project has decreased over subsequent decades, its absolute importance is still high, and as some would say (e.g. WindEurope and Eurofer 2023), critical for the future success of the European project (see also Chap. 2). Steel remains the most important engineering and construction material and in recent years, thousands of new types and grades have been innovated to expand the range of applications in many sectors such as construction, automotive and mechanical engineering. Moreover, steel is durable, reusable and recyclable and is therefore an ideal material for the circular economy (Eurofer 2023). Within Europe, steel is still produced and processed in over 500 sites in 21 EU member states as well as in the United Kingdom and the steel industry employs more than 300,000 people directly and is supporting more than 2.25 million jobs indirectly in other sectors (Eurofer 2023).

But the continued survival of the European steel industry itself is under threat and to survive the sector has to face and overcome two technological challenges at the same time: on the one hand, it needs to embrace digitalisation and Industry 4.0 to remain competitive but also to deal with expected skills and labour shortages that become ever more noticeable. On the other hand, the sector needs to radically decarbonise its production systems and supply chains to remain viable and operational beyond 2050 when European states and the EU itself are legally bound to reach Net-Zero, which effectively means a state or group of states such as the EU will not be adding to the amount of greenhouse gases that is already in the atmosphere (European Commission 2023b).

2 Facing a Technological Twin Challenge: Industry 4.0 and the Decarbonisation of Steel

The present collection of essays is concerned with a twin challenge that is facing almost all European industries, but which seems to be particularly daunting for the European steel industry. The two challenges can be described and analysed separately, but they are to some extent intertwined and both have to be successfully met for the industry to have a long-term future on the European continent.

One challenge is to adapt to an already ongoing technological ‘revolution’, which is commonly referred to as the ‘Fourth Industrial Revolution’ or Industry 4.0 (e.g. Kagermann et al. 2011, 2013; Reischauer 2018; Enrique et al. 2022; see also Chaps. 3 and 4 for more extensive descriptions of Industry 4.0).[1] The name implies three previous industrial revolutions (Davies 2015). The first and best known industrial revolution, emerging in the second half of the eighteenth century, saw the emergence of mechanical manufacturing processes that were largely powered by water or steam and which started to replace hand production methods. The second industrial revolution, which began in the late nineteenth century was characterised by the emergence of electric-powered mass production systems that were based on the division of labour. ‘Assembly lines’ are probably the most iconic imagery of this period. The third industrial revolution is said to have emerged in the 1970s and is typified by the automation of complex tasks based on breakthroughs in electronics and information technology.

The fourth industrial revolution originates in the early 2000s and represents a further step-change in industrial production technologies. Industry 4.0 is underpinned by a range of new technological developments:

- The application of information and communication technology (ICT) to digitise information and integrate systems at all stages of product creation and use (including logistics and supply), both inside companies and across company boundaries;
- Cyber-physical systems that use ICTs to monitor and control physical processes and systems. These may involve embedded sensors, intelligent robots that can configure themselves to suit the immediate product to be created, or additive manufacturing (3D printing) devices;
- Network communications including wireless and internet technologies that serve to link machines, work products, systems and people, both within the manufacturing plant, and with suppliers and distributors;
- Simulation, modelling and virtualisation in the design of products and the establishment of manufacturing processes;
- Collection of vast quantities of data, and their analysis and exploitation, either immediately on the factory floor, or through big data analysis and cloud computing;
- Greater ICT-based support for human workers, including robots, augmented reality and intelligent tools (Davies 2015).

In short, Industry 4.0 offers new technological opportunities and means to organise, monitor and continuously adapt and improve industrial production systems. Industry 4.0 is expected to lead to significant efficiency gains while at the same time

[1] The term Industry 4.0 can be traced back to an initiative coordinated and driven by representatives from politics, economy and science called ‘Industrie 4.0’ that went public during the ‘Hannover Messe’ (Hannover Fair). The term was used to link to previous technological paradigm shifts and to signify the revolutionary character of the current technological transformation (Kagermann et al. 2011).

allowing for more customisation of products. While the steel industry has not necessarily always been at the forefront of technological developments and industrial transformations, there is little doubt that the sector needs to embrace Industry 4.0 to retain its relevance within the European industrial landscape.

The steel sector is, however, not particularly well set up to face the challenges presented by Industry 4.0. Technological change tends to be relatively slow in the sector due to the capital-intensity of production technologies, which, once in place, disincentivise change as technological upgrades are costly. The fierce competition in the sector, underpinned by continuous global overproduction reduces the financial wriggle room for companies to fund investments in cutting-edge technologies. The industry also struggles to attract the right talent, be that skilled workers or engineers and technologists without whom the technological transformation of the industry cannot succeed.

Industry 4.0 is not the only technological challenge facing the sector at this juncture. An even bigger technological challenge comes with the need—due to legal commitments made by European nations and by the EU under the Paris Climate Accord—to radically decarbonise steel production. Steel production, not just in Europe, is responsible for significant Greenhouse Gas (GHG) emissions that if left unchecked threaten the continued existence of modern societies and indeed the survival of many organisms and species, including humans. Even if current steel production routes—mainly the blast furnace route that requires vast amounts of coking coal —were technologically optimised to the absolute maximum, the resulting reduction of GHG emissions would not be enough to fulfil the legal obligations emanating from the Paris Climate Accord.[2] Without a technological revolution, the steel sector in Europe faces an existential threat by the middle of this century as states would be legally obliged to shut down steel production facilities to reach their national emission targets.

There are some encouraging signs that this second challenge has been recognised as critically important by the industry as well by the EU and individual states. The presentation of the European Green Deal in 2019 has signalled a long-term policy and regulatory commitment to decarbonise the whole EU economy and decouple growth from unsustainable resource use.[3] It builds on and complements other green initiatives such as the European Emissions Trading Scheme (ETS), and now the Carbon Border Adjustment Mechanism (CBAM) to address carbon leakage. From the perspective of the steel industry, the most important aspect concerning the greening of the sector is a switch to energy sources for steel production that drastically, if not entirely, reduce the release of GHG. For electric arc furnaces, this means ensuring that

[2] The EU-funded LowCarbonFutures project estimates that exhausting all efficiency gains of currently available steel making technologies (including all uneconomic measures but excluding Carbon Capture and Storage (CCS)) might reduce the CO_2 output of the sector by around 40%, which is nowhere near enough to reach the sector aim of above 80% CO_2 reductions (Stubbe 2019).

[3] The presentation of the European Green Deal has subsequently been accompanied by a wide range of initiatives such sectoral strategies, a 'Climate Pact', a 'Circular Economy Action Plan', a 'Just Transition Mechanism' and so on. For details, please see the time line here: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

the utilised energy is not based on any fossil fuels but on renewable energy sources. The greening of the European electricity network is under way and the European Union has exceeded its own strategic targets concerning energy consumption from renewable sources as the 27 EU states reached 22% in 2020 while it was aiming for 20%. The real technological challenge for the steel industry is, however, related to its main steel production route using blast furnace—basic oxygen furnaces (BF-BOF)—responsible for just under 60% of all steel produced in Europe—which requires vast amounts of coking coal to generate the required energy to make steel and therefore releases significant amounts of carbon dioxide into the atmosphere. The European steel industry will not reach the emissions targets set by the EU and by individual European states without a technological revolution that allows it to produce steel without using any fossil fuel (e.g. Eurofer 2019).

The green transformation of the steel industry is under way even though it has just begun. At the European level, ESTEP, the European Steel Technology Platform, is particularly active in this regard and leads on initiatives and projects such as the 'Clean Steel Partnership' and 'Green Steel for Europe'[2] which try to support the technological developments needed to achieve net-zero steel making. Almost all large steel producing companies have drawn up their own plans for decarbonising steel production and more than 60 concrete projects are under way across the continent. In this respect, the industry is embracing hydrogen which can replace fossil fuels such as coal and gas that are currently used in steel making processes. This approach is known as Carbon Direct Avoidance (CDA) and numerous projects of this nature are under way or are planned in the near future. The Swedish Hybrit (Hydrogen Breakthrough Ironmaking Technology) system made headlines around the world in 2021 by being the first to deliver its first batch of fossil fuel-free steel to customers. Another approach is referred to as Smart Carbon Usage (SCU) which aims to reduce the release of GHG in steelmaking processes by either reusing waste gases within their own production systems or to make them available to other companies as a resource which can then be used to create other products. Whichever approach or combination of approaches are taken by the industry, it is clear that business-as-usual is not a viable option (see also Chap. 2 for more on this). Moreover, any approach to reduce GHG needs to be part of a wider economic and societal transformation towards a circular economy that reduces 'waste' of any kind as much as possible. Steel is highly durable and thus reusable but also fully and infinitely recyclable: steel is the quintessential material of the circular economy (Eurofer 2019).[4]

There is also an inherent connection between Industry 4.0 and the decarbonisation of the steel making processes. Industry estimates suggest that the economically viable technical improvements of current steel making processes could reduce CO_2 emissions by 15%. While this is insufficient in itself and a more radical technological revolution in steel making is required to meet the legally binding emission target in 2050, it is also clear that the optimisation of currently utilised processes can still meaningfully contribute to reaching net-zero steel production in a few decades. It is

[4] Of course, as pointed out above, steel production would need to switch to entirely renewable and green energy sources to be truly sustainable.

in this area where current Industry 4.0 and digitalisation trends have an important role to play. There is, for example, scope to further optimise the inputs required in EAF-based steel making in a bid to ultimately reduce GHG emissions (see Chap. 4 for a more extensive analysis of the link between Industry 4.0 and decarbonisation).

3 Responding to the Twin Challenge

There seems to be hardly any doubt among European steel industry stakeholders that the transformative challenges of adopting Industry 4.0 technologies as well as decarbonising the production of steel are genuine challenges that cannot be left unaddressed. The big question, which this edited collection begins to address and answer, is how best to respond to these challenges to safeguard the future of the European steel industry.

The first section of the book, *The EU steel industry: a social and technological transformation* grapples explicitly with this question on a theoretical and conceptional level. The broad consensus among the diverse set of authors is that technological challenges require more than 'technological responses'. This approach is informed by social scientific research over the last few decades which has convincingly shown that technologies not only have social effects and consequences, but that they are also themselves shaped by wider social forces (e.g., Salento 2018; Bijker et al. 1987; Winner 1980). This perspective, when taken seriously, has profound implications for the design, development and deployment of technologies. Instead of regarding technology as 'neutral', 'inevitable' or even 'natural', recognising the socially shaped and constructed nature of technology opens up avenues to shape technology in such a way that is aligned with desirable societal values and objectives.

In some cases, this is entirely obvious and already widely accepted: as pointed out above, using blast furnaces to make steel is a possible technological route that the industry has relied on for many decades, but this is no longer compatible with societal needs which require a radical decarbonisation of steel production. Hence, the broad consensus to develop alternatives, even though many different challenges—funding the development of new hydrogen-based steel making technologies, creating the infrastructure to produce green hydrogen at acceptable prices, drawing up appropriate regulatory regimes, reskilling the workforce and so on—will have to be overcome to replace one working technology with an alternative that fits changing societal needs.

Often, however, the way in which technologies are designed and how they are intended to function is not sufficiently questioned and challenged (Edwards and Ramirez 2016), resulting in suboptimal outcomes. In some cases, this will take the form of workers actively resisting or rejecting technologies when these are perceived as threatening or undermining. In other cases, technologies are allowed to shape workplace experiences that devalue the contribution of workers or create dull and boring working environments where workers are stripped of any autonomy. It thus makes sense for all relevant stakeholders involved in addressing technological challenges to always consider whether proposed technologies and technological developments can be shaped in such a way that they will be widely accepted when deployed and that they do not create any undesirable consequences. Instead of imposing technological change, it might be far more beneficial to actively shape technological change to increase benefits and minimise negative consequences (see in particular Chap. 3).

4 The European Steel Skills Agenda (ESSA)

Over recent decades, much has changed in the theory and the practice of how to deal with technological change. A narrow focus on technology as a means to increase efficiency and productivity has given way to more holistic perspectives that are capable of pursuing and reconciling a broader set of goals such as sustainability, dignity, resilience and social justice beyond narrow economic concerns (Rip, Misa and Schot 1995; European Commission 2021).[5]

The Erasmus+ funded European Steel Skills Agenda (ESSA) project that (directly or indirectly) binds all the contributors to this edited collection together embodies this holistic approach to technological change. The ESSA project aims to draw up a developmental blueprint for the European steel sector that maps out a holistic response to the pressures arising out of the rapid technological change described above that is already beginning to affect the industry. Identifying available technologies, or designing, developing and/or implementing entirely new technologies appropriate and relevant for the sector, is just one aspect forming part of a wider, holistic response. As technologies require an appropriately qualified workforce, the ESSA project also analysed current and future skill needs and competence gaps with regard to job profiles and occupational qualification programmes, which can then inform the design of new or additional training instruments to prepare the workforce to be able to cope with the ongoing technological transformation. Recommendations concerning the adjustment of vocational education and training also consider the need to 'train the trainers'.

While the holistic blueprint for the transformation of the steel industry represents a European approach, the industry tends to be embedded in regional industrial networks as steel plants tend to cluster in geographical areas that historically provide relatively easy and reliable access to traditional steel making resources such as coal or abundant electrical energy and/ or iron ore. Thus, regionalised responses have been identified as the most promising approach to create localised 'Communities of Practice' consisting of stakeholders from the industry including employer associations and trade unions, but also those from academia, civil society, governmental and non-governmental organisations, etc., that can not only organise and coordinate technological innovation

[5] Social Innovation; Industry 5.0

but also complement these with appropriate social innovations (training regimes, organisational changes to accommodate technological change).

As suggested above, almost all contributors to this collection are in some ways associated with the ESSA project. The project has brought together a highly diverse set of steel sector stakeholders including representatives from all large European steel companies, regional, national and European steel associations, trade unions, policy-makers, Vocational Education and Training (VET) providers administrators as well as researchers and academics. The ESSA project has also created fruitful links and connections with a range of other collaborative European research projects. Moreover, most of the contributions in this collection are at least partly, if not fully informed, by research conducted as part of the ESSA project (as well as other research projects, too).

5 This Edited Collection

This edited collection consists of three sections. The first section *The EU steel industry: a social and technological transformation* consists of four chapters that look in some detail at the case for the transformation of the sector as well as at theoretically informed accounts of how the transformation ought to be organised.

Chapter 2 by sociologists of work Dean Stroud, Luca Antonazzo and Martin Weinel takes a more in-depth look at the twin challenges of adopting Industry 4.0 technologies and decarbonising steel production.[6] By adopting a historic perspective, the chapter reveals how wider, non-technological factors such as ownership structures, attitudes and approaches to skills and competence development and relationships between social partners are crucial in shaping the consequences of technology use and the trajectory of the European steel industry on the whole. Their findings lend further support to the approach advocated in this book, which suggests that a successful transformation of the European steel industry has to be grounded in a holistic approach that pays attention to not only to the economic but also the social, political and environmental implications of technology use. In doing so, they set the scene for the next chapter which provides more detail on how best to respond to the challenges facing the sector.

Chapter 3 by Dortmund-based German sociologists Antonius Johannes Schröder, Mathias Cuypers and Adrian Götting takes up the themes developed in Chap. 2 and offers a coherent and holistic, forward-looking theoretically informed framework referred to as Industry 5.0. Slightly counter-intuitively, the term *Industry 5.0* does not refer to the next technological revolution. Instead, it denotes a complementary

[6] All three authors worked together at Cardiff University in Wales on the ESSA project. While Stroud and Weinel are still at Cardiff, Antonazzo is now an external researcher at the Centre for Workplace Research at the Prague University of Economics and Business in the Czech Republic and he is also located at the Department of Human and Social Sciences, University of Salento, Lecce, Italy.

conceptual framework designed to guide stakeholders through dealing with the adaptation and implementation of Industry 4.0. The suggested Industry 5.0 framework at the heart of the chapter posits that the industry has to not only undergo the technological revolution, i.e. Industry 4.0, but also—and at the same time—a complementary social, cultural and environmental transformation to make the technologies work effectively and to thus survive and thrive in the long run. The suggested Industry 5.0 framework recognises that technologies do not exist in a (societal) vacuum: their particular form and functionality, but also their consequences for companies, communities and society as a whole is the result of many different choices. Schröder and colleagues argue that the Industry 5.0 framework offers a more holistic approach to technology development and implementation as it centralises environmental and societal concerns, which are often overlooked in favour of a narrow focus on efficiency and costs.

In Chap. 4, Italian researchers Teresa Branca, Valentina Colla and Maria Murri in collaboration with Antonius Johannes Schröder take a closer look at the connections between the technological, social and environmental transformation in support of the argument that a holistic approach is required to deal with the technological challenges facing the steel industry. Their particular focus is on the complementing effects of digital technologies for the wide-ranging transformation of the industry. As the authors convincingly show, digital technologies are not only critical in achieving desirable environmental outcomes, for example by helping to reduce energy and resources needed to produce steel. They are also crucial in supporting the required social transformations, for example by aiding the delivery of training or through simplifying communication between different actors involved in steel production.

Chapter 5 by Italian researchers Marco Vannucci, Ruben Matino, Maria Murri and Roberto Piancaldini, in collaboration with Antonius Johannes Schröder and Dean Stroud, focuses on technological responses by describing the current technological state-of-the-art of Industry 4.0 applications and by analysing how two specific technologies—robots and unmanned aerial vehicles (drones)—can be applied in steel plants and what their potential for the modernisation of steel plants is. While the authors focus is on technologies, social and organisational aspects are also considered as the way in which technology is experienced by workers has important effects on the acceptability and ultimately the usability of technologies in particular work settings.

The second section, *Industry Perspectives on Industry 4.0 and Workplace Change*, changes perspective from academic and theory-informed accounts towards the view of actors operating within the industry. The focus is thereby mainly on the consequences of technological change on workplaces in the industry. The section includes chapters from HR managers, trade unionists and representatives of industry associations. While some chapters take a historic perspective to trace how technological change has led to changing workplaces, other authors reflect on their own experiences gathered while working in the steel industry to highlight practical steps companies can take to respond to rapidly changing circumstances without jeopardising recruitment and talent retention.

Chapter 6 by Anna Mowbray, a former research and policy officer for the British trade union Community, traces the long and at times tumultuous history of the relationship between steel companies and trade unions in the United Kingdom. The United Kingdom, while no longer a member of the EU, remains an interesting case study. It had the first industrialised steel sector in the world and used to be the world's biggest producer of pig iron and crude steel in the second half of the nineteenth century. Like steel sectors in other European countries, the industry's fortunes were cyclically changing over the decades until the 1970s industrialisation of steel making fundamentally changed the workforce organisation and labour relations. Highlighting a range of critical junctures in the history of the British steel industry, Mowbray shows that periods of prosperity in the sector tended to be accompanied by good and cooperative relationships between employers and employees, while the numerous periods of crisis the sector has experienced over the last century were usually accompanied by strained and at times hostile labour relations. In light of this historic analysis of industrial relations, Mowbray argues for the importance of good working relationships between employers, employees and state to ensure the well-being of the sector in a challenging context while also protecting and preserving jobs and communities dependent on the sector. This is an especially important lesson in light of the required transition to net-zero that must balance environmental, economic and societal needs and is likely to fail if the main stakeholders cannot successfully and productively work together to safeguard the future of the British steel industry.

Chapter 7 is another contribution using a historic lens to understand the challenges and opportunities that come with the advent of adopting Industry 4.0 technology in the steel industry. Written by Roman Ďurčo, Marcel Pielesz and Dana Sakařová from the Czech union OS KOVO, the chapter reflects on the changing fortunes of the Moravian steel region around the city of Ostrava in the Czech Republic and its intricate relationship to other industries. Having operated for 40 years or so in the protected environment of a socialist production regime, the steel industry in the Ostrava region suffered a significant downturn in the wake of the political change sweeping through Eastern Europe at the end of the 1980s and in the early 1990s. The loss of industrial jobs on a large scale in conjunction with an ageing population has left Ostrava in a marginal and potentially perilous position that has also been experienced by many other former industrial regions across Europe. Yet the authors also emphasise the potential importance of Industry 4.0 as well as the drive to decarbonise human activities can have in the economic renewal of the Ostrava region. Looking at other examples of industrial renewal, the authors suggest that in a context where regional stakeholders work together strategically and use available resources to create an innovative and dynamic environment for companies and communities to thrive, the economic decline of a region traditionally associated with steel and coal is not inevitable. In the case of Ostrava, metallurgy and steel-making continue to play a vital role in attracting investment and skilled workers and thus helping to shape the economic, social and cultural future of the city and the region.

In Chap. 8, José Ignacio Alonso Osambela, who works as Human Resource Manager for the Celsa Group, provides fascinating insights into the changing practices of recruitment and training in a steel company as a consequence of increasing digitalisation of processes. Digitalisation affects HR practices in at least two different ways: on the one hand, the digitalisation of steel plants increases the pace of change that affects an increasing number of jobs, which means HR professionals have to change their practices. At the same time, digitalisation also directly changes HR practices as hiring processes are no longer paper-based, new opportunities to rethink the provision of training open up and social media offer new avenues for recruitment of talent. Consequently, the chapter describes and analyses in detail how certain key HR practices, such as finding and hiring new staff or training new and existing staff, have changed due to the increased digitalisation of steel companies.

In Chap. 9, Nicole Rudolph and Martin Kunkel, who both represent the *European Federation of the National Associations of Cold Rolled Narrow Steel Strip Producers and Companies* (the associations acronym is CIELFFA, which stands for *Comité International d'Étude du Laminage à Froid du Feuillard d'Acier*) puts the challenges facing the European cold rolling industry into the focus. An important downstream part of the European steel production community, the European cold rolling industry is presented with similar challenges that the industry as a whole is facing: fierce global competition as well as high pressure to adapt to technological change such as Industry 4.0 in order to stay competitive and innovative. The chapter focuses, however, on a problem that is common across the steel sector but acute in the Cold Rolling Industry: an ageing workforce that is facing more demanding and changing working conditions. The challenge for cold rolling companies in this context is to safeguard the employability and the innovative potential of their ageing workforces on inclusive and appropriate training and development initiatives. The chapter focuses on one particular sector-wide initiative, the so-called KaGiWi[12] project, that is designed to address the challenges of retaining and continuously training older employees by raising awareness and expertise among managers. The project applies a participatory framework that analyses at company level parameters such as the age structure of the work force, the skill requirements associated with a range of tasks and stress points that can have adverse effects on the health of employees. The project not only helps managers and employees to jointly understand how work is experienced, but also provides a range of practical advice and resources that improve working conditions and strengthen the organisational resilience of companies.

In Chap. 10, German Human Resource experts Veit Echterhoff, Peter Schelkle and Stefan Cassel continue to explore how steel companies can deal with workforce challenges such as recruitment, retention and training of staff.[7] Their contribution provides answers to the question as to what steel companies can do to attract and retain highly qualified talent in a context of steel jobs that are seemingly less attractive than jobs in other sectors. Based on insights gained from European-level research projects that identify a range of internal and external factors that influence the success or failure of talent recruitment and talent retention, the Chapter develops a range of practical recommendations for steel companies but also for sector associations and

[7] All three authors work or worked for Thyssen Krupp Steel Europe. Echterhoff and Cassel continue to do so, while Schelkle now works for another steel company, the Hüttenwerke Krupp Mannesmann GmbH.

organisations that, if followed up and implemented, promise to ease the recruitment challenge faced by European steel companies.

The third section *New skills requirements, training and recommendations* returns to a more academic and theoretically informed perspective on how to organise the twin transformation facing the European steel industry. All three chapters are directly based on empirical research conducted across Europe.

Chapter 11 by Luca Antonazzo, Dean Stroud and Martin Weinel discusses the implications of extensive automation and digitalisation for the European steel industry and the responses of national vocational education and training (VET) systems to emerging skill demands. Based on research conducted as part of the ESSA project, the authors shed light on the issue of emerging skills gaps in the industry. Their findings suggest that so-called transversal skills—skills that are considered as not specifically related to a particular job or task such as critical thinking, teamwork or problem-solving—become ever more important. The chapter then investigates the responses of national VET systems in Germany, Italy and the United Kingdom drawing on an institutionalist framework that pays particular attention to the role that VET institutions and organisations play in shaping national responses to continent-wide problems. By showing that national responses to common problems vary significantly, the chapter demonstrates the importance of institutions and organisations and their particular characteristics and capabilities in the ongoing transition of the European steel sector.

Chapter 12 by Spain-based steel industry experts Tugce Akyazi, Aitor Goti and Félix Báyon changes perspective from institutional VET context to concrete practices at sector and company level needed to manage the twin transition. As the European steel sector is undergoing constant and substantial changes due to the technological change and the need to decarbonise steel production, the majority of older workers in the steel sector do not have the technological, digital and social competences that changing technologies, business models and organisational structures require. To deal with the complex task of re- and up-skilling the existing workforce, the authors propose the creation of a sectoral occupational database as a practical tool that can help companies and sector organisations to continuously manage changing skills requirements. The chapter describes the method and the utilised data that inform the sectoral occupational database. Presenting some exemplary results and illustrations of the database output, Akyazi, Goti and Báyon highlight the added value of their dynamic and constantly evolving database compared to existing occupational databases such as the European Skills, Competence, Qualifications and Occupations (ESCO) database which is static and lacks the sector-specificity.

The last substantive contribution to Sect. 3, Chap. 13, has been written by German-based social researchers Adrian Götting, Clara Behrend and Michael Kohlgrüber. Starting with the premise that the digitalisation of work is accompanied by far-reaching processes of change, which also affects the jobs and skills of employees and managers, the chapter presents findings from the empirically oriented Beyond4.0 project on the future transversal skills demand due to increasing digitalisation. In particular, the results of a case study involving the steel industry located in the Rhine/Ruhr region in Germany are presented. The focus thereby rests on skills that are gaining in importance across all occupations and at all qualification levels. Given the focus on the digital transformation of the steel industry, the assessment of future digital skill needs was an important part of the study. Interviews with regional stakeholders reveal that basic digital skills become a necessary requirement for all jobs, while higher-level digital skills requirements increase in line with skill levels of jobs, i.e. high-skilled jobs require advanced digital skills. One key insight of the study is that the digital transformation affects skills beyond those that might be narrowly classified as digital skills, which might include the use of digital devices, cybersecurity, the secure handling of data as well as the use of complex digital communication tools and so on. The study reveals that a wide range of transversal skills, including social, personal and methodological skills gain greatly in importance in conjunction with digital skills as the digital transformation takes place. While digital skills are important when it comes to the actual operation of digital devices and infrastructure, non-digital transversal skills are vital when it comes to designing, planning and implementing the use of digital technologies as well as when it comes to interpreting or acting upon digital data.

References

Bijker WE, Hughes TP, Pinch T (eds) (1987) The social construction of technological systems: new directions in the sociology and history of technology. MIT Press, Cambridge, MA

Davies R (2015) Industry 4.0: digitalisation for productivity and growth. Briefing. E.P.R. Service, European Parliament, Brussels

Edwards P, Ramirez P (2016) When should workers embrace or resist new technology? N Technol Work Employ 31(2):99–113

Enrique DV, Marodin GA, Santos FBC, Frank AG (2022) Implementing industry 4.0 for flexibility, quality, and productivity improvement: technology arrangements for different purposes. Int J Prod Res. https://doi.org/10.1080/00207543.2022.2142689

Eurofer (2019) Low carbon roadmap: Pathways to a CO_2-neutral European steel industry. Eurofer, Brussels. https://www.eurofer.eu/assets/Uploads/EUROFER-Low-Carbon-Roadmap-Pathways-to-a-CO2-neutral-European-Steel-Industry.pdf

Eurofer (2023) About the European steel association (EUROFER). https://www.eurofer.eu/about-steel/learn-about-steel/#About-the-European-Steel-Association-EUROFER. Accessed 01 Mar 2023

European Commission (2021) Industry 5.0. Towards a sustainable, human-centric and resilient European industry. Publications Office of the European Union, Luxembourg

European Commission (2023a) History of the EU. https://european-union.europa.eu/principles-countries-history/history-eu_en. Accessed 01 Mar 2023

European Commission (2023b) Paris agreement. https://climate.ec.europa.eu/eu-action/international-action-climate-change/climate-negotiations/paris-agreement_en. Accessed 01 Mar 2023

Hybrit (2021) The world's first fossil-free steel ready for delivery. https://www.ssab.com/en/news/2021/08/the-worlds-first-fossilfree-steel-ready-for-delivery

Kagermann H, Lukas WD, Wahlster W (2011) Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. Industriellen Revolution. VDI Nachr 13(1):2–3

Kagermann H, Wahlster W, Helbig J (2013) Securing the future of German manufacturing industry: recommendations for implementing the strategic initiative Industrie 4.0. Final report of the Industrie 4.0 Working Group. Acatech

Reischauer G (2018) Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. Technol Forecast Soc Chang 132:26–33

Rip A, Misa TJ, Schot JW (eds) (1995) Managing technology in society: the approach of constructive technology assessment. Pinter, London

Salento A (2018) Digitalisation and the regulation of work: theoretical issues and normative challenges. AI Soc 33:369–378

Stubbe G (2019) Low carbon future. Eurosteel master 2019. Brescia, Italy, unpublished

WindEurope and Eurofer (2023) Ensuring access to critical materials for steel and wind sectors essential for EU clean-tech economy. Joint Press release by WindEurope and Eurofer. https://windeurope.org/newsroom/press-releases/ensuring-access-to-critical-materials-for-steel-and-wind-sectors-essential-for-eu-clean-tech-economy/

Winner L (1980) Do artefacts have politics? Daedalus 109(1):121–136

The EU Steel Industry: A Social and Technological Transformation

The Technological and Social Transformation of the European Steel Industry: Towards Decarbonisation and Digitalisation

Dean Stroud, Luca Antonazzo, and Martin Weinel

1 Introduction

Since the nineteenth century, when we might first begin to talk of the 'modern' steel industry, making steel has become a central feature of production and manufacturing across Europe (Bell 2020). Production was initially driven by the demand for railway infrastructure and confined to a small number of countries (e.g. Germany, the United Kingdom) (Spoerl 2004), but it is now produced in twenty-one European countries utilising blast furnace-basic oxygen furnace (BF-BOF) and electric arc furnace (EAF) production technologies to produce goods for a wide range of sectors (e.g. automotive, construction, white goods, etc.) and customers (according to Eurofer (2022a) the top three shares of total finished steel demand per sector in the EU is 37% construction, 16% automotive, 15% mechanical engineering).[1]

In many ways the fundamental processes of steel production have not changed substantially since the mid-nineteenth century when blast furnace technologies were first introduced. But, at the same time, it is indisputable that the industry has undergone significant periods of technological and social transformation. What this chapter discusses is some of those transformations, as the background to a more focused discussion of current developments—the latter being the principal focus of this volume. With regard to current developments we might say that the industry is

[1] Austria, Belgium, Bulgaria, Croatia, Czech Republic, Finland, France, Germany, Greece, Hungary, Italy, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom (Eurofer 2020). Some commentators (e.g. WorldSteel) include Russia, Turkey and Kazakhstan as European producers, increasing the number to twenty-four.

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entering a period of hugely fundamental and significant change, which is driven by what the European Commission (EC) has expressed as the twin challenges of (and opportunity for) decarbonisation and digitalisation (e.g. EC 2022). EC and European Union (EU) policy briefs have stressed how successfully managing the green and digital 'twin transition' is key for delivering a sustainable, just and competitive economy to future generations. If adequately regulated, the green and digital transition can be mutually reinforcing and digital technologies can catalyse greening (Muench et al. 2022)

As noted in Chap. 1, global warming and the climate crisis are driving the need for changes in the ways steel is made. Energy sources and traditional production technologies will eventually give way to processes of decarbonisation involving, for example, hydrogen and renewable energy, alongside the introduction of innovations in methods of carbon capture, storage and use (Antonazzo et al. 2021a). It is estimated, that 74 million tonnes of steel will be required for renewable energy alone, which speaks to the opportunities available for Europe's steelmakers (Eurofer 2023: 2). At the same time, the digitalisation of manufacturing processes—so-called Industry 4.0—comprising 'cyber-physical systems' of production configured upon digital networking systems and the centrality of 'big data' for 'smart factories' (Briken et al. 2017) is aimed at achieving a 'business model transformation' and greater efficiencies for industry. It is clear that digitalisation has moved from 'strategic hype' to 'operational reality' within the wider European manufacturing sector and within the steel industry specifically (Naujok and Stamm, 2017; Murri et al. 2021).[2]

The 'twin challenges' indicate the direction of travel for the steel industry in Europe and the innovations and technological transformations currently demanded of, and being experienced by, EU/European producers. The transformation of the industry in this direction perhaps represents a paradigmatic shift not experienced by the European steel industry since the mid-nineteenth century and Henry Bessemer's and Karl Wilhelm Siemens' respective innovations, the Bessemer process in 1856 and open hearth furnace in 1860, which continue to provide the foundations for steel production today (see Spoerl 2004; Bell 2020). The transformation of the industry is, however, not technological alone, but accompanied by a process of social transformation, such as in the way work is organised and the increasingly high levels of skills now required for employment in the industry (e.g. Antonazzo et al. 2021b; Bacon and Blyton 2000; Stroud 2012). When connected to the twin challenges, the latter perhaps represents a third challenge, i.e. a social challenge, focused on the recruitment, retention and continuous training of a highly skilled workforce to support the industry's transformation in Europe.

As the first substantive chapter in this volume, we aim to help situate the EU and European industry's current technological and social transformations and provide some context for later chapters. Hence, we provide something of a brief overview of the industry in technological and social terms, as well as an account of its place

[2] See, for example, Naujok and Stamm (2017) for an overview and Stroud and Weinel (2020) for discussion of a specific case (discussed also in Chap. 5 of this volume), as well as other chapters in this volume, which document numerous Industry 4.0 developments.

as a regional entity in the European context. The latter half of the chapter draws on data from two research projects—the European Steel Skills Agenda (ESSA) project and research commissioned by a British trade union, Community, on the 'greening' of the steel industry[3] and *Preparing for a Just Transition*—to discuss current sector processes of decarbonisation and digitalisation. We finish with a short discussion that provides an analysis of the broader implications of the industry's process of innovation, technologically and socially, and raise questions that focus particularly on the 'social consequences' of the sector's transition and transformation. First, in what follows, we situate the steel industry within its EU context— reflecting on the European industry as a steel producing region—beginning with the formation of the European Coal and Steel Community (ECSC).

2 The Steel Sector in Europe

The steel industry has historically been at the very basis of the European project. Since the establishment of the ECSC in 1951, the steel industry has gone through phases of expansion, consolidation, modernisation, rationalisation and (more recently) shrinkage. It is currently dealing with urgent issues, such as overproduction, dumping from non-EU competitors, protectionist measures and serious environmental concerns (including unilateral environmental measures, e.g. ETS, CBAM[4]), as well as, at the time of writing, the fall-out from the coronavirus pandemic and concerns over the stability and security of energy supply (with concomitant concerns over energy costs) and supply-chain issues because of the conflict in Ukraine.

The ECSC is one of the forerunners of the European Community, and thus the European Union. It was principally devised as a way to overcome international political and economic risks linked with a situation of overproduction and cartels formation that resembled the situation of Europe in the early 1930s (Fairbrother et al. 2004; Mason 1955). As pointed out in the Schuman Declaration of May 1950, the coming together of the European nations required first the elimination of an enduring enmity between France and West Germany. From Schuman's perspective, placing West Germany and France's coal and steel production together with that of other European countries (Belgium, Italy, Luxembourg and the Netherlands) under a common authority, would provide the common foundations for economic development and would have made any war between France and Germany 'materially

[3] The ESSA project is funded by the EU Commission's Erasmus+ programme and aims to build a Blueprint to tackle skill needs emerging from Industry 4.0 and decarbonisation. The research informing this paper is based on case studies of the sector in Germany, Italy, Poland, Spain and the UK, based on interviews and a survey with trade unions, HR managers, trainers and industry experts. The Community funded research involved interviews with five industry experts on processes of decarbonisation and a survey of 100 steelworker trade union members in the UK gathering their views on decarbonisation and green skills.

[4] The ETS is the European Trading Scheme for carbon emissions and the CBAM is the Carbon Border Adjustment Mechanism to address carbon leakage.

impossible' (EU n. y.; Mioche 1998). The High Authority of the ECSC was charged with the task of securing the modernisation of production and the improvement of its quality, the supply of coal and steel on identical terms to the markets of other member countries and the improvement of the living conditions of workers in the industries (see Mason 1955; Mioche 1998).

The immediate economic aim of the ECSC, as made clear in the founding Treaty of Paris 1951, was the constitution of a unified and competitive market, without national barriers and with strict rules of competition enforced: this was aimed at starting a process of expansion and modernisation of the European coal and steel industry (Mason 1955; Mioche 1998). However, when the Treaty of Paris expired in 2002 the ECSC ceased too. The outcome was that the ECSC's former activities became wholly absorbed by the European Community under the framework of the Treaties of Amsterdam and Nice. When the ECSC ended, the European sector's union federation (European Metalworkers' Federation, now industri*ALL*) and the employers' federation (Confederation of Iron and Steel Industries i.e. Eurofer) made a request to the European Commission to establish a social dialogue committee for the steel industry (Eurofound and Whittall 2006; Eurofound 2018). As Eurofound and Whittall (2006) note, 'the sectoral social dialogue committee for the steel industry was ratified in 2006 and is designed for constructive social dialogue between the social partners, in the spirit of the ECSC, by promoting productive relations between both sides of industry, particularly given the far-reaching changes in the steel industry in terms of competition and working practices' (see also Eurofound 2018). It remains a principal means by which the sector addresses industry challenges.

A further legacy of the ECSC is found in the Research Fund for Coal and Steel (RFCS), which funds research and innovation projects within the industry and supports research and pilot projects on many different aspects of production (Boom 2014),[5] including the implementation of key Industry 4.0 and decarbonisation technologies (see Murri et al. 2021 for a review of the latest technological developments in the sector). The social dialogue committee, the RFCS, as well as initiatives such as the European Steel Technology Platform[6] (ESTEP), remain important means by which the industry's economic and social challenges—globally and within the European region—are addressed.

A global challenge that the industry is facing is certainly the environmental one. In this respect, the European Green Deal, presented in 2019, with its aims for a more resource-efficient and competitive economy across Europe, has placed particular pressures on energy intensive industries like steel, and has made it urgent to embrace technological innovation. The EU has strategised to improve energy efficiency by 32.5% by 2030, based on 1990 levels, and to cut carbon emissions by 50% by 2030,

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[5] Horizon 2020, and now Horizon Europe, are also important sources of funding for supporting industry innovation.

[6] ESTEP engages in collaborative EU actions and projects on technology, which are tackling EU challenges (notably on renewable energy, climate change (low-carbon emission), circular economy) in order to create a sustainable EU steel industry. This is namely done by disseminating results of projects, by facilitating a supportive environment for collaborative projects, by the Strategic Research Agenda and by the active network of ESTEP's community. ESTEP—ESTEP at a glance.

as part of its transition to a sustainable low carbon economy. The industry is central to both the EU's Green Deal Industry Plan and integral to the Net-Zero Industry Act (Eurofer 2023). However, as reported by ESTEP (2017), 'the EU steel industry is already very close to the physical limits of conventional steelmaking technologies, in terms of CO_2 emissions reduction, and there is a need for further disruptive innovation to help the industry meet the targets set'. Within the context of unilateral EU environmental measures, e.g. ETS, CBAM, the long-term sustainability of the steel industry depends on the possibility of steel to become a fully circular commodity (ESTEP 2017). Hence, initiatives such as the Clean Steel Partnership[7] (CSP)—funded by RFCS and Horizon Europe and involving ESTEP and Directorates-General (DG-) RTD and DG-Grow—are an important part of tackling the industry's sustainability challenge.[8]

The necessary transformations are driven not only by technological innovation, but social innovation too and both carry significant social consequences. Technological transformations, for instance, have long had a severe effect on levels of employment in the industry (Gibellieri 1998), but workforce numbers have been in steep decline for numerous reasons over many decades. The steel industry directly employed 308,675 people in 2021 across the EU27, with an estimated 2.6 million jobs supported by the industry through its induced and indirect effects (Eurofer 2022a), but the numbers directly employed are just a fraction of what the industry once employed (as recently as 2014, 332,228 people were directly employed in the EU industry, which represents a decline of about 7.1% in the 7 years till 2021). Eurofer (2023: 2) reports that the EU industry has lost 25% of its workforce over the past decade, and there have been substantial cuts to numbers since the 1970s. As an illustration, in 1971 the UK steel industry directly employed 323,000 workers, numbers similar to those now employed across the EU27 as a whole (Eurofer 2022a). By 2020 the UK industry directly employed just 16,427 steelworkers (Eurofer 2022a). Germany is currently the largest employer in Europe with its companies directly employing 83,200 people, which is many more than its nearest competitor, Italy at 30,389 (*Ibid*).

At the same time as contributing to declining levels of employment, the technological transformation of the industry in Europe has contributed to increases in production (Gibellieri 1998). Production across the EU region went from 132 million tonnes in 1993 to an average annual production of 190 million tonnes between 2006 and 2016—admittedly with some expansion in member state numbers during these periods (ESTEP 2017). Eurofer reported a production volume for the EU-28 of 168 million tonnes in 2018, for a workforce of approximately 320,000 workers directly employed (Eurofer 2019). The fortunes of the industry in Europe ebb and flow and reflect that since the early 2000s the EU steel industry has been constantly and

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[7] Started in 2021, the Clean Steel Partnership is **a mechanism to pilot and demonstrate breakthrough technologies up to Technology Readiness Level (TRL) 8 that can reduce CO_2 emissions stemming from EU steel.** Aligned with the European Green Deal targets, the partnership supports EU leadership in transforming the steel industry into a carbon-neutral one, serving as a catalyser for other strategic sectors. ESTEP—Clean Steel Partnership (CSP).

[8] Directorates-General (DGs) are **European Commission** departments responsible for developing and implementing EU policies across a range of areas, from agriculture to trade.

increasingly threatened by globalisation and increased competition. For example, Chinese steel producers have multiplied their production from 128 million tonnes in 2000 to 928 million tonnes in 2018.[9] There must also be a recognition that the steel industry more widely is subject to cyclical trends and often chronic over-capacity, with consequences for company planning and strategy (Eurofer 2023; Fairbrother et al. 2004). In view of such pressures, the EU was lobbied successfully by the sector social dialogue committee to introduce anti-dumping measures in 2020. Nonetheless, over the past decade the EU industry has shifted from being a net-exporter to net-importer and lost 30 million tonnes of sales on the EU and export markets, losing 26 million tonnes of export capacity in the last decade (Eurofer 2023: 2).

But, as noted above, this is not to say that technological transformation is responsible alone for the rationalisation of workforce numbers, and it is not singularly responsible for any increases in productivity that might be reported. For example, social transformations, such as changes in work organisation, as well as in related patterns of recruitment and skill demands, have also changed the profile of the industry workforce and its productive capacities in multiple ways (Bacon and Blyton 2000; Stroud 2012). It is, moreover, important to note the consequences of globalisation and privatisation too, which have had a marked effect on the European industry and shaped processes of restructuring and rationalisation, particularly since the 1980s (Fairbrother et al. 2004). Indeed, according to Fairbrother et al. (2004), beyond the ECSC, the foundation for the EU steel industry, as a regional industry (i.e. EU/European), was laid in the 1980s and 1990s when the deregulation of the industry began, involving privatisation of the industry (away from what was largely state ownership) and the associated moves toward the establishment of a more internationally focused industry (see also Eurofound 2018).

Within Europe, this resulted in major institutional changes, with a restructuring of the industry that included increased emphasis on productivity, technological innovation and development, an emphasis on downstream activity and a re-composition of the industry via mergers and acquisitions. In effect, the foundations were laid for the materialisation of an embryonic globalised industry, with the European steel region a key component in this process, and the emergence of major steel multinationals (Tata, Arcelor-Mittal, ThyssenKrupp, etc.) (Fairbrother et al. 2004). The industry in Europe, and the EU specifically, has thus undergone a significant transformation, in numerous ways since the inception of the ECSC, and in what follows we pay more attention to its social and technological transformation, focusing particularly on the more recent areas of innovation: decarbonisation and Industry 4.0.

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[9] Worldsteel data.

3 Social and Technological Transformations

As noted earlier in this chapter, the 'modern' steel industry is regarded to have its beginnings in the mid-nineteenth century. Iron and steel-making predates this period, of course, and we can look back 4000 years to the Iron Age to identify the first exploitation of iron-ore (Bell 2020). But, as Bell notes, it is from the sixth century onwards that we see the use of a form of blast-furnace which produced pig and cast-iron, both of which are strong but brittle because of high carbon content (see also Spoerl 2004). Much later, from 1784, puddling furnaces were introduced with the literal stirring of molten material to introduce oxygen and reduce carbon, which was a labour and fuel intensive means to produce wrought iron (Spoerl 2004; Bell 2020; Landes 1965; 1969). The first 'steel' produced was in Germany and the United Kingdom, and followed a 'cementation' furnace process to achieve the desired quantity and distribution of carbon in the product (Bell, 2020). The outcome was a form of iron with a high carbon content called blister steel that could be rolled and pressed more easily than wrought iron (Spoerl 2004; Bell 2020).

Technologically we move rapidly to the Bessemer process and Siemens' open hearth furnace, which mark the start of steel production as we currently know it; these processes introduced more efficient and higher quality steel in larger quantities by rapidly manipulating the oxygen and carbon content, along with further innovations for removing a range of impurities (Bell 2020; Spoerl 2004). The outcome was the technological basis for the Blast Furnace (BF) and Basic Oxygen Furnace (BOF) production that forms approximately two-thirds of steel production today. Later, at the turn of the twentieth century we see Paul Herloult's electric arc furnace (EAF) innovation, using an electrical charge for the production of speciality steels and steel alloys primarily from scrap (Bell 2020). From the bases of BOF and EAF we see ever refined processes of production to produce high-quality steel products (e.g. billets, blooms, slabs, wire, bar, etc.) for construction, automotive, ship-building, white goods and numerous other sectors (see Bell 2020).

From these beginnings, the competitiveness of the European industry has further relied on the development of a range of technological and production (e.g. lean/ just-in-time and flexible) innovations. From the 1990s onwards, in particular, new casting and rolling mill technologies, such as thin slab casting and strip casting facilities, along with smelting and direct reduction technologies and the introduction of Near Net Shape Casting changed the way steel was produced and improved the competitiveness of the European sector (Gibellieri 1998). There is, moreover, a greater emphasis on a faster and more comprehensive service, higher quality products, and better levels of customer service. To facilitate this new responsiveness to customer demand, steel companies increasingly looked to decentralise their operations and make the way production is organised more flexible. Such developments have impacted on the steel industry workforce in a number of different ways.

Most evidently, this is in the way that work in the steel industry is organised, its levels of employment and the skills profile of the industry. As organisations look to become more flexible and responsive, steel producers adopt new working practices e.g. team working, high performance working and recruit differently for a more diverse and highly skilled workforce. Indeed, technological transformations and related production developments have been paralleled by concomitant transformations in the role that skilled labour plays in steel production. That said, while we may have travelled some considerable distance since workers were, for example, first employed in the labour-intensive process of ‘puddling’ (Spoerl 2004) or recruitment relied on a supply of unqualified labour from generations of family (Stroud 2012), the changes and challenges that workers might experience to the material realities of their work and employment from the insertion of new technologies and other industry developments are as present today as they have always been (see Edwards and Ramirez 2016; Stroud and Weinel 2020).

Current technologies and processes might, for example, make for a safer workplace from when the strenuous labour, heat and fumes of ‘puddling’ could mean a very short life expectancy for ‘puddlers’ (Spoerl 2004; Landes 1965; 1969), but there remains the potential for intensified labour and deskilled work and/or job losses from more recent developments (see Stroud and Weinel 2020). This requires some reflection on the relations of power and control, as well as regulation, which are critical to the development, selection and deployment of workplace technology, often driven by the seemingly irresistible logic of efficiency and productivity. On this basis we might view the insertion and use of technology along with its effects as socially and politically variable, i.e. the decision to deskill, upskill or ‘rationalise’ is a management decision, but it is one that is shaped by wider forces (see, for example, Pfeiffer’s (2017) analysis of Industry 4.0 as a discourse promoted by ‘economic elites’ to increase control over labour).

Hence, while new technologies might have the potential to improve, for example, safety, by means of increased levels of automation, it is only with legislation, regulation and codes of practice (e.g. International Labour Organisation 1981 code of practice), as well as training, leadership and increased management accountability that safety begins to improve. Worldsteel data shows that significant improvements in lost time to injury between 2006 and 2019—by some 82%—are not only accountable to new automated processes but the result of social transformation in health and safety cultures supported by strong international and national legislation and codes of practice (Worldsteel 2022). Equally, we might then view the rationalisation and restructuring of the industry workforce as a process not only informed by its technological transformation, but also subject to cultural, social, economic and political forces too.

In view of such discussions, we now reflect on the findings of two research projects, *ESSA* and *Preparing for a Just Transition*, to shed some further light on the ‘twin challenges’ of digitalisation and decarbonisation, as the main focus of this volume.

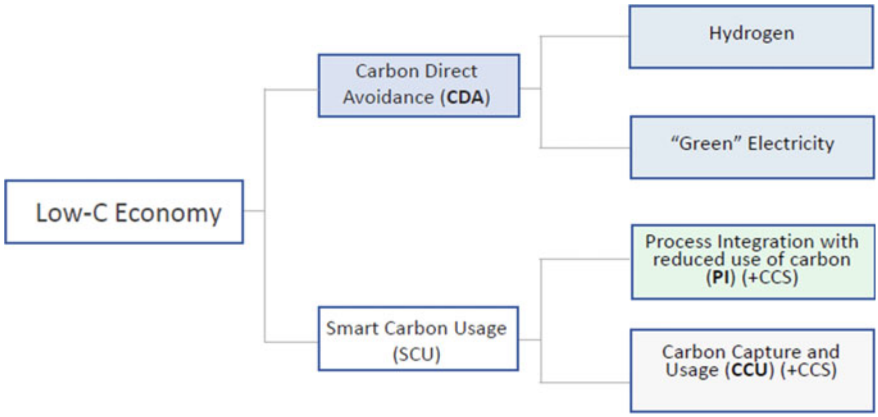

Fig. 1 Technological pathways to reduce CO_2 emissions in the steel sector. *Source* BFI 2019

Decarbonising the Steel Industry

A strong socio-political force shaping steel production is the transition to net-zero and the European Commission's commitment to a sustainable low carbon economy (this was clearly expressed in the European Green Deal). The steel industry currently contributes the largest share of global CO_2 emissions of all manufacturing, approximately 27%. It is also energy intensive and has the largest single energy-related CO_2 emissions globally by industry, at 7.2% (Ritchie and Roser 2016). Greening efforts are heavily reliant on technological innovation, particularly decarbonising by means of carbon capture and usage/storage and greener sources of energy (e.g. renewables, hydrogen). In what follows we draw on data from the ESSA project and a project funded by the Community trade union, *Preparing for a Just Transition*, to discuss current approaches to decarbonising the industry and the extent to which the workforce is prepared for making 'green' steel (see Antonazzo et al. 2021a).

When considering the prospects for decarbonisation, it is possible to distinguish between two principal approaches (see Fig. 1):

1. *Carbon Direct Avoidance*: using hydrogen and/or electricity for producing iron and steel. The use of electricity directly to electrolyse iron ore[10] is still at an early research stage and not ready for commercial implementation. The hydrogen-based process is potentially ready, dependent on hydrogen supply.
2. *Smart carbon usage*: making processes more efficient so that less energy input is required, thus partially cutting emissions. This can be complemented by carbon capture and storage (CCS), or carbon capture and usage (CCU) to transform CO_2 into by-products for other industries.

However, a third approach, a *circular approach*, whereby the carbon input is substituted by utilising other by-products as carbon carriers might also present an

[10] See also Worldsteel (2022).

opportunity for necessary reductions (Antonazzo et al. 2021a). Industry experts interviewed for the Community project remarked that these (three) approaches are not mutually exclusive and companies will likely adopt a combination of different approaches and technologies to cut their emissions:

> We believe that we will need all of this. We will need to use CCS and CCU, we are going to have hydrogen in some places, renewables […] it will depend on what kind of resources you have available. If you are in a place where there is natural gas and great storage, why not use it in forming blue hydrogen, you start to store the CO_2 […] if you have plenty of renewables or biomass, then you should go ahead and use that (Community Research: Steel Industry Environment and Climate Change Expert)

Hydrogen-based steelmaking has a promising future, but meeting the relatively short-term target for reducing emissions will require other solutions more at hand:

> Hydrogen probably has a role as a fuel at some point in the future when there's genuinely green hydrogen, but that is the longer term 2050 perspective. And essentially all industry has got to work on the 2035 [target], because you can't operate as you do and get your 50% reduction (Community Research: Steel Industry HR Manager)

As a recent report by Syndex and the Material Processing Institute (2021) has remarked, in a mid-term scenario blast furnaces and DRI furnaces[11] will remain the main routes for European steel producers, and EAF-based steel will only reach a share of 40% of production by 2050. But, large European companies are now engaged in the development of a DRI-Hydrogen solution, including a transition from blast furnaces to Electric Arc Furnaces (EAF) over the next 20 years. Such solutions will need an increased amount of CO_2-free electricity, thus the issue of energy supply and costs is an important part of the green transition. Policy support is key to provide the industry with resources, as well as overarching national and EU strategies that factor in direct investments along with infrastructure and the cost of energy supply.

Wide-ranging technological transformations like the ones outlined bring about legitimate concerns about the effects that these will have on employment levels in the industry (as well as on the composition of the workforce). For a greener industry, experts have pointed to a two-phase scenario. The first 'transition' phase will likely increase employment and could last up to 2050. The second phase might result in a reduced workforce, mainly because of the resizing of the plants and leaner processes:

> The build phase, transition phase, always absorbed people. So, we are going to have more assets constructed and deconstructed in the next 20 years because of the change. […] if an asset has got a carbon footprint that's unsustainable, it's going to be replaced in the next 15 to 20 [years], regardless (Community Research: Steel Industry HR Manager)

Planning ahead and strengthening social dialogue is likely to be key to ensure a smooth and just transition: workers need to have a clear understanding of the companies' prospects and to trust that no one is going to be left behind as the industry

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[11] The direct-reduced iron (DRI) process reduces iron ores directly to sponge iron using gaseous reducing agents. In the electric steel process, crude steel is made from the sponge iron obtained from DRI. Scrap is also added to this process as well as pig iron from the BF process (Syndex and the Material Processing Institute 2021).

transitions. There remains high uncertainty regarding the technologies and routes that will provide the best opportunities for companies, as well as uncertainties at the policy level. But, it is crucial to be proactive in anticipation of change, particularly on skills development:

> We talk a lot about anticipation of change […] what's going to happen? Not tomorrow, what's gonna happen in five years, 10 years, 20 years? What skills do we need now, what skills do we need in the future? Because remember that steel is an ageing workforce […] if you have a huge amount of people, and they're late 50s, early 60s who retire, you may also need people have the good old-fashioned skills like welding(Community Research: Steel Industry HR Manager)

With the green transition being a major change and a critical target for companies throughout Europe, data from the ESSA project identifies 'green skill' needs at the sector level, including skills related to environmental awareness, energy efficiency, water conservation, waste reduction and waste management, and resource use and recycling. Although the idea of skills that are inherently 'green' can be criticised and calls for some reflection, it still makes sense in the context of this chapter to use this as an encompassing label while addressing the relationship between required skills and the process of greening the industry. In some indication of the readiness for the green transition, a survey of one-hundred steelworker UK Community members reported that whilst 92% of the current steel workforce view the transition as necessary only half view themselves as possessing the necessary skills to support the transition and 41% feel threatened by it. Another 79% have not been consulted on the necessary changes, with 78% expecting the transition to involve radical and disruptive technological change. But 'readiness' for the transition will differ by firm and/or country: evidence from the ESSA project suggests that a more holistic approach to vocational education and training in some countries e.g. Germany is likely to facilitate a much smoother 'green skills' transition, than for their counterparts elsewhere, e.g. United Kingdom.

Industry 4.0: Digitalising Steelwork

This section draws on data from the ESSA project to discuss Industry 4.0 technologies in the steel industry and what the innovations mean for steelwork and steelworkers i.e. the 'social innovation' that goes hand in hand with technological innovation (see Chap. 3). Beyond the ESSA project, a wide array of evidence suggests that the steel industry is experiencing Industry 4.0 transformation. For example, with regard to the use of Internet of Things models, sensors and big data analytics to improve energy efficiency and resource management (and thus contribute to greening the industry), as well as quality monitoring and defects detection (Branca et al. 2020; Stroud et al. 2020). Robot-assisted production is increasingly/potentially allowing workers to supervise, instead of perform, dangerous and labour-intensive processes and tasks, e.g. drones (Stroud and Weinel 2020), and extensive generation, storage and analysis of data means that steel companies can now improve processes and plan recurring intervention on machinery based on sensor data and computer simulations, and signals moreover the potential effects of digitalisation and automation on jobs and skills in the sector (Murri et al. 2021).

However, stakeholders at the European level describe the sector as still uneven in technological terms:

> [When it comes to Industry 4.0] you're going to get different answers, depending on who you ask. Because you might have one company that they've already made a lot of changes […] You might have others who've done no digitalization, and they're not prepared, and maybe they're not going to do it in the best way... The feedback we've got from a lot of our steel experts is the sector has already been digitized quite a lot already' (ESSA: Trade Union Representative, Europe).

Where Industry 4.0 has penetrated the sector, of particular note is the volume of data generated and the need for increased capacity for its analysis. More advanced sensors and measuring technologies mean that many more data sources are now embedded in the various processes and a vast amount of data becomes available for real time, as well as historical, analysis:

> Data collecting systems…vibro-acoustic (analyse the noise and with AI identify problems) Data collecting in general analysis with AI of all of these data. There is an algorithm that reach conclusions with AI and support the decision-making process. Before the most important variables were the target. Now the priority is to collect as many variables (data) as possible (ESSA: Rolling Mill Manager, Spain).

Thanks to these new developments, companies have many more opportunities to act and improve their processes:

> We have experienced years or better decades of technological change […] we have now data, we can collect them, analyse them, act on the data [implement changes] and that is the great advantage we have now (ESSA: Head of Training Centre, Germany.)

Data generation and capturing are also used to improve the reliability of systems, also offering the opportunity to implement predictive maintenance models, which reduce the risk of system failures.

Another area in which Industry 4.0 technologies can be found in steel companies is that of quality assurance, for instance in the case of defects detection of rolled steel. Further, Industry 4.0 solutions are adopted in some sites directly in production, for instance in melting shops or in rolling mills:

> In some melting shops I saw really excellent installations not only to measure, to do some typical stuff, but even with some kind of Artificial Intelligence, with kind of sampling and some predictive methods, not only like a reaction to the problem but prediction…. But I would say we are at the beginning of that in the steel plants in Poland (ESSA: Steel industry expert, Poland).

Further, as indicated above, advanced robotics is an aspect of Industry 4.0 that is gradually being integrated into steel production:

> [Recently we have had] the introduction of ABB[12] robots […] the labs have implemented quite a new automation system. So, automation is obviously a key thing within the works (ESSA: Company Training Advisor, United Kingdom).

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[12] A Swedish-Swiss supplier of advanced electrical and robotic technologies.

What is evidenced here is that the European steel industry is progressively moving towards Industry 4.0, which requires a level of adaptation for the workforce or social innovation. The question is the extent to which workers can easily adapt to changed tasks and processes:

> That is why we already use robots extensively and this is not by accident […] there will be simplifications of work but at the same time there will be more complex and difficult tasks and the simple work will increasingly be automated because, slightly exaggerated, the simple and the complex tasks incur the same costs [when humans are involved] and this means that it makes economic sense to automatize the simple work as far as possible so that I do not have to pay the high costs associated with human staff […] but I believe that for us the advantage is that our people are much more holistically trained and are therefore far more flexible in their response to new developments and changes.' (ESSA: Head of Training Centre, Germany).

In accordance with such views, commentators such as Pfeiffer (2016) maintain that the qualitative role of workers has increased with automation, thus undermining the idea of technologically driven deskilling. Where simple tasks will be replaced by robots, or algorithms, new requirements will emerge, particularly in supervision, analysis and maintenance. The underlying question is not whether entire occupations will be replaced by technology (see Frey and Osborne 2017), but in what way the automation of specific tasks will reconfigure existing jobs (Arntz et al. 2017; Dengler and Matthes 2018).

Certainly, the ESSA data point more to the complementation of human workers and technologies, rather than a full replacement. On an empirical level, the relationship between task automation and substitution is of a non-linear type, and workers displacement should not be assumed on the mere basis of task automation. What was remarked upon several times by our (ESSA) interviewees was the importance of contextual understanding and practical experience directly associated with technological developments, with workers required to make sense of the data they are presented with by machines and digital devices and to project them onto real-work situation, and act upon them accordingly.

A related demand, and what analysis of the ESSA data point to, is the need for more holistically trained workers who can easily adapt to technological changes within the companies:

> We are working in the direction of a multiskilled workforce. So, in the production line they are involved in training programmes so that a worker will be able to work in lamination, but also in other parts of the production, and also be able to do some part of the maintenance process (ESSA: Human Resources Officer, Spain).

On this, the question that remains is the extent to which current patterns of work organisation and systems of vocational education and training, as well as training offered by steel firms, can meet the demand for new ways of working and the emerging skill needs deriving from the developments discussed. Evidence from the ESSA project suggests that like the uneven spread of technological advancement across the European industry (as for decarbonisation), some firms and countries seem better placed than others to support and make the transition (see Antonazzo et al. 2021b).

4 Conclusion

The steel industry was once characterised by limited cross-border cooperation between steel producers, with few mergers and acquisitions. But, from the mid-1990s things began to change significantly, reflected in churns in ownership and the establishment of huge multi-nationals, e.g. the merger of British Steel and Koninklijke Hoogovens to create Corus, which was then purchased by the Indian conglomerate Tata, as well as the creation of new global entities e.g. Liberty Steel. In the context of over-capacity and global competition it is perhaps that there will be further consolidation within the steel sector as producers position themselves in relation to changing market patterns, price volatility and fluctuation, and national and regional consolidation, with the European industry just one player on a global market (see Fairbrother et al. 2004).

What is evident is that the transformation of the EU and European industry involves interrelated processes of globalisation, privatisation, rationalisation and restructuring, and it is these processes which provide the background for the industry's technological and social transformation, and the more specific twin challenges of digitalisation and decarbonisation. The twin challenges discussed in this chapter might be framed as an opportunity for a more efficient, competitive and sustainable industry, better able to meet global challenges. Often, however, there are also opportunity costs and in this chapter we are careful to reflect on the social transformations that accompany the industry's technological transformation, and their attendant social consequences.

The developments discussed have important implications for the organisation and control of labour in steelworks. In the context of competitive markets, between companies and between countries and regions, steel companies are beginning to integrate Industry 4.0 technologies and explore alternative forms of more sustainable and decarbonised production (Branca et al. 2020; Antonazzo et al. 2021a). Parallel to this are attempts to recompose steel workforces, to upskill and also recruit a more highly skilled workforce that is overall reduced in numbers. Some have (long) argued that some of the focus of such activity has been on creating a more malleable and compliant workforce (Fairbrother et al. 2004; Pfeiffer 2017) with the introduction of various forms of team work and high-performance work systems (Bacon and Blyton 2000; Appelbaum et al. 2000).

Others have focused on workers' levels of engagement with the technologies that change the nature of work in fundamental ways—including the skills necessary to work within new 'greener' and digitalised contexts (Antonazzo et al. 2021a, b). Certainly, against the backdrop of organisational and occupational restructuring, in line with the twin challenges, steel employers have looked to develop the skills profile of their workforces. The introduction of new knowledge intensive data led technology, for example, demands a more highly skilled workforce, with restructuring towards flatter, more functionally flexible working practices demanding workers with higher degrees of generic skills, which places a higher premium on education and training to develop the skills and competencies of workers (Fairbrother et al. 2004;

Antonazzo et al. 2021b). However, the contexts in which all of these developments take place raise distinct questions for the industry and those employed within it.

The first question is what are the implications for European producers and steelworkers of the increasing internationalisation and globalisation of steel production and consumption? What are the implications of moves by, for example, the US[13] and China to create a more innovative and competitive environment for investment in green steel? Clearly European producers face a new global reality which necessitates making a strong and green industrial base a strategic priority (Eurofer 2022b, 2023). And as a 'social consequence' it seems a likely concern that there will be a continued emphasis on the repositioning and reconstructing of workforces to meet the challenges of these developments (see Fairbrother et al. 2004; Eurofer 2023: 12).

Second, and related, what is the precise impact of Industry 4.0 and decarbonisation—with changing production processes involving increased automation and experiments with new processes? Certainly, it is likely that there will be pressures on firms and workers to adapt and change, i.e. social innovation to meet these new circumstances, and be more flexible and adaptable, which will carry consequences for the material realities of employment in the industry (see, for example, Stroud and Weinel 2020).

Third, to facilitate technological and social transformation what is the training offer? With the re-composition of the steel labour process (deriving, for example, from the twin challenges) there is likely to be pressure to ensure that steelworkers have the skills base to deal with the changes that are taking place—as we have indicated training and skills will come to acquire a different significance in such circumstances.

Fourth, will the range of developments discussed in this chapter lead to common patterns of development across the industry? We know that as the industry consolidated over recent decades it witnessed similar approaches to the way work is organised (e.g. team working) across firms and countries (albeit introduced at different speeds), but might we then expect, for example, similar approaches to skill development and training to emerge? At present there is some evidence to the contrary, particularly with regard to systems of vocational education and training, as well as patterns of digitalisation and decarbonisation (see Stroud 2012; Antonazzo et al. 2021a, b).

Finally, there is the question of what role trade unions and social dialogue might play in addressing these questions and the challenges we have discussed? Our view is that—as with vocational training arrangements—it is the national context and the strength or weakness of participative arrangements at this level that has long informed the protection of workers' interests, across the European sector. We thus expect the outcomes (or social consequences) for workers to differ in the same way, as the processes of digitalisation and decarbonisation unfold (see Stroud 2012; Stroud and Fairbrother 2011; Stroud et al. 2020; Antonazzo et al. 2021b *cf*. Bechter et al. 2012).

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[13] The US Inflation Reduction Act, for example, looks to provide in the region of USD 85 Billion of funding for steel production and upstream energy requirements (Eurofer 2023: 5).

References

Appelbaum E, Bailey T, Berg P, Kalleberg AL (2000) Manufacturing advantage: why high-performance work systems pay off. Cornell University Press, New York

Antonazzo L, Stroud D, Weinel M, Dearden K, Mowbray A (2021a) Preparing for a just transition: meeting green skills needs for a sustainable steel industry. Community. https://indd.adobe.com/view/a9bc234c-6235-442a-8355-bc9fab727c00

Antonazzo L, Stroud D, Weinel M (2021b) Institutional complementarities and technological transformation: IVET responsiveness to Industry 4.0—meeting emerging skill needs in the European steel industry. Econ Ind Democr 44(1):25–46

Arntz M, Gregory T, Zierahn U (2017) Revisiting the risk of automation. Econ Lett 159:157–160

Autor D (2015) Why are there still so many jobs? The history and future of workplace automation. J Econ Perspect 29(3):3–30. https://doi.org/10.1257/jep.29.3.3

Bacon N, Blyton P (2000) High road and low road teamworking: perceptions of management rationales and organizational and human resource outcomes. Hum Relat 53(11):1425–1458

Bechter B, Brandl B, Meardi G (2012) Sectors or countries? Typologies and levels of analysis in comparative industrial relations. Eur J Ind Relat 18(3):185–202

BFI (2019) Low Carbon Future. http://www.bfi-blogs.de/lowcarbonfuture/

Bell T (2020) The history of steel. https://www.thoughtco.com/steel-history-2340172

Boom R (2014) Research fund for coal and steel RFCS: a European success story. Ironmak Steelmak 41:647–652. https://doi.org/10.1179/0301923314Z.000000000313

Branca T, Fornai B, Colla V, Murri M, Streppa E, Schröder A (2020) The challenges of digitalisation in the steel sector. Metals – Open Access Metall 10(2):288

Briken K, Chillas S, Krzywdzinski M, Marks A (2017) Labour process theory and the new digital workplace. In: Briken K, Chillas S, Krzywdzinski M, Marks A (eds) The new digital workplace: how new technologies revolutionise work. Palgrave, London, pp 1–17

Dengler K, Matthes B (2018) The impacts of digital transformation on the labour market: substitution potentials of occupations in Germany. Technol Forecast Soc Chang 137:304–316

Edwards P, Ramirez P (2016) When workers should embrace or resist new technology? N Technol Work Employ 31(2):99–113

ESTEP (2017) Strategic research agenda. https://www.estep.eu/library/publications/2017-sra

Eurofer (2019) European steel in figures 2019. https://www.eurofer.eu/publications/archive/european-steel-in-figures-2019/

Eurofer (2020) European steel in figures 2020. Eurofer, Brussels

Eurofer (2022a) European steel in figures 2022. https://www.eurofer.eu/publications/brochures-booklets-and-factsheets/european-steel-in-figures-2022/

Eurofer (2022b) Press release: upcoming decisions crucial to test EU determination to keep industry in Europe. European Steel Association (Eurofer), Brussels

Eurofer (2023) Position paper: an EU industrial policy providing a strong business case for green investment in Europe. European Steel Association (Eurofer), Brussels

Eurofound (2018) Representativeness of the European social partner organisations: Steel sector, Dublin

Eurofound and Whittall, M. (2006) Social Dialogue Committee for steel industry at European level, Dublin https://www.eurofound.europa.eu/en/resources/article/2006/social-dialogue-committee-steel-industry-european-level

European Commission (2022) European industrial strategy. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

European Union (n. y.) Schuman Declaration May 1950. https://european-union.europa.eu/principles-countries-history/history-eu/1945-59/schuman-declaration-may-1950_en

Fairbrother P, Stroud D, Coffey A (2004) The European Union steel industry: from a national to a regional industry. Working paper. Cardiff University, Cardiff

Frey C, Osborne M (2017) The future of employment: how susceptible are jobs to computerisation. Technol Forecast Soc Chang 114:254–280

Gibellieri E (1998) Social consequences of technological innovation. In: Ranieri R, Gibellieri E (eds) The steel industry in the new millennium. Volume 2: institutions, privatisation and social dimensions. IOM Communications, London, pp 197–216

Landes, D. (1965) Technological change and development in Western Europe, 1750–1914. In: Postan and Habakkuk (eds) The Cambridge economic history of Europe, Vol VI, Part I. Cambridge: Cambridge University Press, pp 274–601

Landes D (1969) The unbound Prometheus: technological change and industrial development in western Europe from 1750 to the present. Press Syndicate of the University of Cambridge, Cambridge, New York

Mason H (1955) The European coal and steel community: experiment in supranationalism. Springer, Dordrecht

Mioche P (1998) The European coal and steel community in an historical perspective. In: Ranieri R, Gibellieri E (eds) The steel industry in the new millennium, Vol. 2: Insitutions, Privatisation and Social Dimensions, IOM Communications Ltd, London, pp 273–284

Muench S, Stoermer E, Jensen K, Asikainen T, Salvi M, Scapolo F (2022) Towards a green and digital future. Publications Office of the European Union, Luxembourg

Murri M, Colla V, Branca T (2021) ESSA deliverable 2.1. Digital transformation in European steel industry: state of art and future scenario. Blueprint “New Skills Agenda Steel”: industry-driven sustainable European steel skills agenda and strategy, . https://www.estep.eu/assets/Uploads/ESSA-D2.1-Technological-and-Economic-Development-in-the-Steel-Industry-Version-2.pdf

Naujok N, Stamm H (14 Jun 2017) Industry 4.0 in steel: status, strategy, roadmap and capabilities. Keynote presentation future steel forum, Warsaw

Pfeiffer S (2016) Robots, Industry 4.0 and humans, or why assembly work is more than routine work. Societies 6(2):1–26

Pfeiffer S (2017) Industrie 4.0 in the making—discourse patterns and the rise of digital despotism. In: Briken K, Chillas S, Krzywdzinski M, Marks A (eds) The new digital workplace: how new technologies revolutionise work. Palgrave, London, pp 21–41

Ranieri R, Aylen J (eds) (1998) The steel industry in the new millennium. Vol. 1: technology and the market, IOM Communications, London

Ritchie H, Roser M (2016) Emissions by sector. https://ourworldindata.org/emissions-by-sector

Spoerl, J. (2004) A brief history of iron and steel production, Saint Ansem College, Philosophy Dept. https://www.academia.edu/31060927/A_Brief_History_of_Iron_and_Steel_Production

Stroud D (2012) Organising training for union renewal: a case study analysis of the European union steel industry. Econ Ind Democr 33(2):225–244

Stroud D, Fairbrother P (2011) The limits and prospects of union power: addressing redundancy in the steel industry. Econ Ind Democr 33(4):649–688

Stroud D, Weinel M (2020) A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology ‘effects’ in the European steel industry. N Technol Work Employ 35(3):297–313

Stroud D, Evans C, Weinel M (2020) Innovating for energy efficiency: digital gamification in the European steel industry. Eur J Ind Relat 26(4):419–437

SYNDEX (2021) Decarbonisation of the steel industry in the UK. Towards a mutualized green solution. https://www.mpiuk.com/downloads/industry-papers/SI-Series-Paper-05-Decarbonisation-of-the-SteelIndustry-in-the-UK.pdf

Worldsteel (2022) Safety and health. https://worldsteel.org/steel-topics/safety-and-health/

From Industry 4.0 to Industry 5.0: The Triple Transition Digital, Green and Social

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1 Introduction

The terms fourth industrial revolution and Industry 4.0 describe the implementation of advanced (digital) automation solutions in production technologies (Kagermann et al. 2011; Schwab 2016), e.g. in process industries comprising ‘Artificial Intelligence and Industrial Internet of Things (IoT) for improving self-monitoring, diagnostic, forecasting and self-optimization capabilities of automation systems’ (Branca et al. 2020: 1). Even this short list shows the strong technological orientation of Industry 4.0. Under the term Industry 5.0, ideas and concepts that expand Industry 4.0 have been discussed for some time, some focussing on technological improvements (Østergaard 2018; Sachsenmeier 2016), others on fundamental critique (e.g. Özdemir and Hekim 2018).

Against this backdrop, the recently introduced Industry 5.0 concept (Breque et al. 2021) is grounding and framing technological developments with societal challenges, demands and aims making industrial production more sustainable, placing wellbeing of workers at the centre of the production process, and enabling a resilient industry overcoming crises more effectively. However, Industry 5.0 is therefore not an alternative or technological step forward but improves the primarily technological and economic oriented Industry 4.0 and looks at the development and implementation of innovative technologies with a new lens and frame (Breque et al. 2021: 14–16).

As Industry 4.0 technologies and related investments are already taking place for ten years, a stronger integration of non-technological (e.g. skills needs, regulatory and economic conditions), social aspects and social innovations was already called for in the discourse (e.g. ASPIRE 2021; Müller 2020). Besides other non-technological

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topics, the Strategic Research Agenda of the Processes for Planet Program listed the need to close skills gaps explicitly (see Table 1).

Against this backdrop, (1) the differences between Industry 5.0 and 4.0 will be discussed, (2) the conceptual connection between Industry 5.0 and Social Innovation will be expressed, and (3) concretised by new ways of adjusting skills demands for Industry 4.0 technologies by improving human-centricity in the sense of Industry 5.0.

Table 1 Checklist Non-technological Aspects concerning human resources, skills and labour market (ASPIRE 2021: 263)

Human resources, skills and labour market	New way to close skills gaps and mismatches, improving the capacity of the process industry to unfold the potential of digitalisation and innovation: • Considering impact of the transformation of the process industry on the new skills required • Developing new education and training schemes responding to regional, pan European workforce planning within the (digital and ecological) transformation • Recruit and retain talent needed by the companies, how to attract talents to the production industry in Europe (e.g., by attracting more women, high skilled workers) • Transforming of training supply (company internal and external) and the labour market • Creating the innovators of the future: combining technology innovation and business model innovation for the process industry • Cooperation with local/regional education and training providers on the reginal/local level (within companies and H4C), bridging with schools and universities, developing new teaching materials • Investments in education and training (division of responsibilities for industry, public VET institutions/universities, and the individual), new learning models for 'learning to learn' • Change management within the companies to upskill the existing workforce • Integrate experience and competences of the experts in the workplace (operators) within technological innovation development

2 From Industry 4.0 to Industry 5.0

One way to trace the historic development of industrial production is to focus on particular disruptive changes in terms of technology as well as their impact on industrial productivity. In retrospect, mechanisation, steam and water power (end of the eighteenth century), mass production and electricity / IT systems (end of the nineteenth century), and automation and electronic and IT systems (second half of the twentieth century) have been framed as the first, second and third industrial revolution (Schwab 2018). The widespread paradigm Industry 4.0, which first emerged in 2011 (Kagermann et al. 2011), refers to these historical classifications and claims that currently a new, fourth industrial revolution, characterised by the emergence of cyber-physical systems, takes place. In contrast to the first three industrial revolutions, this fourth industrial revolution is not based on a retrospective, historical classification, but on a present-day analysis. Also, the concept is connected to an economic policy agenda, first proposed by the chairman of the World Economic Forum in Davos, Klaus Schwab (2016).

The paradigm is said to be very technology-focused (Buhr and Trämer 2016; Kopp 2016). While there are Industry 4.0-related discussions that explicitly consider impacts of technological changes on other aspects of the economy and society (e.g. Work 4.0 (Kopp 2016) or Education 4.0 (Fisk 2017)), the field of technological change itself is entirely attributed to the market and not presented as influenceable. Only technological-induced *consequences* are presented as influenceable, but not the technological development itself. This limits approaches that want to shape technological change and hampers the capturing of (inter-)relations between technological change, societal impact and goals and economic developments. The limitedness of the Industry 4.0 concept is not so much its focus on technologies per se, but that political and societal possibilities for shaping and directing technological change against the backdrop of societal demands and economic goals are not adequately considered: Buhr and Trämer (2016) argue that the potential of growing digitalisation can be exploited above all if its potential for society as a whole is considered, with humans taking on the central role.

With its Industry 5.0 concept the European Commission attempts to compensate for some of the weaknesses of the Industry 4.0 concept. The difference between this concept and Industry 4.0 does not lie in the enabling technologies, which are not very different from the ones dedicated to Industry 4.0 (Müller 2020: 8–10). Rather, the difference relates to other aspects, as summarised by the Expert Group on Economic and Societal Impact of Research and Innovation (ESIR) within its transformative vision for Europe (see Table 2).

While the concept of Industry 4.0 tends to focus on the supply of technologies, with the societal demand for technologies playing a subordinate role, the European Commission is now taking a different path. The new Industry 5.0 concept does not necessarily describe a fifth industrial revolution but rather a change in policy strategy. It is no longer an increase in private economic profitability that is regarded as the central goal of the technological transformation. Rather, the central goal of

Table 2 Differences between Industry 4.0 and 5.0 (Dixson-Declève et al. 2022: 6–7)

Industry 4.0	Industry 5.0
• Centred around enhanced efficiency through digital connectivity and artificial intelligence • Technology-centred around the emergence of cyber-physical objectives • Aligned with optimisation of business models within existing capital market dynamics and economic models—i.e. ultimately directed at minimisation of costs and maximisation of profit for shareholders • No focus on design and performance dimensions essential for systemic transformation and decoupling of resource and material use from negative environmental, climate and social impacts for sustainability and resilience	• Ensures a framework for industry that combines competitiveness and sustainability, allowing industry to realise its potential as one of the pillars of transformation • Emphasises impact of alternative modes of (technology) governance • Empowers workers through the use of digital devices, endorsing a human-centric approach to technology • Builds transition pathways towards environmentally sustainable uses of technology • Expands the remit of corporation's responsibility to their whole value chains • Introduces indicators that show, for each industrial ecosystem, the progress achieved on the path to well-being, resilience and overall sustainability

Industry 5.0 is a human-centric, sustainable and resilient industry, aiming at a future production in which tackling societal challenges takes centre stage:

- As a **human-centric approach**, Industry 5.0 differs fundamentally from the technology-driven concept of Industry 4.0. Accordingly, the starting point is not a single technology and its efficiency potential. Rather, societal demands and human interest are placed in the foreground of the production process: 'Rather than asking what we can do with new technology, we ask what technology can do for us' (Breque et al. 2021: 14). Consequently, in the labour context, this means that the needs of workers in the digital age should also be taken more into account, which in turn has implications for the topic of skills, as will be further elaborated in this article.
- Against the background of the environment and the careful use of planetary resources, Industry 5.0 must also be **sustainable**. Here, too, the approach is human-centric in the broadest sense, since the ultimate aim is to manage and produce sustainably without jeopardising the needs of future generations (Breque et al. 2021).
- **Resilience** refers primarily to the attempt to make the industry more resistant in all its components. The focus is primarily on globalised production, for which resilient strategies are to be developed that ultimately target supply chains and production processes. In this context, the Covid-19 pandemic has highlighted weaknesses and fragilities, which are also considered in the context of the Industry 5.0 approach (Breque et al. 2021).

All in all, Industry 4.0 as a techno-euphoric approach tends to emphasise how to deal with a given supply of increasing availability of digital technologies —while the demands on technologies in the sense of societal challenges are rather neglected. Industry 5.0, however, functions as a policy model that calculates the demand for technologies based on their utility, putting societal challenges and solutions in front. This role of technology as an enabler has already been emphasised by the OECD (FORA 2009).

3 Social Innovation and Industry 5.0

In accordance with the paradigm of Industry 5.0, the understanding of innovation must not be limited to entrepreneurial success and has to include other success and target benchmarks—a different and more comprehensive understanding of innovation is needed (for an overview on understandings of innovation, see Butzin et al. 2014). Shaping industry policy according to the concept of Industry 5.0, the theoretical framework of social innovation can be very helpful, particularly regarding human-centricity. Social practices are in the centre of a definition by Howaldt and Schwarz (2010: 21):

> A social innovation is a new combination and/or new configuration of social practices in certain areas of action or social contexts prompted by certain actors or constellations of actors in an intentional targeted manner with the goal of better satisfying or answering needs and problems than is possible on the basis of established practice.

Technological innovations need to be supported by non-technological elements. Innovation processes should be understood as social innovation processes, opening them up to co-creation—involving users, workers and citizens as well as cross-sector collaboration (Kohlgrüber et al. 2019). For a smooth implementation of new (technological) solutions and to 'bring technology into society' (ibid.), economic, social and environmental impact as well as organisational and personnel development must be considered right from the beginning. Especially, the implementation of new technologies is related to a change in the way of working (Kohlgrüber et al. 2019). Against this backdrop, the European twin transition (green and social transformation, see European Commission 2020) has to be completed by the necessary social transition dimension (triple transition). Such a social innovation process is leading to **changing social practices—**in the sense of Industry 5.0 towards a human-centric, resilient and sustainable industry.

The concept of Social Innovation can frame this multi-layered development in the interplay of technology and social practices by:

- looking at the problem solution and not only at the given (technological) possibilities,
- putting societal, regional, local challenges at the centre of innovation policy—not economic prosperity, which can only partially solve societal challenges, as short-term goals conflict with long-term goals,
- combining social and technological innovations into system innovations and promoting innovation capability,

- ensuring an interaction of different, not only economic actors, e.g. in the creation of sustainable supply chains using the circular economy. In Social Innovation theory, the cooperation of actors is an important enabler of social innovations (Butzin et al. 2014: 111).

Against the backdrop of the described Industry 5.0 and the Social Innovation approach, the following section will discuss the relevance of skills for the human-centric pillar.

4 Skills: Central Part of Human-Centricity

Technological changes in the form of the introduction of new technologies and the associated organisational decisions and adjustments create new skills requirements for employees and managers—a phenomenon that already accompanied earlier phases of technological progress in the working world (Autor et al. 2003). Yet, within the framework of the Industry 5.0 concept, workers are seen less as a cost factor and more as an investment (Breque et al. 2021). Although this perspective is not new—e.g. the Human Capital (Fleischhauer 2007) and the socio-technical system approach (Guest et al. 2022) are based on this—this human-centricity is a crucial aspect that distinguishes Industry 5.0 from Industry 4.0. Accordingly, the Industry 5.0 approach offers a framework for systematically introducing a human-centred approach before starting to develop and implement a technological solution (combining technological and social innovation).

As a result, the topics of education and training and therefore skills for the digital transformation also take up a bigger scope. While aspects related to employee qualifications were previously seen as necessary factors for the successful implementation of digital technologies, a human-centred approach brings them further to the fore. Especially with regard to the industrial context, the question arises how workers can be empowered to work in a digital age, while technological changes, which go hand in hand with changing roles and an increasing dependence on technology, have often been perceived as a threat by employees so far (Breque et al. 2021). Going further, the question has to be answered, in how far new technologies could support the workers in their workplace (see workplace innovation approach fostered by the European Workplace Innovation Network (EUWIN n. y.)).

As skill needs evolve about as fast as new technologies appear on the market, it is crucial to equip workers with the appropriate skills to ensure that they can cultivate employment opportunities in the digital age. Thereby, the first question is which skills are needed for the digital labour market and, in a second step, how these skills can be taught and made accessible. The introduction of digital technologies may also create new potential for the inclusion of vulnerable groups, such as non-native speakers, people older than 55, early school leavers and people without degrees as well as women—provided that they also have the necessary skills and competences (see BEYOND 4.0 project results; Kangas et al. 2022).

The Industry 5.0 approach aims at making technologies even more user-friendly and application-oriented so that workers are not overburdened with new skill requirements. Indirectly, this formulates a strategy of using technology in a complementary way to facilitate and advance human work. In contrast, the consequences for human labour in the Industry 4.0 approach remain rather open, which sparked the discussion about uncontrollable automation scenarios, not least in the public, but also in the scientific debate. Although this does not banish possible negative automation effects, an Industry 5.0 perspective helps to keep possible effects already in mind when designing technologies. An analysis of the task structure of jobs and their individual affectedness can help in this regard. However, in accordance with the idea of an Industry 5.0, Fernández-Macías and Bisello (2020) argue that the analysis needs to move beyond a purely technical and deterministic view of jobs, not only viewing jobs as bundles of tasks but also as part of the social structure of productive organisations. Therefore, social factors such as the set-up of production and service provision are key to understanding the implications of technological change on employment, tasks and skill demands.

Apart from the need to adapt technologies to human labour, there is also a need to develop training measures systematically to teach workers the necessary skills for the digital transformation. The vision of Industry 5.0 is thereby that all employees and industrial workers will be up- or reskilled. Detecting new skills demands and timely adjustments are therefore of utmost importance for the Industry 4.0 technology implementation and the Industry 5.0 approach. According to the social innovation theoretical concept (Butzin et al. 2014), a comprehensive bottom-up social innovation process, integrating all the relevant stakeholder groups (companies, training providers, research institutions, associations and social partners) right from the beginning is needed. This also includes the integration of managers, workers and trainers from concerned departments. Taking up this holistic approach the transformative potential and power of technological and social (people related) change is considered in a systemic way. To move things forward in this direction, new alliances with new constellations, roles, tasks and responsibilities in a reciprocal interplay have to be established.

In this chapter's approach of focusing on skills and considering them as an essential characteristic of a human-centred approach, the activities of the EU-funded projects BEYOND 4.0, SPIRE-SAIS and ESSA will be considered more profoundly as qualitative examples. All three projects recognise that skills and related training demands have to be aligned with the technological development. At the same time, it is recognised that skills development is a broad task for stakeholders from different sectors of society and is not only limited to industry players, whereby the initiation of co-creation and social innovation processes in order to convey the necessary skills is of central importance. We already experienced such an approach in empirical European-funded projects by integrating digital, green and social priorities in technological development conducted as a social innovation process, with a focus on:

- Analysing the impact of new technologies on the future of jobs, business models and welfare (BEYOND 4.0; see Beyond 4.0 n. y.).
- Explore the extent to which digital technologies have an integrative power and can promote employment, especially for disadvantaged labour market groups—with regard to the role of different actors as well as needed skills (also BEYOND 4.0).
- Close involvement and new role of workers in technological design and development (COCOP (COCOP n. y.), emphasising their experience of the workplace.
- New human–machine collaboration and work division (ROBOHARSH).
- Simultaneously developing technology and training (COCOP, ROBOHARSH).
- Combining technological trends with pro-active skills adjustment (ESSA (ESTEP n. y.), SPIRE-SAIS (ASPIRE n. y.)).

5 Skills Alliances: Multi-level Governance Fostering New Social Practices

Industry 5.0 needs a change in the social practices and cooperation of companies and the education system, to overcome technological resistance of the workforce (Cirillo et al. 2021) looking for new and short-term ways of adjusting skills closely linked with the industry demands. This cannot be done by the different actors alone. An ecosystem-oriented alliance has to be established integrating the competences and expertise as well as the possibilities and responsibilities of the concerned stakeholders of all societal areas: industry, policy, research and education and civil society.

Against this backdrop, the development of European Skills Alliances was initiated by the 'New Skills Agenda' and the related program for Sectoral Blueprints on Skills launched by the European Commission and funded by ERASMUS+ already since 2018 (European Commission n. y.). The purpose of these already more than 20 different sector-related Blueprints is to:

- 'Gather skills intelligence and feed this into CEDEFOP's Skills Intelligence tool.
- Develop a sector skills strategy.
- Design concrete education and training solutions for quick take-up at regional and local level, and for new occupations that are emerging.
- Set up a long-term action plan.
- Make use of EU tools e.g. EQF, ESCO, Europass, EQAVET.[1]
- Address skills shortages and unemployment'.

Within the European Steel Skills Alliance (ESSA) and the European Skills Alliance for Industrial Symbiosis (SPIRE-SAIS) a multi-sectoral, multi-stakeholder

[1] EQF: European Qualifications Framework; ESCO: European Skills, Competences, Qualifications and Occupations; EQAVET: European Quality Assurance for Vocational Education and Training.

cooperation was established to support up-/reskilling actions and to enhance competitiveness of the energy-intensive industries sector by a well and high skilled workforce. Within a common social innovation process both projects started on behalf of 24 partners each, composed by the main European stakeholders, integrating companies, education and training providers, associations and social partners and research institutions with their dedicated roles and responsibilities. This core partnership was enhanced by a growing number of associated partners leading to about 40 engaged organisations in each of the alliances showing the great attention and relevance of this alliance covering ten industry sectors (Chemical, Water, Ceramics, Raw Materials, Cement, Non-ferrous Metals, Minerals, Engineering, Refinery, Pulp and Paper)—leading to a sound ground for sustainability already during the project but also for sustainability beyond the funding period.

The partners bring together the full range of stakeholders and perspectives required to establish a sustainable strategic sector Skills Alliance ensuring European-wide delivery, engaging with national VET systems and cross-European frameworks to meet skill needs. Integrating the complementary competences of all partners is the ground for networking, policymaking, training delivery, and Europe-wide dissemination and implementation.

6 Future Skills and Adjustment

Among the main objectives of the Industry 5.0 approach, the teaching of skills for digital transformation plays a central role. However, this raises the question of which skills and competences are demanded for employees and managers to work in the digital age and in modern work organisations.

The BEYOND 4.0 research project offers a first orientation in that matter. Within the framework of the project, a systematic literature research on digitalisation skills was carried out, on the basis of which a category system for future skills was developed, which was then tested by empirical field work. In the process, new and also already known skills that are increasingly important in the modern world of work were classified that are considered important for the digital transformation (Kohlgrüber et al. 2021). As a result, it can be stated that not only digital, but also non-digital skills, in the form of personal (e.g. required personal traits, e.g. adaptability to technological changes), social (e.g. communication/collaboration) and methodological skills (e.g. problem-solving) gain importance in the course of the digital transformation (Kohlgrüber et al. 2021).

Within BEYOND 4.0's skills framework, primarily transversal skills were considered that tend to gain in importance across different professions in all sectors due to the influence of digitalisation. The high number of occupations and job profiles, combined with countless skills that are important for the respective tasks, make it difficult to specifically address job-specific skills (Kohlgrüber et al. 2021: 20). Nevertheless, these have an important function both in general and in the context of the digital transformation, so that job-specific skill demands are considered in the categorisation (*cf*. ibid.). Furthermore, it is assumed that digital competences in particular are closely related to job-specific skills and that there are interdependencies here with regard to changing work tasks (Kohlgrüber et al. 2021). Nevertheless, digital competences are classified as general, transversal competences, in line with various studies (*cf*. Eckert et al. 2018; Kohlgrüber et al. 2021; Rampelt et al. 2019).

ESSA offers more detailed insights into steel sector-specific skill requirements and a corresponding categorisation. The skills categorised here are not only those that are important for the digital transformation, but also those that are important for the green transformation and de-carbonisation—a topic that is particularly important in European industrial sectors. However, a wide range of skills related to almost all job profiles in production and maintenance are affected by Industry 4.0 technologies (Antonazzo et al. 2021). Not only technical skills are needed but more and more a set of transversal skills, e.g. green, social and methodological skills (see Fig. 1).

Concerning new skills to increase industrial symbiosis of Energy Intensive Industries the Skills Alliance for Industrial Symbiosis (SPIRE-SAIS) is also mainly looking at the upskilling of related job profiles in production and functional areas for industrial symbiosis, across the industry sectors (steel, chemicals, ceramic, cement, etc.) concerning specific job profiles in the companies. However, in this skill setting a new job profile appears: The Industrial Symbiosis Facilitator, further developed also with a training program by the INSIGHT project (Insight n. y.) (see Fig. 2).

Concerning the related skills demands additional managerial and related operational skills are needed. Technical/technological and individual/personal skills are in place for the management and operational areas; additionally, the management level

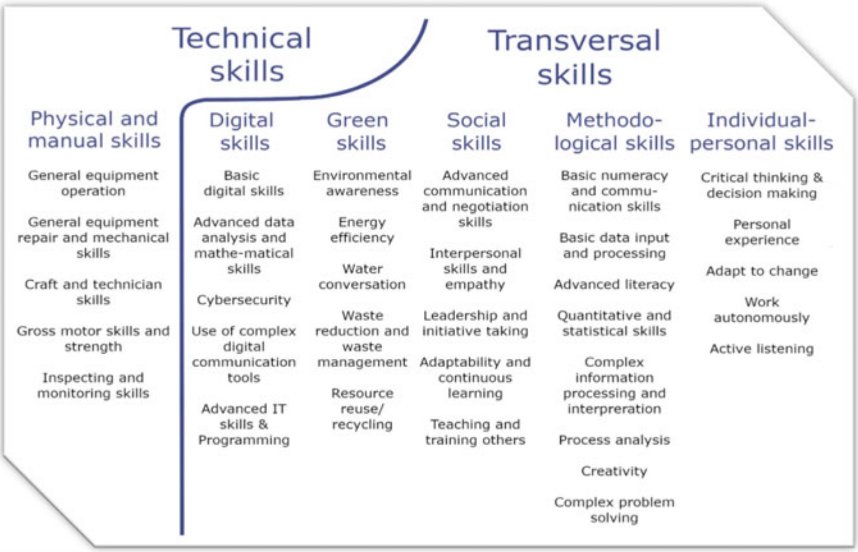

Fig. 1 Technical and transversal skills demands in the European steel industry (own depiction, based on ESSA skill categorisation, see Bayón et al. (2020: 33))

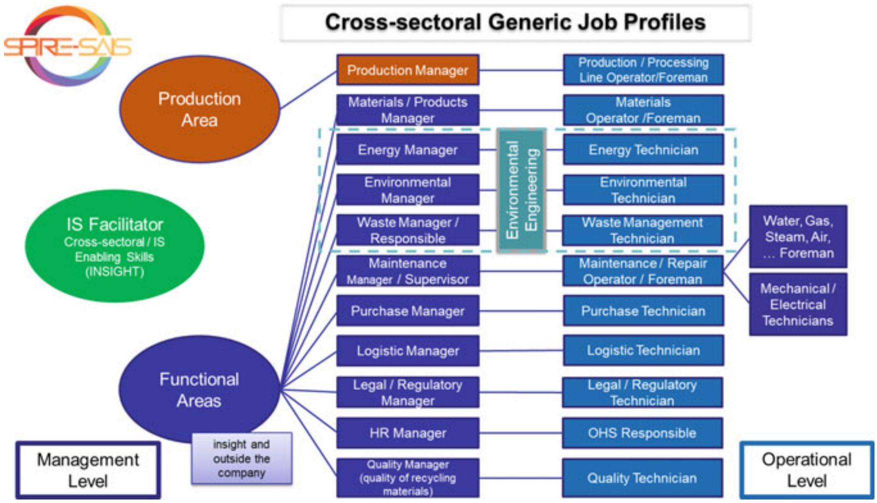

Fig. 2 Cross-sectoral job profiles affected with new skill for industrial symbiosis (based on Schröder (2021, p. 25))

is focusing on business and regulatory-related skills, which are needed both within the company and also for cross-company industrial symbiosis cooperation. In this way, the T-shaped approach of technological/technical skills (industrial symbiosis and energy efficiency related) and transversal skills (individual/personal) is broadened by business and regulatory-related skills on the management level.

7 Co-creation Processes of Developers and Operators

Beside considering and valuing new skills demands for the implementation of new technologies a more intensive element of fostering the human-centric approach of Industry 5.0 is to integrate the competences and experiences of the workers (or end users) at the concerned workplaces already in the (technological) development process (Colla et al. 2021; Schröder et al. 2020). This is not only leading to mutual learning processes and new skills during the development process but also ensures acceptance, usage and unfolding the potential of new technologies at the workplace.

Within the project Coordinating Optimisation of Complex Industrial Processes (COCOP), complex production processes of industry plants were digitally supporting the operators by guidance of a coordinating, real-time optimisation system to optimally run the production process (plant-wide optimisation as part of a socio-technical system). The development of this new software the technological development was combined with a social innovation process of co-creation and co-development for improving effectiveness and impact of the innovation and the operator acceptance.

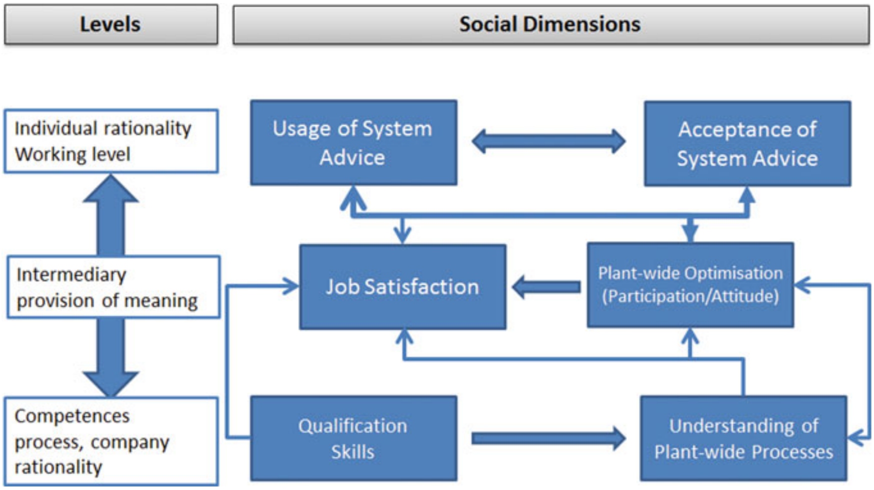

Fig. 3 Social key performance indicators

Skills play an important role here, as does embedding in organisational working conditions and tailoring the new solution to the requirements of future users.

With the integration of the workplace competences and experiences of the operators, human factor requirements for the technological development were detected and monitored by an interdisciplinary team of human factor experts, Key Performance Indicator experts and software developers elaborating a workflow covering the human factor integration. Beside technological also Social Key Performance Indicators were defined and evaluated (see the main indicators—social dimensions in Fig. 3).

Following the new innovation paradigm described above and also summarised by Kohlgrüber et al. (2019) and the Industry 5.0 approach a purely technological view was enhanced to a broader societal perspective:

- from a technological to a solution-oriented process perspective understanding technology as an enabler to solve a societal challenge;
- in the COCOP case: to improve energy efficiency, reduce waste and emissions, reduction of rejection, ensure competitiveness in a global market, improving qualification and employability of the workforce;
- to new overall and comprehensive structural principles of the innovation system;
- in the COCOP case: to integrate the human competences, experiences, and requirements in the technological development within a co-creation process as much as possible;
- organised in a comprehensive social innovation process to shape the technological development with non-technological issues taking impact on diverse areas (workforce, organisation, acceptance, mutual learning of developers and end-users) into account;

- in the COCOP case: combining the technological development with a social innovation perspective (Schröder et al. 2020, p. 39).

In summary, the practical insights indicate that a successful human-centred approach in the context of Industry 5.0 requires a combination of technological and social innovation. This is especially true regarding skills. In the Industry 5.0 approach, the aspects of education and training thereby come more to the fore. In a first step, the assessment of the important digital future skills is of great importance to be able to teach them successfully and proactively. For the concrete and systematic development of training programmes, the right stakeholder groups must be involved not only with their competences but also with their responsibilities.

8 Conclusion

Industry 5.0 and Social Innovation is changing the view on Industry 4.0 technologies to a triple transition: Digital, Green *and Social*. The empirical results of the skills analysis and activities illustrated by recent projects underline that, from an Industry 5.0 perspective, specific skills demand and adjustments are pushing Industry 4.0 to a more human-centric, resilient and sustainable industry. Concerning the three pillars of Industry 5.0, skills

- are evidently an essential part of **human-centricity**, needed to develop, implement and use technology primarily for the benefit of people/workers but also to unfold the full potential of innovations at the workplace,
- are needed at the workplace for improving reduction of waste and emissions as well as for industrial cooperation reducing environmental pollution (**sustainability**),
- are the ground for better and constantly adapting and managing change (**resilience**).

This includes also **changing social practices**:

- Considering impact of new technologies on future of jobs, business models and welfare right from the beginning of an innovation.
- Better integration of social and green priorities in technological innovation (technological development as a social innovation process).
- Close involvement of workers and people concerned in technological design and development, integrating their experience of the workplace.
- Empowerment of workers, proactive re- and upskilling.
- New human–machine collaboration and work division.
- Simultaneously developing technology and training, combining technological trends with pro-active skills adjustment.

However, it has not to be forgotten that human and technological changes go hand in hand with organisational ones. The triangle ‘human-technology-organisation’

(Dregger et al. 2016) has to be considered by looking explicitly at the interfaces between these three pillars. Therefore, Industry 5.0 is also socio-centred approach (Müller 2020) based on socio-technical work system performance.

A deeper overview of the state of the art and preconditions for adding the Industry 5.0 perspective (human-centric, resilient, sustainable) to Industry 4.0 related innovations and implementations is needed, followed by an Industry 5.0 framework for engaging stakeholders, raising awareness, increasing acceptance, gathering and exchanging good practices, enabling policy and regulations, market conditions, development indicators, and others. This should also include an evidence-based and long-term management of the European Industry workforce and skills needs, which accounts for an inclusive working environment and empowered workforce strategy, in order to build a human-centric European Industry.

Multi-level and multi-governance engaging all societal areas (industry, policy, research and education, civil society) is the needed ground for setting the scheme for a comprehensive social innovation process, engaging the willing stakeholders from all societal areas to develop an Industry 5.0 roadmap and movement for new social practices, skills and mindsets (especially in industry) within respective ecosystems. Within such a social innovation process from the challenge and idea over related interventions to an implementation and institutionalisation industry-driven transition pathways for achieving human-centric innovation and a social, resilient and sustainable transformation to the Industry 5.0 approach should be developed (roadmaps).

References

Antonazzo L, Weinel M, Stroud D, Szulc W, Paduch J (2021) Identification of national (Sector) VET qualification and skills (Regulatory) frameworks for steel (ESSA Deliverable No. 4.1). https://www.estep.eu/assets/Uploads/ESSA-D4.1-Identification-of-National-Sector-VET-Qualification-and-Skills-Regulatory-Frameworks-for-Steel-Version-2-final.pdf

ASPIRE (n. y.) Skills alliance for industrial symbiosis—a cross-sectoral blueprint for a sustainable process industry. https://www.spire2030.eu/sais

ASPIRE (2021) Processes4Planet: strategic research and innovation agenda. https://www.aspire2050.eu/sites/default/files/users/user85/p4planet_07.06.2022._final.pdf

Autor DH, Levy F, Murnane RJ (2003) The skill content of recent technological change: an empirical exploration. Q J Econ 118(4):1279–1333. https://doi.org/10.1162/003355303322552801

Bayón F, Goti A, Akyazi T (2020) Company skills requirements and foresight (ESSA Deliverable No. 3.2). https://www.estep.eu/assets/Uploads/ESSA-D5.2-Industry-Skills-Requirements-Version-1.pdf

Beyond 4.0. (n. y.) BEYOND 4.0. https://beyond4-0.eu/

Branca TA, Fornai B, Colla V, Murri MM, Streppa E, Schröder AJ (2020) Current and future aspects of the digital transformation in the European steel industry. Matériaux Tech 108(508). https://doi.org/10.1051/mattech/2021010

Breque M, Nul L de, Petridis A (2021) Industry 5.0: towards a sustainable, human-centric and resilient European industry. European Commission, Brussels. https://doi.org/10.2777/308407

Buhr D, Trämer M (2016) Industrie 4.0 braucht auch soziale Innovation. WISO 39(4)

Butzin A, Howaldt J, Domanski D, Kaletka C, Weber M (2014) Innovation studies. In Howaldt J, Butzin A, Domanski D, Kaletka C (eds) Theoretical approaches to social innovation: a critical literature review (SI-DRIVE deliverable No. 1.1), pp 105–121

Cirillo V, Fanti L, Mina A, Ricci A (2021) Digitalizing firms: skills, work organization and the adoption of new enabling technologies (LEM Working Paper Series). http://www.lem.sssup.it/WPLem/files/2021-04.pdf

COCOP (n. y.) Coordination optimisation of complex industrial processes. https://www.cocop-spire.eu/

Colla V, Matino R, Schröder AJ, Schivalocchi M, Romaniello L (2021) Human-centered robotic development in the steel shop: improving health, safety and digital skills at the workplace. Metals 11(4):647. https://doi.org/10.3390/met11040647

Dixson-Declève S, Balland P-A, Bria F, Charveriat C, Dunlop K, Giovannini E, Tataj D, Hidalgo C, Huang A, Isaksson D, Martins F, Mir Roca M, Morlet A, Renda A, Schwaag Serger S (2022) Industry 5.0: a transformative vision for Europe (ESIR Policy Brief No. 3). https://doi.org/10.2777/17322

Dregger J, Niehaus J, Ittermann P, Hirsch-Kreinsen H, Hompel MT (2016) The digitization of manufacturing and its societal challenges: a framework for the future of industrial labor. https://doi.org/10.1109/ETHICS.2016.7560045

Eckert N, Gallenkämper J, Heiß H-U, Kreulich K, Mooraj M, Müller C, Müller G, Schumann C-A, Sowa T, Spiegelberg G (2018) Smart Germany. Ingenieursausbildung für die digitale transformation. VDI

ESTEP (n. y.) European steel skills agenda (ESSA). https://www.estep.eu/essa

European Commission (n. y.) Blueprint for sectoral cooperation on skills. https://ec.europa.eu/social/main.jsp?catId=1415&langId=en

European Commission (2020) A new ERA for research and innovation: communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. European Commission, Brussels. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0628

EUWIN (n. y.) The European workplace innovation network (EUWIN): a European movement for sustainable competitiveness and workforce health & well-being. https://workplaceinnovation.eu/euwin/

Fernández-Macías E, Bisello M (2020) A taxonomy of tasks for assessing the impact of new technologies on work. https://joint-research-centre.ec.europa.eu/system/files/2020-05/jrc120618.pdf

Fisk P (2017) Education 4.0 … the future of learning will be dramatically different, in school and throughout life. https://www.thegeniusworks.com/2017/01/future-education-young-everyone-taught-together/

Fleischhauer K-J (2007) A review of human capital theory: microeconomics. SSRN electronic journal. Advance Online Publication.https://doi.org/10.2139/ssrn.957993

FOR A (2009) New nature of innovation: report to the OECD, Copenhagen. https://web.archive.org/web/20160426045708/. http://www.tem.fi/files/24835/New_Nature_of_Innovation.pdf

Guest D, Knox A, Warhurst C (2022) Humanizing work in the digital age: lessons from socio-technical systems and quality of working life initiatives. Hum Relat 75(8):1461–1482. https://doi.org/10.1177/00187267221092674

Howaldt J, Schwarz M (2010) Social innovation: concepts, research fields and international trends. http://www.sfs.tu-dortmund.de/odb/Repository/Publication/Doc/1289/IMO_Trendstudie_Howaldt_Schwarz_englische_Version.pdf

Insight (n. y.) Insight: fostering industrial symbiosis through the development of a novel and inovative traing approach. https://www.insight-erasmus.eu/

Kagermann H, Lukas W-D, Wahlster W (2011) Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution. VDI Nachr (13):2

Kangas O, Karonen E, Kohlgrüber M, Behrend C, Cuypers M, Götting A (2022) Education and training in inclusive welfare states (BEYOND 4.0 deliverable 6.2, Version 3.0). https://beyond4-0.eu/storage/publications/D6.2%20Education%20and%20Training%20in%20Inclusive%20Welfare%20States/BEY4.0_WP6_D6.2_Working%20paper%20uspkilling%20schemes.pdf
Kohlgrüber M, Behrend C, Götting A, Cuypers M, Warhurst C, Wright S (2021) Understanding future skills and enriching the skills debate. Version 3.0—Second report (Deliverable No. 6.1). https://beyond4-0.eu/storage/publications/D6.1%20Understanding%20future%20skills%20and%20enriching%20the%20skills%20debate.%20Full%20version./BEY4.0_WP06_Task_6.1_Report%20overview%20new%20skills.pdf
Kohlgrüber M, Schröder A, Bayón Yusta F, Arteaga Ayarza A (2019) A new innovation paradigm: Combining technological and social innovation. Matériaux Tech 107(1). https://doi.org/10.1051/mattech/2018065
Kopp R (2016) Industrie 4.0 und soziale innovation: Fremde oder Freunde? Düsseldorf. http://eldorado.tu-dortmund.de:8080/bitstream/2003/35869/1/FGW-Studie_Ralf_Kopp_Industrie_Vier_Null_und_soziale_Innovation.pdf
Müller J (2020) Enabling technologies for Industry 5.0: results of a workshop with Europe's technology leaders. European Commission, Luxembourg. https://doi.org/10.2777/082634
Østergaard EH (2018) Welcome to Industry 5.0: the "human touch" revolution is now under way. https://info.universal-robots.com/hubfs/Enablers/White%20papers/Welcome%20to%20Industry%205.0_Esben%20%C3%98stergaard.pdf?submissionGuid=00c4d11f-80f2-4683-a12a-e821221793e3
Özdemir V, Hekim N (2018) Birth of Industry 5.0: making sense of big data with artificial intelligence, "The Internet of Things" and next-generation technology policy. Omics: A J Integr Biol 22(1):65–76. https://doi.org/10.1089/omi.2017.0194
Rampelt F, Orr D, Knoth A (2019) Bologna digital 2020: white paper on digitalisation in the European higher education area, Berlin. https://hochschulforumdigitalisierung.de/sites/default/files/dateien/2019-05_White_Paper_Bologna_Digital_2020.pdf
Sachsenmeier P (2016) Industry 5.0—the relevance and implications of bionics and synthetic biology. Engineering 2(2):225–229. https://doi.org/10.1016/J.ENG.2016.02.015
Schröder A (2021) Prototype of the blueprint new skills agenda energy intensive industries (Deliverable No. 5.2). https://www.aspire2050.eu/sites/default/files/users/user85/spire-sais_deliverable_d5.2_blueprint_prototype_2021.pdf
Schröder A, Kohlgrüber M, Liinasuo M, Ivaska R (2020) Co-creation, combining technological and social innovation (COCOP deliverable No. 6.1)
Schwab K (2016) The forth industrial revolution. World Economic Forum
Schwab K (2018) The fourth industrial revolution. https://www.britannica.com/topic/The-Fourth-Industrial-Revolution-2119734

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The Impact of the New Technologies and the EU Climate Objectives on the Steel Industry

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1 Introduction

In recent years, seven drivers of change for the industrial technological transformation in Europe have been identified (Murri et al. 2021),[1] as follows: 1. Advanced manufacturing (Industry 4.0), 2. Advanced materials development, 3. Complex and global supply chains, 4. Market competition and over-capacity, 5. Life cycle design, pollution prevention and product recyclability, 6. Decarbonisation and Energy Efficiency and 7. Evolution of customer requirements. In this context, digital transformation is considered the key enabler directly impacting on advanced manufacturing and it transversally affects the pathway towards sustainability (Neligan 2018).

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Production processes can become more effective and efficient through the implementation of digital solutions at operation/company level, such as business information systems in combination with measurement sensors, smart production services, tools from information, communication and automation technology (e.g. simulation and forecasting models, self-learning assistance systems and diagnostic tools, or lab-on-chip systems for real-time analysis). As a consequence, the flexibility of production processes will be enhanced through the application of networked machines and components communicating with each other via the Internet and form Cyber-Physical Systems (CPS) (Iannino et al. 2019) and Cyber-Physical Systems of Systems (CPSoS) (Biedermann 2019). In addition, new additive manufacturing (AM) processes, such as 3D printing technologies, can improve resource efficiency by enabling customisation of components production; optimised component structures can lead to weight savings and waste reduction, resulting in lower life cycle costs.

As far as the steel sector is concerned, current technological transformations and developments are expected to have a very relevant impact (Branca et al. 2020). The application of digital technologies in the steel production processes is mainly focused on advanced tools for the optimisation of the whole production chain (Maddaloni et al. 2015) as well as on specific technologies for product quality monitoring and optimisation (Damacharla et al. 2021), energy and resource efficiency (Matino et al. 2019a, b) and CO_2-lean production (Porzio et al. 2013).

In addition, the social innovation represents one of the key factors for the effective way of developing and implementing this technological transformation (Colla et al. 2017). This can be achieved by integrating workplace experience and demands, by upskilling the workforce and by improving working conditions and safety, creating qualified jobs and enhancing the workers' competencies through the support of digital technologies. On the other hand, digital innovation can enable social innovation through knowledge sharing, cooperative work and networking. Nevertheless, one of the most relevant barriers to overcome to effectively implement these technologies is the lack of qualified personnel.

As Energy Intensive Industries (EIIs) are responsible for about 8% of the European Union (EU)'s emissions (European Commission 2020a), to become more competitive at global level, they have to manage energy transition, energy technologies for resilience and cost reductions. On this subject, the technological development represents a key aspect to reach their environmental sustainability through emission reductions and energy saving. In the context of the sustainable development, the EU has been committed to deliver on the 2030 Agenda for the Sustainable Development Goals (SDGs), adopted by the United Nations (UN) General Assembly in 2015 (United Nations 2015), as outlined in 'Towards a Sustainable Europe by 2030' (European Commission 2019a). In this context, digital technologies could positively affect the SDGs implementation through 'green growth' development patterns (Eteris 2020), by using digital solutions in sustainability.

After the Energy Union initiative (European Commission 2015), the European Commission (EC) launched the European Green Deal (EGD) for the EU and its citizens (European Commission 2019b). This ambitious objective reflects the EC's commitment to transform Europe into the world's first climate-neutral continent by 2050 as well as into a sustainable, prosperous, modern, resource-efficient and competitive economy according to 'A New Circular Economy Action Plan' (European Commission 2020b), which is one of the main building blocks of the EGD for creating incentives to promote circular business models. The EGD will have an important impact on process industries, as EU aims at becoming the world's first climate-neutral continent, achieving net-zero greenhouse gas (GHG) emissions by 2050, cutting GHG emissions, investing in cutting-edge research and innovation. Significant opportunities and challenges for EIIs can rise to reach a strong international competitiveness (Lechtenböhmer and Fischedick 2020) as they are responsible for around 20% of total GHG emissions. Therefore, an integrated climate and industry strategy is crucial in their activities, as key element to implement the EGD objectives.

Digitalisation, as a key factor affecting the technological transformation of EIIs, is fundamental to achieve the EU climate objectives, according to the European Green Deal (European Commission 2019b). In this context, green technologies, combined with EU initiatives, aimed at Digitising European Industry (European Commission 2016), including a better and growing use of technologies, such as Big Data (Brandenburger et al. 2016) and Artificial Intelligence (AI) (Duft and Durana 2020). To this purpose, companies are committed to enclose sustainability into their business models for improving their corporate image and to save energy and material costs, resulting in industrial resource efficiency (Matino et al. 2016, 2017a). On this purpose, research activities can help industries in renewing their business model and better account for environmental sustainability in their business ecosystems (Arens 2019). Furthermore, the Processes4Planet (P4Planet) partnership aims at transforming European EIIs in order to achieve overall climate neutrality at EU level by 2050 (SPIRE 2021). In particular, the Process4Planet 2050 roadmap aims at reaching the transition to a climate neutral and circular society by both technological innovation and a holistic systemic socio-economic approach.

As the EGD achievements depend on the horizontal, cross-sectoral integration of an industrial strategy implemented throughout the full value chain, the European steel industry needs a supportive regulatory framework to ensure its international competitiveness, during and beyond the transition towards CO_2-lean production of steel (EUROFER 2020). On this subject, the agreement between EU steel industry and the EU institutions and governments can lead to set an action plan to a market for green steel in the period from 2021 to 2030. In this regard, the EU steel industry is committed to achieve the EU's climate objectives by reducing CO_2 emissions by 2030 by 30% compared to 2018 (which equates to 55% compared to 1990) and by 80 to 95% by 2050.

The present work aims at analysing current and upcoming developments related to the digital transformation and Industry 4.0 in the steel sector, according to the four levers of the digital transformation (i.e. Digital Data, Automation, Connectivity and Digital Customer Access). In addition, digital technologies were presented as enabler of green technologies to achieve the climate objectives, and in accordance to the 'Green Steel for Europe' project (Green Steel for Europe 2022) and the Clean Steel Partnership (CSP) roadmap (ESTEP 2020). In the 'Green Steel for Europe' an innovative approach has developed impacts to tackle the decarbonisation of the European steel industry. On the other hand, according to the CSP and its roadmap, digitalisation, as enabler, has been included among the six areas of intervention (CDA: Carbon Direct Avoidance, SCU-CCU: Smart Carbon Usage—Carbon Capture and Utilization, SCU-PI: Smart Carbon Usage Process Integration, CE: Circular Economy, their combination and Enablers) that aim at achieving the carbon–neutral steel production. In addition, the current and upcoming role of digital technologies as support of social innovation aims to improve safety and health of employees and to enable a new way of work within efficient plants to face the new challenges and to remain competitive and sustainable at the same time. In fact, the successful implementation of new technologies strongly depends on the human perspective in all steps of the applied technical solution, integrating and encompassing the context of social innovation.

The centrality of human beings inside the manufacturing chain or in the neighbouring community is highlighted in the context of Industry 5.0 (European Commission 2021a), concerning the transition towards a sustainable, human-centric and resilient European industry, where production respects the boundaries of planet and the centrality of workers wellbeing in the production process. In addition, Industry 5.0 is based on the integration of social and environmental European priorities into the technological innovation (Paschek et al. 2019).

However, technological achievements, from human labour centred production to fully automated way (Larsson and Lindfred 2019), have different impacts on the workforce: on one hand, relieving humans from monotonous and physically strenuous work to be replaced with creative work, and, on the other hand, increasing unemployment and widespread workforce de-skilling. However, the impact of the digital technologies application on the low skilled workers is an open issue, which needs to be faced in the near future, with different approaches, such as up-, reskilling, reduction of 'middle qualification level' workers (polarisation), use of external personnel, etc. Further analyses of future impacts of digital technologies on the workforce (BEYOND 4.0 2022) suggest the combination of professional skills and digital skills on sectoral level and provide indications both for Vocational Education and Training (VET) systems and stakeholders at regional level. Furthermore, a first VET systems analysis has been performed in the ESSA project through the identification possible contributions from different systems in the member states, mainly focused on five case study countries (Germany, Italy, Poland, Spain, United Kingdom) (ESSA 2020).

Started in January 2019 (see chapters "Introduction: The Historic Importance and Continued Relevance of Steel-Making in Europe" and "The Technological and Social Transformation of the European Steel Industry: Towards Decarbonisation and Digitalisation" for more information on the project). [2]

This chapter is organised as follows: Sect. 2 introduces digital technologies as enabler of green technologies. In Sect. 3, digital technologies as a support of the

[2] The work presented in this chapter is part of the Erasmus+ Blueprint project '*New Skills Agenda Steel: Industry-driven sustainable European Steel Skills Agenda and Strategy*' (ESSA)

social innovation are analysed. Section 4 discusses the future scenario for the metal sector. Finally, Sect. 5 provides some concluding remarks.

2 Digital Technologies as Enablers of Green Technologies

As highlighted in the EGD (European Commission 2019b), digital technologies play a fundamental role as enablers of new green technologies to achieve a sustainable ecological transition. Therefore, the development of both green and digital technologies aims at a twin transition (digital and green) as the main driver for the European industry's competitiveness. For instance, digital technologies represent new opportunities for monitoring air and water pollution as well as for monitoring and optimising energy and natural resource consumption.

According to the SPIRE's (Sustainable Process Industry through Resource and Energy Efficiency) new Vision 2050 (SPIRE 2018), the future of Europe will be based on a strong cooperation across industries in order to achieve physical and digital interconnection, through the development of innovative 'industrial ecology' business models addressing climate change and enabling a circular society. On this subject, developments in the future process industry will be crucial (Glavič et al. 2021), such as climate change with GHGs emissions and ecosystems, energy with renewable sources and efficiency, (critical) raw materials and other resources, water resources and recycling, zero waste, Circular Economy (CE) and resource efficiency (Matino et al. 2019b; Rieger et al. 2021), supply chain integration, process design and optimisation (Colla et al. 2016), process integration (Porzio et al. 2014) and intensification, industrial ecology and life cycle thinking, industrial-urban symbiosis, product design for circularity, digitalisation, sustainable transport, green jobs, health and safety, hazardous materials and waste reduction, customer satisfaction, education and lifelong learning (Branca et al. 2021).

Consequently, several benefits can be obtained, such as preserving the EU technological leadership through the maintenance of its competitive position, enabling innovative solutions (including technical, organisational, financial, etc.) and developing new business models and social practices, which can contribute to the sustainability by reducing environmental impacts. Both Industry 4.0 and the CE aim at improving products and processes and optimising resource usage and costs. CE can drive the transition of manufacturing industries towards systemic sustainability (Bradford 2015) and Industry 4.0 can drive innovation and the digital transformation towards smart and resilient manufacturing industries.

Digital technologies as enabler of green technologies can help at reducing natural resource exploitation, enhancing material and energy efficiency. In particular, they have a strategic role in increasing technological performances with the aim of reducing and optimising energy and materials consumptions along the steel production routes. For instance, process optimisation and monitoring, as well as systems integration, are crucial for the optimal energy management along the steel production (Colla et al. 2019). In addition, real-time monitoring ensures the product quality

(Vannocci et al. 2019), leading to reduced by-products and waste production. Furthermore, the combination of novel tools for a rapid characterisation of solid and liquid slags, advanced models and complex data analytics and AI models can increase valorisation and reuse of slags, resulting in boosting the slag reuse and recycling (Matino et al. 2017b). AI-based predictive models can also be used for the optimised maintenance and production scheduling. In this context, digital technologies effectively can support the transaction to the new green production. In this context, the International Energy Agency (IEA) technology Roadmap (International Energy Agency 2020) analysed key technologies and their integration in steel sector to achieve the ambitious goal of at least 50% of CO_2 emissions reduction by 2050. On this subject, in a short term, the technology performance improvement in the current production routes will play a fundamental role, while, in the medium-long term, a new technological transformation based on carbon capture and storage/carbon capture, utilisation and storage (CCS/CCUS) and the substitution of carbon with other energy sources (i.e. hydrogen), will become increasingly important.

To transform the EU into a prosperous, modern, resource-efficient and competitive economy, major technological developments in the EU steel industry will be in line with the recent European initiatives following the Green Deal strategy and strongly oriented towards the climate objectives in Europe in terms of low-carbon steelmaking ('zero-carbon steelmaking'). For this purpose, a recent project, 'Green Steel for Europe' (Green Steel) (Green Steel for Europe 2022) aims at supporting EU towards achieving the 2030 climate and energy targets and the 2050 long-term strategy for a climate neutral Europe, through effective solutions for clean steelmaking to meet the decarbonisation of the European steel industry. The most promising technologies, in terms of CO_2 mitigation potential, were identified in Deliverable D1.2 (Green Steel for Europe 2021a). In particular, along with currently addressed CO_2 mitigation pathways in the European steel industry (i.e. Carbon Direct Avoidance (CDA), Process Integration (PI) and Carbon Capture and Usage (CCU)), the identified technologies are: Hydrogen-based Direct Reduction (H2-DR), Hydrogen Plasma Smelting Reduction (HPSR), Alkaline Iron Electrolysis (AIE), Molten Oxide Electrolysis (MOE), Carbon Dioxide Conversion and Utilization (CCU), Iron Bath Reactor Smelting Reduction (IBRSR), gas injection into the BF, substitution of fossil energy carriers by biomass, high-quality steelmaking with increased scrap usage.

In addition, different barriers, such as technical, organisational, regulatory, or societal, and financial ones, (Collection of possible decarbonisation barriers, D1.5) (Green Steel for Europe 2021b) have been identified. On the other hand, significant investments and economic efforts will be needed up to 2050 for the decarbonisation technologies deployment (Green Steel for Europe 2021c). As a joint collaboration among the steel industry and other stakeholders for achieving the Green Deal decarbonisation targets is crucial, the Clean Steel Partnership (CSP) (ESTEP 2020) initiative under the framework of Horizon Europe is associated with the creation of focused Public Private Partnerships (PPP). The CSP Roadmap provides six areas of intervention corresponding to the identified technological pathways and including digitalisation and skills as enablers for the implementation of the technologies and combination of technologies for carbon–neutral steel production. In particular, the

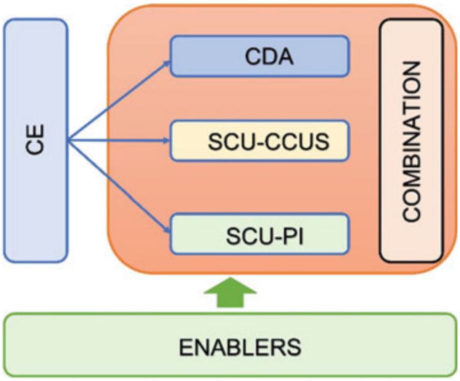

Fig. 1 Connection among the 6 areas of intervention for carbon–neutral steel production

six areas of intervention (CDA, SCU-CCU, SCU-PI, CE, their combination and Enablers) are shown in Fig. 1.

The 'Enablers & support actions' aim at integrating the most recent digital technologies, such as AI and digital solutions in industrial production as well as new measurement systems and digital tools for monitoring and control, by using Internet of Things (IoT) (Xia et al. 2012; Zhang et al. 2016) in the new steel production. In addition, further examples are represented by new predictive and dynamic models and scheduling tools, tailored to process planning, assessment and optimisation. Beside digitalisation also skills and competences are seen as a relevant enabler to unfold the full potential of new solutions at the workplace.

Based on a technology 'building blocks' (BB) approach (see Table 1), each block represents basic actions for providing decarbonisation technologies, such as digital technologies for developing green technologies in different intervention areas, to reach the effective decarburisation of steel production.

For instance, under CE frame (BB9), a major contribution is expected through the definition of a common Life Cycle Inventory for residues, and design and development of a tool for continuous monitoring of effects of circular approach/solutions on CO_2 emissions. On the other hand, in the dedicated building block on 'Enablers (skills, digitalisation) for clean steel development', enablers are necessary for implementing technical and organisational conditions to plan and manage a sustainable steel production. In this context, new technologies will be crucial for the integration of new digital tools for monitoring and control as well as the extensive use of Industrial IoT (IIoT) approach. Such approach allows, for instance, fast integration of new measurement techniques into the set of data streams to be monitored and used for controlling process. For this purpose, Machine Learning (ML), AI techniques and Cybersecurity will play an ever-increasing role. In the standardised description of the Information and Communications Technology (ICT) and automation systems (see Fig. 2), the automation levels of Plant Control, Scheduling and Production Planning and Control are involved.

Additionally, it has been underlined in Colla et al. (2020) that a full exploitation of the potential of the data collected through all the steps of the manufacturing processes,

Table 1 Building blocks contributions to the six areas (ESTEP 2020)

Areas of intervention						
Building blocks (1–12)	CDA	SCU-CCUS	SCU-PI	CE	Combination	Enablers
1. Gas injection	Major	Minor	Major	Minor	Major	Minor
2. Metal oxide reduction	Major	Minor	Major	Major	Major	Minor
3. Melting technology	Major	NO	Major	Minor	Major	Minor
4. Adjustment production	Major	Major	Major	Major	Major	Major
5. CO/CO_2 utilisation	NO	Major	Major	Minor	Major	NO
6. Raw materials preparation	Major	NO	Minor	Major	Major	Major
7. Heat generation	Major	Minor	Major	Minor	Major	Minor
8. Energy management	Major	Minor	Major	Major	Minor	Major
9. Steel specific CE solutions	Minor	Minor	Major	Major	Major	Major
10. Enablers (skills, digitalisation)	Major	Minor	Major	Minor	Major	Major
11. Low CO_2 emissions downstream processes	Major	Major	Major	Minor	Major	Major
12. Innovative steel applications for low CO_2 emissions	Major	Minor	Minor	Minor	NO	Minor

in the light of the transformation of traditional plants and machineries into CPSoS, is only possible through a gradual transition from the classical pyramidal structure depicted in Fig. 2 to a flat and flexible architecture, such as the exemplar RAMI4.0 (Schweichhart 2019).

Process optimisation and monitoring, as well as systems integration, are important for the energy management along the steel production. In particular, AI-based predictive models are used for optimised maintenance and production scheduling. This shows, as digital technologies effectively support the new green technologies, that they are also contributing to their development at early stages. On this subject, two current EU-funded projects, such as Retrofeed (Implementation of a smart RETROfitting framework in the process industry towards its operation with variable, biobased and circular FEEDstock) (Retrofeed 2022) and REVaMP (Retrofitting equipment for efficient use of variable feedstock in metal making processes) (REVaMP 2022) are focused on how digital technologies can support

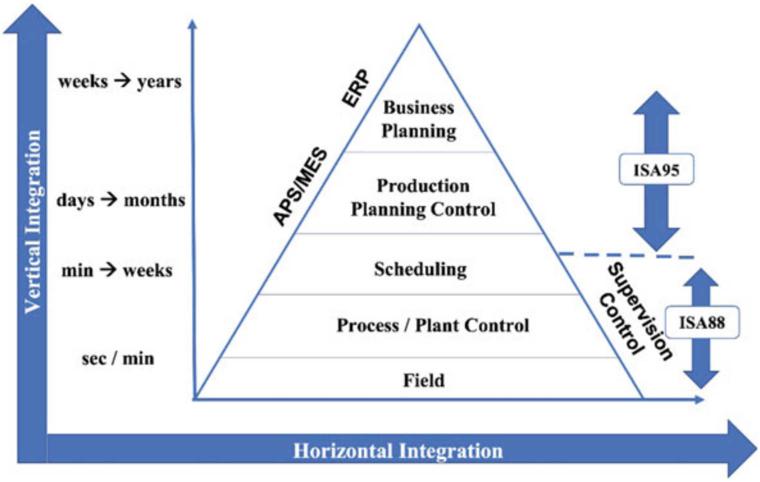

Fig. 2 Standardised description of the ICT and automation systems (ESTEP 2020)

to implementation of process improvements to achieve materials and energy efficiency in the steel production. The use of renewable feedstock and industrial residues as a complement of the furnace feedstock supply (Retrofeed) and the management of feedstock variability and selection (REVaMP) in steelmaking are two different approaches on resource efficiency and low-carbon technologies in existing steel plants. In particular, in the Retrofeed project advanced monitoring and control systems and a Decision Support System for supervising retrofitting activities and evaluating the best retrofitting capabilities along the production chain have been developed. On the other hand, in the REVaMP project retrofitting technologies, based on sensors for the chemical characterisation of metal scrap, advanced monitoring and control of the melting process for the adaptation and the integration in existing processes have been applied.

Further digital technologies as enabler of green technologies in the steel sector concern green recycling in the Electric Arc Furnace (EAF) steelmaking route. In particular, the introduction of the concept of ABSC (Activity-Based Standard Costing) integrated into Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES) aimed at achieving an efficient production management in a digital environment (Tsai 2019), supporting smart manufacturing, such as work forecasting, status monitoring, Work In Process (WIP) tracking, throughput tracking and capacity feedback. Furthermore, ABSC as costing tool can enhance the business operating abilities of quality, cost, delivery, service, resources and productivity. Additionally, an ongoing project co-funded by the EU Research Fund for Coal and Steel (RFCS), entitled 'Optimising slag reuse and recycling in electric steelmaking at optimum metallurgical performance through on-line characterization devices and intelligent decision support systems (iSlag)' (iSlag 2022), is focused on the improvement of EAF slag valorisation, supporting good practices and exploring new recycling paths by integrating innovative measurement devices with modelling and simulation systems. By developing decision support concepts and systems, which help the implementation of smart slag conditioning practices and optimal slag handling for its internal and external reuse and recycling, iSlag will provide operators with easy-to-use tools to support Industrial Symbiosis and CE practices as well as to reduce slag disposal costs. A further ongoing RFCS project, entitled 'Energy Management in the Era of Industry 4.0' (EnerMIND) (EnerMIND 2022) aims at optimising energy management in steelworks by applying a pioneering software, based on a new IoT/IIoT architecture, able to connect the energy market with the internal energy management. Through innovative AI/ML models for anomaly recognition in energy management this project aims at demonstrating the strong contribution of AI techniques in improving energy efficiency in the electric steelmaking route.

3 Digital Technologies as a Support of the Social Innovation

In order to design a 'Green New Deal' it is also fundamental to consider the transition as a key issue, and, over the last few years, progresses have been achieved in this direction. In particular, guidelines for a just ecological transition (International Labour Organization 2015) and for the Future of Work (International Labour Organization 2019) have been developed.

On the other hand, social transitions will have a deep impact on industry. In addition, current European political priorities can affect industry. In particular, the EGD (European Commission 2019b) will need a transition to a more circular economy and a reliance on sustainable resources including energy and 'Europe Fit for the Digital Age' (European Commission 2020c) aims at increasing technological innovation in Europe, making digital a priority for Europe; the European Research Area (ERA) (European Commission 2020d) will promote research and innovation in Europe, while the new European Industrial Strategy (European Commission 2021b) and Skills Agenda (European Commission 2020e) will address skills shortages. Finally, the White Paper on a regulation of AI (European Commission 2020f), and the European Data Strategy (European Commission 2020g) highlighted the importance that EC ascribes to the social impact of digital technologies.

In addition, up to now decarbonisation and climate adaptation efforts with climate and social justice have been mainly focused on (Bergamaschi 2020):

- creating new quality jobs and inclusive transition processes;
- building resilience activities for protecting groups most exposed to climate impacts;
- achieving the Paris Agreement objectives (Paris Agreement 2015) to ensure climate justice for people and future generations;
- recognising and addressing specific challenges faced by specific sectors, regions, cities and communities most vulnerable to change.

In the next few decades, significant occupation changes will occur, as shown in the draft of National Energy and Climate Plan (NECP) (European Commission 2019c). In particular, new jobs will be required in the renewable sector and in the fossil fuels sector. In addition, in Energy Intensive Industries (EIIs), such as steel, cement and aluminium sectors as well as the car manufacturing industry, the employment landscape will change, due to the technological changes, and, consequently, new plans should be designed and implemented. In particular, the need for skills to achieve a carbon–neutral economy by 2050 and the zero-pollution goal (European Commission 2019b) represents a boost for EU governments to include workforce upskilling and reskilling for the energy transition into their National Recovery and Resilience Plans. These plans will outline all projects to be implemented up to 2026, and will have to devote at least 37% of the foreseen expenditure to green investments and reforms to contrast climate change and to achieve environmental objectives (Interreg Europe Policy Learning Platform 2021). In this context, the following aspects are crucial for the EU policy and support:

- stronger climate action under the European Green Deal to implement the Paris Agreement will need a review of EU targets on energy efficiency and renewable for 2030;
- actions to ensure adequate skillset of workers;
- the connection between skills and the new transformations is tackled in the Renovation Wave (European Commission 2020h), the Pact for Skills (European Commission 2020i) and the European Climate Pact (European Commission 2020j), adopted by the European Commission (EC).

Furthermore, fundamental aspects from a regional perspective are:

- setting up a dedicated structure in order to promote skills supporting the energy transition;
- establishing regional energy agencies to improve energy efficiency skills and to define the mission/focus of the dedicated structures;
- pushing for the fiscal measures adoption in order to carry out renovation works by project proposals on energy efficiency in specific sectors;
- introducing incentives in order to engage SMEs in energy efficiency activities and to support employment at regional level.

As far as the steel industry is concerned, the application of digital technologies in all production areas is an ongoing process, although in some steel companies digital transformation is still marginal. Digital technologies, such as AI and AM, help to optimise resource efficiency and minimising by-products and waste. In addition, resilience refers to the development of high robustness in industrial production, to support against disruptions and to provide critical infrastructure in times of crisis. Significant improvements can be achieved in terms of process efficiency, product quality but also in socio-economic and environmental sustainability (Colla et al. 2020). Furthermore, the European steel industry aims at achieving challenges to address workforce and skill demands to exploit the potential of new technologies (Branca et al. 2020). In this context, the implementation of digital technologies and business models aims to the adaptation to a changing market and to the improvement of performances, involving also employees. On one hand, designing a process, its equipment, and products can enable safety and health protection of employees. In particular, using process monitoring and control, automation, even robots can prevent contact with dangerous substances, fires and explosions, accidents at work, release heavy burdens, etc. On the other hand, digital technologies aim at releasing workers from process malfunctions, unexpected events, or accidents, by also considering a social innovation paradigm, combining technological with social innovation (Colla et al. 2017). An innovative system as a human–robot (Bauer and Vocke 2020) cooperative environment implementation in a harsh and complex workplace was recently studied, with important results from field testing of a robotic workstation to support steelworks operators in the maintenance of the ladle sliding gate (Colla et al. 2021). This can contribute to improve workers' health and safety conditions as well as to promote upskilling of the technical personnel, particularly on digital skills. Further applications of the proposed solutions can be related to other types of sliding gate in the steelworks, aiming at reducing the number of operations that need human interventions.

Digital innovation holds a strong potential for enabling and supporting the social innovation, through the facilitation of knowledge sharing, cooperative work, developments and networking. In the integration of digital technological innovations within a social innovation process, digital technologies play a key role in supporting the collaboration, the knowledge sharing and the networking among various stakeholders, resulting in emerging skills and in the promotion of the upskilling process.

Skills mismatch can be overcome by training activities ensuring that the available skillset better matches the skills requirements in industry. This is one of the approaches developed in the ESSA project (The ESSA Project 2022) as well as in two Horizon 2020 projects, such as SAM (Sector Skills Strategy in Additive Manufacturing) (The SAM Project 2019) and SPIRE-SAIS (Skills Alliance for Industrial Symbiosis—a cross-sectoral Blueprint for a sustainable Process Industry) (The SPIRE-SAIS Project 2022).

A top-10 of skills has been identified by the World Manufacturing Forum for the future manufacturing, including four digital skills, such as 'digital literacy, AI and data analytics', 'working with new technologies', 'cybersecurity' and 'datamindfulness', while the other six skills are more transversal and linked to creative, entrepreneurial, flexible and open-minded thinking (World Manufacturing Forum 2019). Training and education activities should include:

- upskilling and reskilling regional schemes, based on identification of missed skills or skills that require upgrading;
- integration of energy efficiency skills into vocational education and training (VET) programmes;
- including such concepts into the offer of academic programmes.

In addition, the study of science, technology, engineering, and mathematics (STEM) should be encouraged, as fundamental knowledge for developing sustainable technologies and processes in the context of CE. A recent analysis on the situation of the European steelmaking workforce (SpA CSM et al. 2020), in terms of most needed skills deals with current and future skills gaps also due to the increased use of digital technologies in steelworks and the lack of suitable educational programmes. The transition to CE and a sustainable society can be supported not only through the condition of new financial investments, but also through political agreements and regulations imposing restrictions on countries and companies.

4 Future Scenario

The future scenario for the metal sector will mainly concern digital technologies as drivers of a new way of work within efficient plants to tackle some crucial challenges in the next future. These main challenges are represented by the supply of raw materials and energy, plants adaptation for CO_2 abatement, lack of skills due to the implementation of digital technologies and changes in steel consumption (ABB 2019).

In the future the steel industry will be ever more digitalised, making available vast amount of data from the whole production chain and even from the areas where steel plants are located. To improve the plants' efficiency, the acquired data need to be properly managed and integrated along the production chain, including the resources optimisation and the equipment maintenance. In addition, the improved process automation will result in requiring plants' operator intervention mainly for maintenance and the management of unforeseen situations. Furthermore, operators can be real time supported by augmented reality tools during maintenance activities, while wireless technologies can support the remote control and the real-time supervision of processes. Finally, advanced material tracking systems, based on digital technologies communicating the material's properties, can support in identifying products along their life cycle up to their recycling.

As the steel industry is one of the biggest GHG emitters, significant actions should be implemented to become a low-emitting and carbon–neutral industry. Modernising production facilities and energy systems and adopting new pioneering technologies, the steel sector could achieve the goal of 0.4–0.5 t CO_2/t steel, reducing two-thirds of its current annual emissions (Holappa 2020). In particular, in the short term, improving energy efficiency by applying best available technologies in all process could decrease the emissions by 15–20%, while further reductions towards 1.0 t CO_2/t steel level are achievable via top gas recycling and replacement of coke by biomass. In addition, replacing hydrogen for carbon in reductants and fuels like natural gas and coke gas can decrease CO_2 emissions remarkably, while more radical cut could be achieved by CO_2 capture and storage (CCS). Furthermore, potential application of hydrogen as a fuel and reductant in ironmaking has been launched in several research programs. Finally, supporting the steel industry in its endeavour to increase the use of recycled steel (from 30 to 50%) in steel production will lead to higher share of EAF production, and strongly increasing demand for carbon–neutral electricity.

The innovation process will enclose not only technological and economic features, but also environmental and social dimensions. This vision is aligned to the transition towards Industry 5.0 based on digital technologies supporting the social innovation, such as working conditions improvement and worker's competences valorisation. On this subject, AI or robotics can contribute to optimising human–machine interactions, also avoiding strenuous jobs. Such transition has already started by harmonising Industry 5.0 with the paradigm of Industry 4.0 through research and innovation to the transition to a sustainable, human-centric and resilient European industry (European Commission 2021a). In this context, actions foreseen as next steps to Industry 5.0 are, as follows:

- increasing awareness in industry;
- implementing a technological landscape to enable the transition from Industry 4.0 to Industry 5.0;
- identifying existing actions and opportunities for the development of Industry 5.0 across Europe;
- checking regulation barriers to innovation relevant for Industry 5.0;
- exploring open innovation and testing new forms of sharing research and innovation results (in line with the directives on competitiveness);
- promoting the hallmark features of Industry 5.0 as guiding principles for the development of common technology roadmaps under the Strategic Innovation Agendas;
- outreaching to other policy areas, as transition into Industry 5.0 will require a number of policy actions different areas.

In the context of Industry 5.0, the integration of social and environmental European priorities into technological innovation and the shifting to a systemic approach are fundamental. In this regard, six categories to be combined with other ones, as a part of technological frameworks, have been identified:

1. Individualised human–machine-interaction;
2. Bio-inspired technologies and smart materials;
3. Digital twins and simulation;
4. Data transmission, storage and analysis technologies;
5. Artificial Intelligence;
6. Technologies for energy efficiency, renewables, storage and autonomy.

In future scenario, further benefits of Industry 5.0 include attraction and retention of talents, energy savings and increased general resilience of industry. In particular, in the long-term, industrial competitiveness will be achieved, while in the shorter term coordinated investments in Industry 5.0 are required. The impact of digital technologies on the workforce of the future (BEYOND 4.0 2022) has been analysed (Kohlgrüber 2021). The project BEYOND 4.0 (Inclusive Futures for Europe BEYOND the impacts of Industrie 4.0 and Digital Disruption) analyses the impact of the new technologies on the future of jobs, business models and welfare. Its current achieved results are:

- expectable skill gaps: basic digital skills are needed in 90% of all jobs, as only 58% of individuals in the EU possess them;
- the impact on skill shortages for the digital future depends on the responsiveness of different national VET systems;
- the roles of education and training providers, but also of employers is fundamental to fill vacancies.

These results from BEYOND 4.0 project can be useful to:

- combine professional skills and digital skills at sectoral level;
- train digital and transversal skills by employers, if not provided by VET systems;
- achieve a strong collaboration among relevant actors at a regional level;
- providing job opportunities for female and older workers, migrants for mitigating skill shortages.

Improving working conditions in the steel sector is a crucial topic. On this subject, in a current project (WISEST 2021) advanced tools, based on enabling technologies application both to steelmaking processes and people, were developed, by considering interactions for assessing the whole system and for improving working conditions and safety. In addition, ergonomics problems due to human–computer interaction, especially for the ageing workforce, were recently addressed (Optimasteel 2021) by analysing advanced technological solutions with holistic systems. In particular, the ageing workforce and their difficulties in using the new technologies reverse mentoring, from young to old, particularly for the training on digital skills, is recommended (SpA CSM et al. 2020). This is an exchange in knowledge between workers being the mentorship usually more focused on the training of the young workers by the older ones (e.g. elder people share their experience, young people their digital skills).

Future research from the social innovation perspective should be mainly focused on the following topics (Howaldt et al. 2021):

- regional, cultural and social context of social innovation;
- possible and favourable outcomes and impacts of new practices, from improving living and working conditions of disadvantaged social groups to enhancing favourable social change;
- relationship to technological and business innovation in processes (e.g. the 'socio-digital transformation', the socio-ecological transition, etc.);
- As impacts in the long-term on existing practices and institutions have hardly been examined so far, a specific focus should be set on the ambivalence of social innovations.

In the next few years, the steel industry will face a deep transformation including a transition phase, which can increase employment by 2050, but, in a second phase might be characterised by a reduction of workforce, mainly due to the resizing of the plants and leaner processes (Antonazzo et al. 2021). Therefore, it is fundamental to anticipate changes, in particular on skills development. Planning ahead and strengthening social dialogue are crucial to ensure a good industrial transition. For this reason, some actions need to be taken:

- Securing talents by investing more resources in training, and including workers in the decision-making process;
- Training needs to address transversal skills (e.g. advanced digital skills, entrepreneurship, sustainable development and analytical thinking) for the green transition;
- Support of governments to a green and just transition;
- More engagement and collaboration with universities and research networks;
- Investing more resources in training on environmental awareness;
- Enhancing social dialogue, both at the company and at sectoral level;
- Establishing channels for workers to report their training needs and concerns concerning possible lack of skills;
- Anticipating changes both at the government and at company level, also involving regional authorities.

5 Conclusions

This chapter presents the analysis of the impact of digital technologies on the workforce as well as the technological transformation and the EU climate objectives in the context of the European steel sector. The main developments funded by EU Research Programs achieved in the above fields as well as of the current literature were analysed. In particular, the chapter concerns the digital transformation as key enabler impacting on advanced manufacturing by increasing production efficiency and reducing the environmental impacts of the European steel sector. On the other hand, it is focused on how application of the digital technologies on the steel production processes can provide advanced tools for the optimisation of the whole production chain as well as specific technologies for low-carbon production. In addition, in the context of the technological transformation, the social innovation supported by digital technologies is analysed as key aspect not only improving working conditions and competencies, and creating qualified jobs, but also facilitating knowledge sharing, cooperative work and networking.

New digital technologies aim at optimising the entire production chain of the steel sector to improve the flexibility and the reliability of its production processes, to maximise the yield and to improve the product quality and the maintenance activities. In addition, they aim at improving energy efficiency and at monitoring and controlling environmental impacts of processes. This can be achieved through the application of new IT, automation and optimisation technologies, Predictive Maintenance, ML, Data Mining techniques and Knowledge Management and by the integration of all systems and productions units, through different processes including vertical, horizontal, life-cycle and transversal integrations.

Based on an interdisciplinary approach, development and implementation of sustainable technologies include key enabling technologies and sustainable processes, supply chains and networks that promote higher efficiency, waste reduction, closed loops and eco-design. Consequently, the transformation of society from a linear to a circular economy will require changes in many areas of society, such as business, education, finance, politics, legislation, etc.

In order to achieve the industry resilience, future research will be focused on innovative techniques, such as more modular production lines, remotely operated factories, use of new materials and real-time risk monitoring and management. In this context, digital technologies will enable resilient technologies, such as data gathering, automated risk analysis and automated mitigation measures, although this could produce industrial technical disruptions.

Furthermore, digital transformation and climate objectives represent the main drivers for increasing energy and resource efficiency and contribute to keeping materials in use for a longer time. A further support for the industrial digital transformation and CE can be provided by exploiting synergies between the different EU initiatives. In last few decades, new relationships between environment and industrial competitiveness have been mainly based on innovation-based solutions to achieve both environmental protection and industrial competitiveness. To this aim, policies and legislation represent drivers for companies to adopt measures and solutions for facilitating innovation. However, some specific regulations and policies, although encouraging the implementation of innovative measures in process industries, can also limit them. Therefore, it is important to have legislation and policies clear, consistent, and less bureaucratic, as well as economic incentives to overcome disadvantages for EU companies. On the other hand, the increasingly stringent environmental legislation represents a driving factor for the steel sector to implement digital technologies for coping energy demand, improving energy efficiency and adopting low-carbon energy systems. The transformation of processes through digital technologies (e.g., through the adoption of high-performance components, machines and robots to optimise the materials and energy consumptions) can help to significantly reduce emissions and improve resources efficiency, by optimising materials and energy consumptions.

However, the workforce has to be integrated in such processes. The EU Industry 5.0 approach is therefore not only highlighting a sustainable and resilient industry but the human-centric orientation, developing technology for the people and solution to societal challenges. New skills requirements, due to the possible impact of AI, are an example as well as advantages for both workers and companies, by attracting and retaining talented people, with consequent benefits for companies' competitiveness.

References

ABB (2019) Metals 2040. https://new.abb.com/metals/future#Report. Accessed 18 Feb 2022

Antonazzo L, Stroud D, Weinel M, Dearden K, Mowbray A (2021) Preparing for a just transition: meeting green skills needs for a sustainable steel industry. Community/Cardiff University

Arens M (2019) Policy support for and R&D activities on digitising the European steel industry. Resour Conserv Recycl 143:244–250

Bauer W, Vocke C (2020) Work in the age of artificial intelligence–challenges and potentials for the design of new forms of human-machine interaction. In: Advances in human factors, business management and leadership: proceedings of the AHFE 2019 international conference on human factors, business management and society, and the AHFE international conference on human factors in management and leadership, July 24–28, 2019, Washington DC, USA, vol 10. Springer International Publishing, pp 493–501

Bergamaschi L (2020) There is no green deal without a just transition. IAI Commentaries

BEYOND 4.0 (2022) https://beyond4-0.eu/. Accessed 15 Feb 2022

Biedermann H (2019) Increasing resource efficiency through digitalization–chances and challenges for manufacturing industries. In: Book of abstracts of the 25th international joint conference on industrial engineering and operations management, IJCIEOM 2019: the next generation of production and service systems, p 177

Bradford CI (2015) Systemic sustainability as the strategic imperative for the post-2015 agenda. https://www.brookings.edu/research/systemic-sustainability-as-the-strategic-imperative-for-the-post-2015-agenda/. Accessed 17 Feb 2022

Branca TA, Fornai B, Colla V, Murri MM, Streppa E, Schröder AJ (2020) The challenge of digitalization in the steel sector. Metals 10(2):288

Branca TA, Fornai B, Colla V, Pistelli MI, Faraci EL, Cirilli F, Schröder AJ (2021) Industrial symbiosis and energy efficiency in European process industries: a review. Sustainability 13(16):9159

Brandenburger J, Colla V, Nastasi G, Ferro F, Schirm C, Melcher J (2016) Big data solution for quality monitoring and improvement on flat steel production. IFAC-PapersOnLine 49(20):55–60

Colla V, Matino I, Cirilli F, Jochler G, Kleimt B, Rosemann H, Unamuno I, Tosato S, Gussago F, Baragiola S, Klung S (2016) Improving energy and resource efficiency of electric steelmaking through simulation tools and process data analyses. Matériaux Tech 104(6–7):602

Colla V, Schroeder AJ, Buzzelli A, Abbà D, Faes A, Romaniello L (2017) Introduction of symbiotic human-robot-cooperation in the steel sector: an example of social innovation. Matériaux Tech 105(5–6):505

Colla V, Matino I, Dettori S, Petrucciani A, Zaccara A, Weber V, Salame S, Zapata N, Bastida S, Wolff A, Speets R (2019) Assessing the efficiency of the off-gas network management in integrated steelworks. Mater Tech 107(1):104

Colla V, Pietrosanti C, Malfa E, Peters K (2020) Environment 4.0: how digitalization and machine learning can improve the environmental footprint of the steel production processes. Matériaux Tech 108(5–6):507

Colla V, Matino R, Schröder AJ, Schivalocchi M, Romaniello L (2021) Human-centered robotic development in the steel shop: improving health, safety and digital skills at the workplace. Metals 11(4):647

Damacharla P, Achuth Rao MV, Ringenberg J, Javaid AY (2021) TLU-Net: a deep learning approach for automatic steel surface defect detection. Paper presented at the international conference on applied artificial intelligence (ICAPAI) 2021

Duft G, Durana P (2020) Artificial intelligence-based decision-making algorithms, automated production systems, and big data-driven innovation in sustainable industry 4.0. Econ Manag Finan Mark 15(4):9–18

EnerMIND (2022) https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/projects-details/31061225/899345/RFCS. Accessed 18 Feb 2022

ESSA (2020) WP 4—VET requirements and regulations/national VET systems (relevant requirements and regulations for the Blueprint). Analysis of cross-European VET frameworks and standards for sector skills recognition. https://www.estep.eu/assets/Uploads/ESSA-D5.2-Analysis-of-cross-European-VET-frameworks-and-standards-for-sector-skills-recognition-Version-1.pdf. Accessed 17 Feb 2022

ESTEP (2020) Clean steel partnership roadmap. https://www.estep.eu/assets/Uploads/200715-CSP-Roadmap.pdf. Accessed 19 Jul 2022. Accessed 15 Feb 2022
Eteris E (2020) Sustainability and digitalization: double strategy guidelines in national development. Acta Prosper 11:42–56
EUROFER (2020) We are ready—are you? Making a success of the EU green deal. https://www.eurofer.eu/publications/brochures-booklets-and-factsheets/we-are-ready-are-you-making-a-success-of-the-eu-green-deal/. Accessed 15 Feb 2022
European Commission (2015) A framework strategy for a resilient energy union with a forward-looking climate change policy. COM/2015/080 final. Brussels https://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF. Accessed 15 Feb 2022
European Commission (2016) Digitising European industry—reaping the full benefits of a digital single market. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016DC0180. Accessed 15 Feb 2022
European Commission (2019a) Reflection paper: towards a sustainable Europe by 2030. Brusselles https://www.eesc.europa.eu/it/our-work/opinions-information-reports/opinions/reflection-paper-towards-sustainable-europe-2030. Accessed 15 Feb 2022
European Commission (2019b) 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, COM (2019) 640 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN. Accessed 15 Feb 2022
European Commission (2019c) National energy and climate plans (NECPs). https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en. Accessed 17 Feb 2022
European Commission (2020a) Energy-intensive industries. https://ec.europa.eu/growth/industry/policy/energy-intensive-industries_en. Accessed 15 Feb 2022
European Commission (2020b) A new circular economy action plan for a cleaner and more competitive Europe. COM/2020/98 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A98%3AFIN. Accessed 15 Feb 2022
European Commission (2020c) A Europe fit for the digital age. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age_en. Accessed 17 Feb 2022
European Commission (2020d) European research area (ERA). https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/our-digital-future/era_en. Accessed 17 Feb 2022
European Commission (2020e) European skills agenda. https://ec.europa.eu/social/main.jsp?catId=1223&langId=en. Accessed 17 Feb 2022
European Commission (2020f) white paper on artificial intelligence—a European approach to excellence and trust. https://ec.europa.eu/info/sites/default/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf. Accessed 17 Feb 2022
European Commission (2020g) European data strategy. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en. Accessed 17 Feb 2022
European Commission (2020h) A renovation wave for Europe—greening our buildings, creating jobs, improving lives. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0662&from=EN. Accessed 18 Feb 2022
European Commission (2020i) Pact for skills (2020). https://ec.europa.eu/social/main.jsp?catId=1517&langId=en. Accessed 18 Feb 2022
European Commission (2020j) European Climate Pact (2020). https://ec.europa.eu/clima/eu-action/european-green-deal/european-climate-pact_en. Accessed 18 Feb 2022.
European Commission (2021a) Industry 5.0: towards a sustainable, human-centric and resilient European industry. https://ec.europa.eu/info/news/industry-50-towards-more-sustainable-resilient-and-human-centric-industry-2021-jan-07_en. Accessed 18 Feb 2022
European Commission (2021b) European industrial strategy. https://ec.europa.eu/growth/industry/policy_en. Accessed 17 Feb 2022

Glavič P, Pintarič ZN, Bogataj M (2021) Process design and sustainable development—a European perspective. Processes 9(1):148
Green Steel for Europe (2021a) Technology assessment and roadmapping (Deliverable 1.2). https://www.estep.eu/assets/Uploads/210308-D1-2-Assessment-and-roadmapping-of-technologies-Publishable-version.pdf. Accessed 18 Feb 2022
Green Steel for Europe (2021b) Collection of possible decarbonisation barriers (Deliverable 1.5). https://www.estep.eu/assets/Uploads/210308-GreenSteel-D1-5-Decarbonisation-Barriers-Publishable-version.pdf. Accessed 18 Feb 2022
Green Steel for Europe (2021c) Report on funding opportunities to decarbonise the EU steel industry (Deliverable 2.4). https://www.estep.eu/assets/Uploads/210319-GreenSteel-D2.4-Publisable-version.pdf. Accessed 18 Feb 2022
Green Steel for Europe (2022) https://www.estep.eu/green-steel-for-europe/. Accessed 15 Feb 2022
Holappa L (2020) A general vision for reduction of energy consumption and CO_2 emissions from the steel industry. Metals 10(9):1117
Howaldt J, Kaletka C, Schröder AJ (2021) A research agenda for social innovation-the emergence of a research field. In: A research agenda for social innovation. Edward Elgar Publishing
Iannino V, Colla V, Denker J, Göttsche M (2019) A CPS-based simulation platform for long production factories. Metals 9(10):1025
International Energy Agency (2020) Iron and steel technology roadmap. France. https://www.iea.org/reports/iron-and-steel-technology-roadmap. Accessed 18 Feb 2022
International Labour Organization (2015) Guidelines for a just transition towards environmentally sustainable economies and societies for all. https://www.ilo.org/global/topics/green-jobs/publications/WCMS_432859. Accessed 17 Feb 2022
International Labour Organization (2019) Global commission on the future of work. https://www.ilo.org/global/topics/future-of-work/WCMS_569528. Accessed 18 Feb 2022
Interreg Europe Policy Learning Platform (2021) Low-carbon economy skills for the energy transition—a policy brief from the policy learning platform on low-carbon economy. https://www.interregeurope.eu/sites/default/files/inline/Skills_for_the_energy_transition_-_Policy_brief.pdf. Accessed 17 Feb 2022
iSlag (2022) https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/how-to-participate/org-details/962112446/project/899164/program/31061225/details. Accessed 17 Feb 2022
Kohlgrüber M (2021) BEYOND 4.0. https://www.estep.eu/assets/Uploads/ESSA-Mid-Term-Conference-Kohlgrueber.pdf. Accessed 15 Feb 2022
Larsson A, Lindfred L (2019) Digitalization, circular economy and the future of labor: how circular economy and digital transformation can affect labor 1. In: The digital transformation of labor: automation, the gig economy and welfare, 1st ed, Routledge, pp 280–315
Lechtenböhmer S, Fischedick M (2020) An integrated climate-industrial policy as the core of the European green deal. In: Energie. Wuppertal Institut für Klima, Umwelt.
Maddaloni A, Porzio GF, Nastasi G, Colla V, Branca TA (2015) Multi-objective optimization applied to retrofit analysis: a case study for the iron and steel industry. Appl Therm Eng 91:638–646
Matino I, Alcamisi E, Colla V, Baragiola S, Moni P (2016) Process modelling and simulation of electric arc furnace steelmaking to allow prognostic evaluations of process environmental and energy impacts. Matériaux Tech 104:104
Matino I, Colla V, Cirilli F, Kleimt B, Unamuno Iriondo I, Tosato S, Baragiola S, Klung JS, Quintero BP, De Miranda U (2017a) Environmental impact evaluation for effective resource management in EAF steelmaking. La Metall Ital 109:48–58
Matino I, Colla V, Branca TA, Romaniello L (2017b) Optimization of by-products reuse in the steel industry: valorization of secondary resources with a particular attention on their pelletization. Waste Biomass Valorization 8(8):2569–2581
Matino I, Dettori S, Colla V, Weber V, Salame S (2019a) Forecasting blast furnace gas production and demand through echo state neural network-based models: pave the way to off-gas optimized management. Appl Energy 253:113578

Matino I, Branca TA, Fornai B, Colla V, Romaniello L (2019b) Scenario analyses for by-products reuse in integrated steelmaking plants by combining process modeling, simulation, and optimization techniques. Steel Res Int 90:1900150

Murri M, Colla V, Branca TA (2021) ESSA: digital transformation in European steel industry: state of art and future scenario (Deliverable 2.1). https://www.estep.eu/assets/Uploads/ESSA-D2.1-Technological-and-Economic-Development-in-the-Steel-Industry-Version-2.pdf. Accessed 13 May 2022.

Neligan A (2018) Digitalisation as enabler towards a sustainable circular economy in Germany. Intereconomics 53:101–106. https://doi.org/10.1007/s10272-018-0729-4

Optimasteel (2021) Holistic solutions to enhance the wellbeing and quality of life in the steel industry. https://www.optimasteel-project.eu/. Accessed 17 Feb 2022.

Paris Agreement (2015) In: Report of the conference of the parties to the united nations framework convention on climate change (21st Session, 2015: Paris). Retrived December. HeinOnline 4:2017

Paschek D, Mocan A, Draghici A (2019) Industry 5.0—the expected impact of next industrial revolution. In: Thriving on future education, industry, business, and society, proceedings of the makelearn and TIIM international conference, Piran, Slovenia

Porzio GF, Fornai B, Amato A, Matarese N, Vannucci M, Chiappelli L, Colla V (2013) Reducing the energy consumption and CO_2 emissions of energy intensive industries through decision support systems—an example of application to the steel industry. Appl Energy 112:818–833

Porzio GF, Colla V, Matarese N, Nastasi G, Branca TA, Amato A, Fornai B, Vannucci M, Bergamasco M (2014) Process integration in energy and carbon intensive industries: an example of exploitation of optimization techniques and decision support. Appl Therm Eng 70(2):1148–1155

Retrofeed (2022) https://retrofeed.eu/. Accessed 17 Feb 2022

REVaMP (2022) https://cordis.europa.eu/project/id/869882. Accessed 17 Feb 2022

Rieger J, Colla V, Matino I, Branca TA, Stubbe G, Panizza A, Brondi C, Falsafi M, Hage J, Wang X, Voraberger B, Fenzl T, Masaguer V, Faraci EL, Di Sante L, Cirilli F, Loose F, Thaler C, Soto A, Frittella P, Foglio G, Di Cecca C, Tellaroli M, Corbella M, Guzzon M, Malfa E, Morillon A, Algermissen D, Peters K, Snaet D (2021) Residue valorization in the iron and steel industries: sustainable solutions for a cleaner and more competitive future Europe. Metals 11:1202. https://doi.org/10.3390/met11081202

Schweichhart K (2019) RAMI 4.0 reference architectural model for Industrie 4.0. InTech 66(2)

SpA CSM, Gibellieri E, Schröder A, Stroud D (2020) Blueprint for sectoral cooperation on skills: towards an EU strategy addressing the skills needs of the steel sector. European vision on steel-related skills and supporting actions to solve the skills gap today and tomorrow in Europe

SPIRE (2018) SPIRE 2050 vision: towards the next generation of European process industries. https://cefic.org/app/uploads/2019/02/SPIRE-vision-2050.pdf. Accessed 25 Jan 2022

SPIRE (2021) Processes4Planet roadmap 2050. https://www.spire2030.eu/content/p4planet-roadmap-2050. Accessed 15 Feb 2022

The ESSA project (2022) https://www.estep.eu/essa/essa-project/. Accessed 18 Feb 2022.

The SAM Project (2019) https://www.skills4am.eu/theproject.html. Accessed 18 Feb 2022

The SPIRE-SAIS Project (2022) https://www.spire2030.eu/sais. Accessed 18 Feb 2022

Tsai WH (2019) Activity-based standard costing product-mix decision in the future digital era: green recycling steel-scrap material for steel industry. Sustainability 11(3):899

United Nations (2015) Transforming our world: the 2030 agenda for sustainable development. A/RES/70/1. New York, NY, USA. https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement. Accessed 15 Feb 2022

Vannocci M, Ritacco A, Castellano A, Galli F, Vannucci M, Iannino V, Colla V (2019) Flatness defect detection and classification in hot rolled steel strips using convolutional neural networks. International work-conference on artificial neural networks. Springer, Cham, pp 220–234

WISEST (Worker Integration SystEm in STeal Processes) (2021) 4.0 lean system integrating workers and processes. https://wisestproject.com/. Accessed 17 Feb 2022

World Manufacturing Forum (2019) The WMF's top ten skills for the future of manufacturing. https://www.worldmanufacturingforum.org/skills-for-future-manufacturing. Accessed 18 Feb 2022

Xia F, Yang LT, Wang L, Vinel A (2012) Internet of things. Int J Commun Syst 25(9):1101–1102

Zhang F, Liu M, Zhou Z, Shen W (2016) An IoT-based online monitoring system for continuous steel casting. IEEE Intern. Things J. 3(6):1355–1363

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Robotic Systems in the European Steel Industry: State-of-Art and Use Cases

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1 Introduction

In recent years, industry in general, and the steel sector more specifically, are at the centre of a series of technical, social and economic changes under the flag of Industry 4.0 (Miśkiewicz and Wolniak 2020). Most of these changes involve the digitalisation of processes and products at different levels, possibly including the adoption of advanced Big Data and/or Artificial Intelligence-based tools, which can provide significant advantages in terms of productivity and socio-economic and environmental sustainability of steel production, with relevant benefits for workers' health and safety (Colla 2022; Brandenburger et al. 2016; Branca et al. 2020; Vannucci et al. 2022; Colla et al. 2021a, b). However, for the complete integration of such technologies in the plant ecosystem and for a successful exploitation of new tools, some effort is required for managers and workers to update their skills and broadening their expertise (Branca et al. 2022).

In this context, robotics is one of the most promising technologies to be applied on the steelworks, characterised by the potential to improve both the productivity of plants and the safety conditions of the workers. In addition, robots' versatility allows their employees' involvement in diverse tasks that leverage their different characteristics. According to an estimation by The Boston Consulting Group (Ringel et al.

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2015), the greater use of robotics and computerisation will reduce the number of jobs in assembly and production, but the creation of new jobs, particularly in IT and data science, will increase. The 'Re-finding Industry Report' of the European Commission, it is stated that over 1.5 million net new jobs in industry have been created since 2013 and a growth of labour productivity of 2.7% per year on average since 2009, higher than both the United States and Korea (0.7% and 2.3% respectively).

Robots are already used to perform specific tasks at various stages of the production pipeline. Many of them are part of manufacturing and assembly lines and operate in clearly defined areas. Conventionally, they are fixed to plant installations and perform recurring work to increase repeatability and product quality or operations that require the application of force or precision that are out of the human capabilities. Robots are tasked with performing operations that are potentially dangerous to humans because of, for example, the environment in which such operations take place or the inherent risks of the operation to be performed. Such situations are very common in the steel production and using robots can help preserve the safety of workers. In these latter applications, the tough environment of the steel plant featuring high temperatures, dust, steam, and aggressive agents represents for industrial robots both an opportunity and an obstacle, requiring the use of special arrangement to survive and perform flawlessly the assigned tasks in a harsh environment.

In the last decade, besides these *stationary* robots that have been used in the industrial setting for many years, the breakthrough evolution of technologies related to artificial intelligence (AI) has enabled the development of a new generation of mobile robots, capable of performing monitoring and inspection tasks by moving autonomously within the steel plant. This class of robots includes both ground vehicles (*Unmanned Ground Vehicles*—UGVs) and aerial ones, typically drones (*Unmanned Aerial Vehicles*—UAVs). In this context, there is potential for UGVs and UAVs to find countless applications by replacing humans in monitoring operations, reducing health risks and the number of accidents. Monitoring in these cases is a popular task. It can be related to product quality, abating the time of such activity, which is often determined by the difficulties of moving within the plant or reaching machinery or parts of it. In addition, when linked to maintenance activities, such operations will reduce plant shutdowns and increase safety and plant throughput.

In this chapter, the state-of-the art regarding the application of stationary and mobile robotic systems in the steel sector is evaluated through an analysis of the relevant literature and projects in the European arena that exploit these technologies in the steelmaking environment by referring to two specific case studies for the identified macro-types of industrial robots. This paper highlights the opportunities, issues and challenges behind the use of robots in the steel sector, focusing not only on technical aspects but also on the human–robot interaction and on the changes requested to managers and operators to fully exploit these new technologies.

The paper is organised as follows: in Sect. 2 a survey of the main application of robots in steel production is presented through an analysis of the literature on the state-of-art and the main research projects for both stationary and mobile robots. In Sect. 3, two use cases of successful research projects where such technologies are exploited in real industrial contexts are presented and discussed. Finally, in Sect. 4, some final remarks on this theme are provided together with the future perspective about the interaction between humans and robots in the steel plants.

2 Use of Robotic Systems in the European Steel Industry

Robots appeared in steelworks at the end of last century. In these early applications they were stationary robots, typically mechanical arms, to which repetitive and well-defined tasks are assigned. Later, the development of technologies and the spread to other sectors of industry brought increasingly complex robots with a greater degree of autonomy to the steel industry as well. Recent years have seen a greater use of mobile robots with varying levels of autonomy not only for performing a specific task, but also in terms of freedom of movement within the plant. In this section, a review of the state-of-art regarding the use of robots in the steel industry is presented through an analysis of literature and projects in which they are involved. Given the two macro families of robots, this analysis is divided into two sub-sections, the first for stationary robots and the other for unmanned robots, both ground and aerial.

Use of Robotic Arms in the Steel Industry

Stationary robots have found wide use in the steel industry to replace human operators in dangerous work or to be performed in unsafe or unreachable locations. Part of this family is constituted by *robotic arms* with a variable number of degrees-of-freedom (DOF) (typically 6) and complexity, equipped with different end-effectors and different level of autonomy, depending on the characteristics of the task and on their complexity. In most of the applications the task to be pursued by robots is clearly defined and their autonomy in terms of control strategy is limited to the task and takes advantage from other sensory systems or sources of information (Gerstorfer et al. 2018).

In the light of this consideration, many applications of robots in steelmaking are related to the casting process where their use can reduce human operators' exposure to high temperatures or to the contact with liquid steel. An exemplar application of a robotic system equipped with a single multi-purpose manipulator demonstrates how different operations can be performed on the casting floor dramatically limiting the human intervention (Demetika et al. 2014). The main functionalities of this system include the identification and opening of ladle nozzles, shroud manipulation and tundish powder management, resulting not only in a safer operation for human operators, but in a better quality of the cast product as well. Another application exploits a six DOF robotic system with an integrated vision system for inspection purposes. In this latter work, the performance of the developed robot is analysed throughout several months of standard production both from the technical point of view and according to the user-experience (Hansert et al. 2016). The centrality of robots in the casting process is demonstrated in several review papers (Meisel et al. 2014).

Robots are used also for liquid steel sampling at different stages of the steel manufacturing chain. A 3 DOF robot, in which all three joints move in revolute form, is used to sample liquid steel from the electric arc furnace (EAF)—a task that would be very hard for human operators, considering the sensitive conditions around the EAF (Soltani 2010). In a similar application, the robot can be supported by a vision system to measure the steel temperature in a ladle during the casting process at different moments of the casting (Bian et al. 2022).

Robots in steel plants are used also for performing tasks that are unfeasible for human operators such as material movement and transportation. For instance, a gripper for steel transportation is used which can move within the plant different types and sizes of steel materials using an advanced multi-purpose gripping-hand that adapts to the different shapes of the handled material (Biermann et al. 2022). Further, a two-arms 6 DOF robot is used for the steel-strapping process of coils. Using this kind of robot—apart from the clear advantages in terms of safety—allows the handling of coils of different dimension abating the processing time and speeding-up the whole manufacturing process and improves the user-experience because of its flexibility (Lee et al. 2012).

Recent trends identify human–robot collaboration as a very promising technological field of development for industrial applications, and steelmaking in particular. The advantage of this approach is clear and is based on the exploitation of the strengths of human operators and robotic systems, avoiding their respective limitations. In this paradigm, the robustness of robots is utilised, avoiding human exposure to risks and potentially dangerous situations. The robots' precision, speed and ability to repeat well-defined operations will also be exploited. On the other hand, the knowledge peculiar to experienced human operators will be used to control the robots and take decisions in a real-time manner together with the ability to adapt to new situations.

Although systems based on human–robot interaction have been already implemented in different industrial fields (Dannapfel et al. 2018; Gopinath et al. 2021) with successful results, not only from the technical point of view but from the social one as well, reaching a high level of acceptability, applications of such approach in the steel sector are not yet familiar. In this context, it is worth mentioning the semi-automatic cooperative robot designed to assist the building of the steel converter wall proposed in Ryu et al. (2012). The robotic system can transport and position refractory bricks in cooperation with a human operator understanding the human operators' intention through a force/torque sensor. The interaction in this case avoids for operators any fatigue from movement of the bricks, which can lead to painful musculoskeletal diseases and grants the required precision for the bricks correct positioning. In addition, refractory brick construction becomes standardised so that it reduces the manpower and hours currently took in the same processes.

Unmanned Ground and Aerial Vehicles

In recent years, steel plants have proved to be an interesting field of application for the use of unmanned robots, particularly for tasks concerning product quality control and process monitoring—including structural inspection—of the plant. Such tasks, given the high productivity that is required, are essential to promptly identify eventual machine failures and ensure the continuous operation of plants and the maintenance of safe conditions for operators, as well as a high level of product quality. Using autonomous robots, which can move with certain freedom within the plant, reduces the time and cost of inspections, which, in this case, do not require actual plant downtime. In addition, most times, such robots have dimensions and movement capabilities that allow them to reach areas that are difficult for human operators to explore or that pose inherent risks due to, for example, height or high temperatures.

Navigation systems make use of a heterogeneous sensor and leverage cameras, GPS data, LIDAR sensors (Bachrach et al. 2012). In addition, in the presence of more than one robot, such data and information are shared and progressively refined to have at a global level a clear picture of the environment in which they move. Vision systems have made great strides for object recognition because of the advancement of Deep Learning and in particular of Deep Neural Networks (DNN) for object recognition purposes (Ahmad and Rahimi 2022). This technology allows robots to promptly and efficiently analyse the scene as it is taken by the camera identifying the position and the type of all the objects in the environment. Finally, in the last years, several breakthrough algorithms have been developed to improve the trajectory planning capabilities of UAVs and UGVs. These algorithms are designed to work flawlessly on controllers with limited computational and power resources and often deployed on optimised firmware that allows the full exploitation of their capabilities (Herrera-Alarcón et al. 2022).

The above-described technological advancements led to the deployment of UAVs and UGVs in many practical applications and to a blooming of literature works that discuss their achievements and issues. The steel industry has many characteristics that make it appropriate for the use of unmanned vehicles.

First applications of drones and ground unmanned vehicles were related to agricultural applications because of the greater simplicity of the context (larger environments, fewer obstacles) (Turner 2010). The monitoring capabilities of drones were exploited for checking gas pipes status (Rathlev et al. 2012) and for the assessment of the integrity of a photovoltaic field in through a swarm of UAVs (Grimaccia et al. 2015), highlighting the aspects of collaboration among swarm drones and on the determination of suitable path planning strategies. Unmanned vehicles are used for the distribution of light parts (small tools) to human operators in an industrial manufacturing chain (Orgeira-Crespo et al. 2020). Structural assessment is the main topic of several literature works. For instance, UAVs are used to detect defects and the health status of steel structures through an integrated image analysis system. That work focuses on the predictive maintenance of the structures and the results show this approach is the best cost-effective and time-compressing solution for this purpose (Chen et al. 2019).

While the literature on the use of unmanned vehicles in the steel industry is still sparse, there is an emerging array of projects in which the technology is being profitably adopted. In the recent EU-RFCS project *DroMoSPlan*, drones are used for monitoring different parts of the plant and processes related to steelmaking. *DroMoSPlan* is described more in detail in section "The DroMoSPlan Project" as an exemplar application of UAVs in the steel production. In another RFCS project, *RoboHarsh*, both UAVs and UGVs are used for different inspection tasks within a steel plant. In this project, the tasks pursued by different unmanned vehicles are deeply integrated with the maintenance strategies of the plant where drones and ground vehicles are assigned to complete periodic and continuous inspection tasks assessing process status and phases, product quality and safety issues within the plant.

3 Use Cases

In this section, two EU projects are presented as use cases where robotics systems are used in specific industrial applications. The aim is to put into evidence their achievements and an analysis of their impact from the technical and social point of view. The two projects involve respectively the two classes of robots previously identified, namely the stationary and the unmanned ones (basically UAVs and UGVs).

The RoboHarsh Project

The *RoboHarsh* project is an EU-RFCS funded project that perfectly highlights the benefits of using a robotic system in a harsh environment like a steel shop (Colla et al. 2021a; b), and the advantages conveyed by the involvement of the end-users in the early stages of the design of the robotic solution, according to a social innovation model (Colla et al. 2017).

The solution developed in this project consistently reduces the need for human intervention in laborious works, and thus limits related health and safety risks. In particular, *RoboHarsh* addresses the problem of the maintenance of the ladle sliding gate during the continuous casting process. In this context, the ladle is a container where liquid steel is refined to obtain the desired chemical and physical characteristics. More in detail, the freshly produced pig iron undergoes a decarburisation process before the next manufacturing phases. Subsequently, the ladle is used for the transport of the steel to the continuous casting machine. At this point, liquid steel flows through a tap hole from the ladle to the mould and the casting station, where it solidifies into semi-finished products as billets or blooms.

The flow of liquid steel is regulated by a sliding gate on the ladle bottom, which is operated by a hydraulic cylinder. During the process, because of the solidification of the steel, the gate is subjected to wear and deposition of solid material, which makes necessary some periodic maintenance on the sliding gate. During maintenance, the ladle is transferred to a dedicated area where some skilled operators analyse the gate surface, clean it and eventually replace the refractory components. Cleaning requires the use of an oxygen lance and is usually performed by two operators, who assess the wear status of the refractory. Based on this visual analysis, operators decide whether to substitute the two refractory plates. Normally, this operation occurs after a few subsequent casts, e.g. 5 or 6. Plates replacements include the positioning of the new plates into the suitable location with high precision (some millimetres) and the application of an adhesive mortar layer to ensure a perfect fit.

This operation takes about 30 min and exposes operators to a temperature around 70 °C. In addition, it requires the use of force from the operators since the weight of each plate is about 20 kg. Overall, this whole task is quite complex since it requires both strength, precision (for plates placement) and experience for the assessment of the wear status of the sliding gate. In this framework a robotic system could be helpful for the completion of most cumbersome operations and for those that involve higher risks for human operators due to their exposure to harsh conditions and high temperatures. On the other hand, human operators are still necessary for operations that need precision and decision capabilities. The context is thus suitable for a cooperative human–robot environment where each agent (human or robotic) is on duty for the task that it can perform best. Based on this consideration, the maintenance operation was subdivided by technicians and plant personnel into elementary operations that were assigned to human operators or to the robotic system as depicted in Table 1.

The operations listed above are pursued on the original maintenance station that was adapted to the use of a robot in cooperation with human operators. This adaption process, as well as the selection of the hardware components, was performed by plant operators and technicians in order to consider all the relevant aspects of the design and implementation. Environmental factors, including plant conditions in terms of temperatures, dusts and operator safety and wellness, were also accounted.

The main robotic part of the system is made up of an industrial ABB robotic arm with foundry protection with a 6 DOF manipulator having the handling capacity of 245 kg. The maintenance platform was slightly modified to host the robot arm and grant operators' safety. Some changes to improve operators' working conditions were performed also outside of the maintenance platform by using conveyor belts for the transportation of the refractory plates to the area and the handling of the oxygen lance. The workstation is depicted in Fig. 1.

The pulpit of the workstation is hosted in an air-conditioned container. All the main operations related to the movement of the ladle and the gathering of refractory can be pursued by the operators from inside the container. In addition, through a window, operators can perform some operations, such as applying the mortar on the plates, without exiting the container and exposing to risks or harsh conditions.

Table 1 Sequence of operations to be pursued during a maintenance cycle associate to the operation mode (automatic or manual)

Mode	Operations
Automatic	– Picking and replacement of the mobile plate – Removal of fixed plate – Inspection of size and contour of the discharger hole to decide if replacement is necessary through robot vision system – Refractory removal
Manual	– Air cleaning of refractory nozzle
Automatic	– Verification of the cleanliness of the nozzle location through robot vision system – Picking and insertion of the mobile plate – Picking of new refractory nozzle
Manual	– Application of mortar layer on the discharger
Automatic	– Insertion of the new refractory nozzle – Verification of planarity – Graphite spraying on nozzle head
Manual	– Application of mortar layer on fixed plate
Automatic	– Location of the fixed plate on the sliding gate
Manual	– Closure of the sliding gate
Automatic	– Movement of the platform away from the ladle – Check the cleanliness of the tapping hole through a buffer tube
Manual	– Disconnection of hydraulic hoses; connection of the piston blocking the ladle rotation system
Automatic	– Ladle movement and rotation – Ladle unlocking and removal

Fig. 1 The RoboHarsh workstation including a detail of the robotic arm in operation

Fig. 2 The tool warehouse of the RoboHarsh workstation

During the maintenance cycle, the robot exploits different tools that are placed in an ad-hoc designed warehouse (see Fig. 2) and are used by the robot to handle the oxygen lance, to remove the material residues from the nozzle and to spray the graphite on the discharger head. Therefore, depending on the specific operation, which is being performed, and has been previously acknowledged by the operator, the robot picks, uses and releases the necessary tool(s).

The robot leverages a vision system for inspection operations throughout different steps of the maintenance cycle. The vision system is encapsulated in a single protective container which incorporates a 2D vision camera IDS UI-5270CP-M-GL (P/N: AB02037) (1/1.8″ 3.45 μm 2056 × 1542 Pixel) and a 3D laser scanner. The vision system communicates to the plant information system through a WiFi network, which allows a satisfactory band and avoids cables. The camera and 3D laser operate together, in particular the laser enriches the image provided by the camera with a 3D cloud of points. Both the image and the 3D cloud are pre-processed and denoised by using a suitably customised commercial software. 3D points are clustered by using a distance-based algorithm to identify the different basic elements of the sliding gate and allow the robot arm to operate.

A lot of attention was paid to the design and development of the Human–Machine-Interface (HMI) (see some screenshots in Fig. 3) to provide a smooth yet full experience to the operators. Through the HMI the operators can set-up the maintenance cycle in detail and monitor all the operations. Different cameras provide a set of images of the whole maintenance area on different screens and some additional screens show the main information provided by the robot during its operation. Operators interact with the robot through the touch screen that, for instance, allows to ask for more detailed information on certain tasks.

During maintenance, the robot is mostly autonomous but asks for acknowledgements to perform specific operations, such as the replacement of the refractory. Similarly, a complete view of the sliding gate is provided to operators by the camera

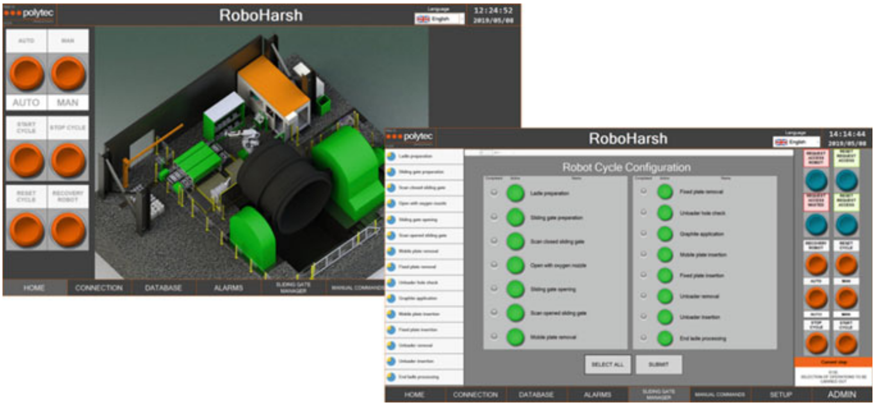

Fig. 3 Exemplar screenshots of the HMI of the RoboHarsh workstation

mounted on the robot, nevertheless operators can decide to manually inspect the area, stopping any robot activity and taking the control.

Within the *RoboHarsh* project, the achievements of the installation of the described robotic system within a real steel plant were assessed in a twofold manner: from a technical point of view, by measuring the success rate of robot operations, and from the point of view of the impact on workers safety and acceptance. From the technical side, the operations minutely described in Table 1 and assigned to the robot have been grouped into macro-tasks and the success rate of each of them was calculated as the ratio between the number of operations totally completed by the robot and the overall number of attempted operations. The system was tested during one year of standard production. Moreover, other performance indicators were accounted:

- the difference in terms of completion time between the fully manual and the fully automated operation,
- the per cent reduction of exposure of human operators to harsh conditions.

The assessment of the social impact of the developed robotic station was made by means of a survey and interviews targeting both the solution developers and the operators of the steelworks. The survey aims at assessing the health, cultural and motivational changes due to the technological enhancement of the maintenance process.

The success rate of the robot macro-operations is reported in Table 2. According to the HMI set-up, in case of partial or total unsuccessful completion of the operation by the robot, the operator can complete manually the task. This is an important aspect of the human–robot interaction, ensuring the quality of the performance and showing that human intervention has to be an integrated part of new technological solutions. In this light, the results presented in Table 2 have to be considered as the *worst* case, since only the full completion of the task by the robot is considered successful while, on many occasions, the robot was able to perform part of the job, reducing the effort required to the human operators.

Table 2 Success rate for the automated task within the *RoboHarsh* project use case (Colla et al. 2021a, b)

Robot task	Success rate (%)
Tap hole opening	93
Tap hole cleaning	50
Removal of the mobile plate	99
Removal of the fixed plate	99
Inspection with the vision tool	90
Insertion of the mobile plate	98
Insertion of the fixed plate	98
Extraction of the nozzle	95
Insertion of the nozzle	95
Graphite application	80

In terms of maintenance cycle completion, the use of the robot slightly extended the task duration since the interaction with the machine brought in some latencies. However, such time difference is about 5 min which is considered tolerable. On the other hand, the use of the robot drastically reduced the exposure of operators to high temperatures. In fact, in case of successful completion of all the automatic tasks, such exposure time is reduced by 80% while in the worst case by 50%.

The project was successful from the social point of view as well. One of the main outcomes of the survey is that all participants agree on the fact that robotic assistance increases health and safety by reducing physical and heavy weight activities, exposure to high temperatures, and hazardous situations. In detail, the exposure to such conditions is perceived to decrease from 67 to 25% during the task. In addition, the system is acknowledged to make the job more interesting and to increase the level of the workers' satisfaction.

The DroMoSPlan Project

The *DroMoSPlan* project is another RFCS-EU project where robots are used within a steel plant environment. In this case, it focuses on unmanned aerial vehicles (drones) and ground charging vehicles to support the drones during certain activities. The project was significant since it allowed an assessment of the applicability of such technology in a harsh environment, where UAVs and UGVs have to complete complex tasks and face diverse issues. Drones are basically used for monitoring purposes. The *potential* advantages in using drones in this context are many and include the ability to easily and quickly reach distant zones of the plant, to inspect areas that cannot be reached or are dangerous to humans (e.g. due to height or high temperatures or harmful emissions). In addition, the use of robots *may* allow such tasks to be performed more frequently than it would normally be done by human operators.

Within the project, 5 different use cases were identified and addressed. These tasks were developed and tested at the different partners sites and are related to the following areas:

- maintenance: with a task pursuing the inspection of plant buildings' (1) roofs and (2) chimneys,
- environment: through a system for the (3) monitoring and (4) detection of chemical leaks,
- safety: through a (5) video surveillance system based on the use of drones.[1]

During the project, particular attention was put in the design of the drones in terms of hardware robustness in order to resist the steel-works harsh conditions. Drones are provided with a communication system that allows them to share information with operators, ground components and among them. The UAVs are equipped with *Pixhawk* flight controllers that currently represent the state-of-the-art among open-source autonomous vehicles control systems and can be used for both UAVs and UGVs. The *Pixhawk* can be expanded and connected to other sub-systems for the wireless communication. In particular, in this case the *SiK* radio module was selected which provides a wi-fi serial interface commonly used for the transmission of telemetry and commands between a vehicle and a ground station. The message exchange between vehicles includes information such as position with respect to a fixed reference system, velocity and acceleration, battery status and is used for coordination purposes. Besides standard equipment, the diversity of the addressed tasks requires the employ of different sensors (e.g. CO detectors, cameras, thermo-cameras) which are eventually mounted on the drones.

On the operator's side, missions are created and monitored through a 'mission management' software that operates through a web interface and allows operators to plan each mission step by step, monitor in a real time manner its execution and collect any relevant data during the tests for future analysis. The main algorithms for mission monitoring and drone control are developed and embedded in the vehicle architecture through an open-source software (ROS—Robot Operating System, platforms libraries) and the *Pixhawk* flight controller with firmware of *Ardupilot*.

The problem of drone autonomy was considered and led to the development of two technologies to address the needs inherent to the distinct applications. Different technologies for recharge (contacts and wireless) and different solution for drone-station synchronisation (stationary and mobile platform) have been developed. The stationary solution uses the landing platform as a recharge station (see Fig. 4). The drone, once landed, automatically recharges its batteries by mean of electrical contacts and without the need to remove them. During the landing phase, the drone can exploit an infrared beacon in the middle of the platform for precision landings on the platform.

An alternative solution to the stationary recharging station is represented by a mobile station that implements a wireless charging technology. This solution is

[1] This use case was not pursued because of regulations pertaining to surveillance of workers at work.

Fig. 4 The drone positioned in the stationary recharge station

supported by the communication between drone and station in order to synchronise the landing point when the drone battery level is getting low. With this synchronisation, the recharging process can take place in a wide area of the mission scenario thanks to the mobility of the station. The mobile charging station is constituted by a UGV that comprises the charging box. The wireless charging system is made of two coils: a transmitting coil, mounted on the autonomous rover and a receiving coil mounted on a landing skid of the UAV.

Several use cases were selected in order to demonstrate the effectiveness and feasibility of drones employed for monitoring tasks in steel plants. For this reason, the applications are varied and have distinctive characteristics and diverse issues. Use cases with main achievements and critical points are briefly described in the following.

Plant Surveillance

This use case concerns the use of one or more drones for the purpose of surveying specific areas of the plant, but was not tested because of regulations pertaining to surveillance of workers at work. The proposed task of the drone in this case was to move within a specific area and detect the presence of unauthorised persons. If so, it raises an alert to the attention of the security staff. While the system was not tested, the theoretical approach can be reported.

The mission was to take place by patrol flights at random time intervals within the area of interest. In Fig. 5 an exemplar patrol path is represented, together with the location of the charging base for the drone. During the patrol, the drone reaches in sequence a set of pre-defined waypoints suitably located by operators to monitor the area and minimise the risks of collisions with building and cables within the plant. Waypoints are specified via their absolute coordinates while planning the mission with the previously described software component. When a new waypoint is reached, the drone rotates 360° on itself to check for the presence of intruders. When no person

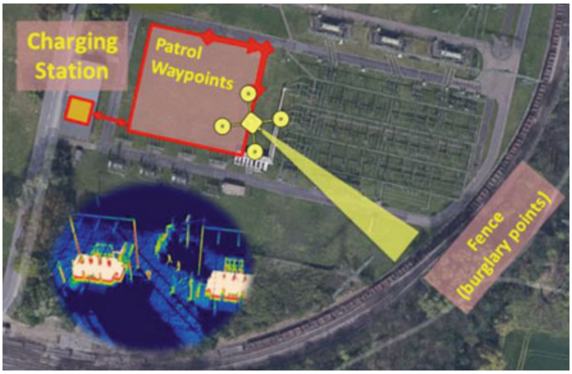

Fig. 5 Exemplar patrol path for the surveillance use case

is detected, it heads to the next point. Between two flights, the drone reaches its base point where it is recharged.

For this use case, the drone is equipped with an infrared camera whose images are processed by an object recognition algorithm seeking humans. The algorithm used is the well known YOLO and is based on a Deep Neural Network. In case of alarm, security employees are informed and, depending on the images they receive from the UAV, they can decide which steps to take next.

Gas Pipes Inspection

Within this task a single drone is used to check for the presence of CO leaks around the gas pipes of the steel plant. The task involves a human operator that brings the drone to the starting position for the inspection and supports the complete phase of the inspection in compliance with the EU regulations that do not permit completely autonomous UAVs operations.

The drone is equipped with a CO sensor whose positioning on the vehicle was carefully determined during laboratory tests. With a constant flow rate of CO through a small opening, the landing gear beneath one of the rotors turned out to be the most efficient because of the redirected airstream. Since the gas pipes network extends throughout a large area of the plant, is distributed through different levels and due to the presence of structures, curves and other obstacles, a purely visual approach was developed for pipes recognition and tracking to favour the exploration and check of the pipes. These latter operations are performed via a customised segmentation algorithm. Then, once the pipe is detected, the drone moves along it at a constant distance (obstacles permitting). In the ROS platform a dedicated algorithm customised to image processing is devoted to gas pipe recognition. Additionally, increased functionality was implemented, such as distance measurement and localisation of the pipe segments. CO measurement is permanently active and warns the operators in case of exceeding threshold value.

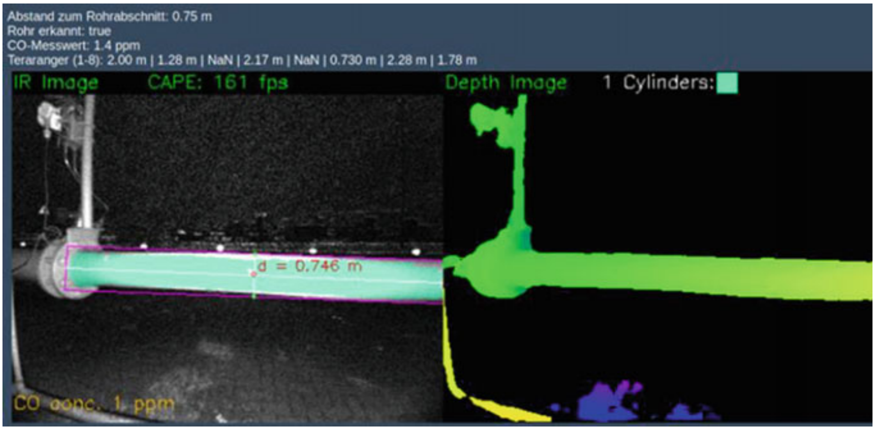

Fig. 6 Graphical user interface for the CO leak gas pipes inspection use case

In this task the operator controls the drone (EU and workplace regulations make this mandatory). For this purpose, a dedicated smartphone app—of which an exemplar screenshot is shown in Fig. 6—was developed to allow the operator to continuously monitor the drone behaviour and the outcome of the segmentation algorithm to be sure that pipes are correctly detected. In case of CO detection, the UAV rises an alarm and signals it to the operator.

Roofs Inspection and Defects Identification for Maintenance

This use case is related to maintenance of building roofs within the steel plant. The evaluation of the condition of a roof concerns not only the current state of preservation and possible damage due to weather conditions, but also the estimation of ageing rate. Using a drone for this task has some advantages among which a significant reduction in risk as the human operator is prevented from climbing on top of the examined buildings and moving on top of them (Stroud and Weinel 2020; Stroud et al. 2021). In addition, a drone can perform such an examination from different distances so as to have a better view of the roof surface.

Within the project, the experimental activity was performed on the surface of a roof of 500 square meters. During one mission, the drone flies above the roof and collects several pictures of it (90 pictures for the 500 m^2 roof of the test) which are then reconstructed into a 2D image of the whole roof (orthophoto) by using the software *WebOpenDroneMap*, an open-source tool for generating maps, point clouds, terrain and 3D models from aerial images. A reconstruction performed by this tool is presented in Fig. 7.

Operators can examine this reconstructed photo; however, the visual inspection of a single picture requires time. For this reason, an automatic classification system was developed. The classifier processes individual tiles of equal size taken from the

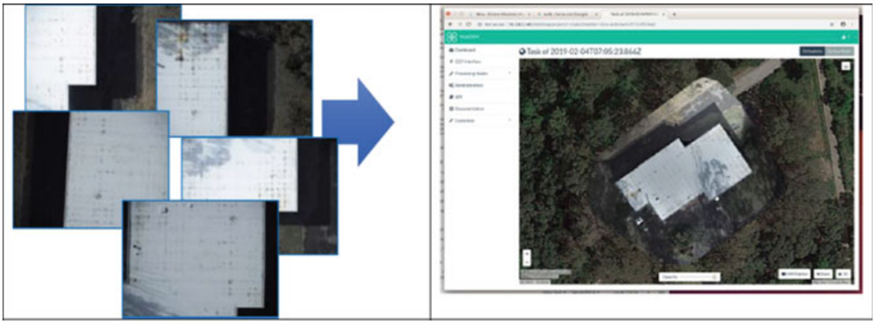

Fig. 7 Reconstruction of the 2D roof image from the individual images taken by the drone during its flight

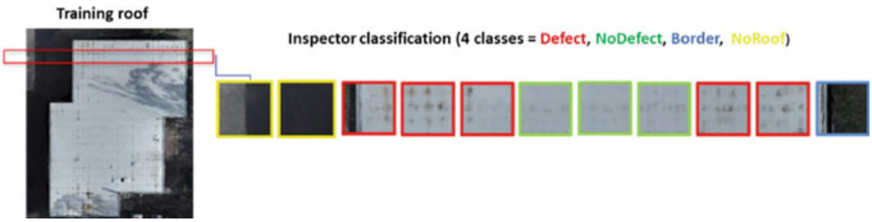

Fig. 8 Tiles representation of an examined roof associate to status classification

2D roof image. For the training of the system, a set of tiles was manually labelled according to 4 classes, reported in Fig. 8: *Defect, No Defect, Edge of roof, No Roof*. Further, in order to increase the number of training samples, data augmentation techniques, including tile flip, reverse, pan and rotation were adopted.

The model used to perform the classification task is a Convolutional Neural Network (CNN) with 2 convolutional layers and 1 dense layer fully connected. The input was the 64 $\times$ 64 pixel sized tile, and the output is made up of 4 nodes, one for each class. The model reached 98% of correct classification, proving a satisfactory result.

Technical and Social Assessment

The developed approaches have been tested during the project both at the level of individual subtasks (e.g. obstacle avoidance algorithms, chemical sensors, classification algorithms, landing) and at the level of the macro tasks (use cases, except use case 5) passing all the validation tests and achieving satisfactory results that for the most part support the adoption of such technologies within the steel plant, which was one of the main purposes of the *DroMoSPlan* project.

This technology has some potential to be successful in terms of social impact and acceptability, but the productivity gains are questionable (Stroud and Weinel 2020; Stroud et al. 2021). During the project, different interviews were conducted to assess the impact of the exploitation of unmanned vehicles technologies on staff in terms of potential benefits and risks to the person. The result of this survey shows that the use of drones is acknowledged to potentially reduce the risks associated with a range of work processes, such as accidents (falls or slips when working at heights indoors; intoxication/poisoning when inspecting gas pipes, etc.). Further, in *some* circumstances, drones are also considered as saving both time and costs as they allow for immediate access to remote areas that, without using drones, require special equipment. However, they also create a range of additional work and training needs, e.g. data analysis from the sensors, which may slow the analysis process and not lead to the anticipated gains. The risks of health and safety stemming from drone crashes in outdoor areas are perceived to be less likely and so overall improvement in health and safety should be realised (Stroud and Weinel 2020; Stroud et al. 2021).

4 Conclusions

The analysis of the contributions in the literature, the research projects and case studies described in this chapter, highlight how digital transformation is at the heart of changes in the European industry and the steel industry in particular. In this context, we see an increasing use of robotic systems due, among the others, to the development of supporting technologies such as AI and sensors.

Robots are increasingly integrated into production pipelines and are in charge of tasks of growing complexity. The industry currently uses both standard stationary robots and mobile ones with a certain level of autonomy in the movement and operation. The first of the two approaches is the one still most commonly used. In such applications, the aim is to have robots do heavy or dangerous work or work that requires exposure to uncomfortable environments. New emerging technologies are also driving the use of unmanned vehicles such as UAVs and UGVs, which have the potential to be autonomous—should EU and workplace regulations permit—and expand the range of applications with monitoring activities at various levels that also cover aspects of quality control and maintenance. These applications can be the key to increased productivity, quality and cost containment, as evidenced by the results of many research projects. In this scenario, an emerging theme is that of human–robot collaboration to exploit the best capabilities of both: accuracy, reasoning ability on the one hand; strength, ability to repeat a task repeatedly, ability to operate in hostile environments, on the other hand.

In the projects mentioned and case studies described, the use of robots has brought the potential for multiple benefits in terms of productivity especially in terms of safety and risk reduction. From a social point of view, the use of robotic systems is also a success: because the robot is seen not as a competitor but as a collaborator who can help decrease the fatigue load and risks to which operators are subjected—it was not foreseen that the robots would replace workers in their tasks.

In the future, it is foreseeable that there will be considerable growth in using robotic systems, both stationary and mobile, in the steel context given the characteristics of the plants and processes. This growth will be driven by the unstoppable development of associated technologies and the increasing competitiveness of the steel market, which requires continuous technological improvements, without neglecting the necessary safety aspects.

References

Ahmad HM, Rahimi A (2022) Deep learning methods for object detection in smart manufacturing: a survey. J Manuf Syst 64:181–196

Bachrach A et al (2012) Estimation, planning, and mapping for autonomous flight using an RGB-D camera in GPS-denied environments. Int J Robot Res 31(11):1320–1343

Bian Y, Yi D, Cao Y (2022) System design of temperature measurement and sampling robot in steel plan. In: Journal of physics: conference series, vol 2370(1)

Biermann F, Gräfe S, Bergs T, Schmitt RH (2022) Additively manufactured robot gripper blades for automated cell production. Processes 10(10)

Branca T et al (2020) The challenge of digitalization in the steel sector. Metals 10(288)

Branca T et al (2022) Skills demand in energy intensive industries targeting industrial symbiosis and energy efficiency. Sustainability 14(23)

Brandenburger J et al (2016) Big data solution for quality monitoring and improvement on flat steel production. IFAC-PapersOnLine 49(20):55–60

Chen Q, Wen X, Wu F, Yang Y (2019) Defect detection and health monitoring of steel structure based on UAV integrated with image processing system. In: Journal of physics: conference series, vol 1176(5), pp 52–74

Colla V (2022) A big step ahead in metal science and technology through the application of artificial intelligence. IFAC-PapersOnLine 55(2):1–6

Colla V et al (2021a) Robotic assistance in the steel shop: a solution to improve health, safety and digital skills at the workplace. Metals 11(4)

Colla V, Pietrosanti C, Malfa E, Peters K (2021b) Environment 4.0: how digitalization and machine learning can improve the environmental footprint of the steel production processes. Materiaux et Téchniques. In press

Colla V et al (2017) Introduction of symbiotic human-robot cooperation in the steel sector: an example of social innovation. Matériaux et Techniques 105(5–6)

Dannapfel M et al (2018) Systematic planning approach for heavy-duty human-robot cooperation in automotive flow assembly. Int J Electr Electron Eng Telecommun 7(2):51–57

Demetika P, Ferrari R, Galasso L, Romano F (2014) Robotic system for a “zero-operator” continuous casting floor. Indianapolis, IN, USA, s.n.

Gerstorfer G et al (2018) Robotics applications contin-uously enancing safety in melt shops. Taranto, Italy, s.n.

Gopinath V et al (2021) Safe collaborative assembly on a continuously moving line with large industrial robots. Robot Comput-Integr Manuf 67

Grimaccia F et al (2015) Planning for PV plant performance monitoring by means of unmanned aerial systems. Int J Energy Environ Eng 6(1):47–54

Hansert P, Stech R, Quant M (2016) Performance experience of the MultiROB at BSW—how safety, productivity and accuracy go hand in hand. Iron Steel Technol 13:70–76

Herrera-Alarcón EP, Satler M, Vannucci M, Avizzano CA (2022) GNGraph: self-organizing maps for autonomous aerial vehicle planning. IEEE Robot Autom Lett 7(4):10721–10728
Lee S-H, Yoon D-H, Choi S, Newkirk J (2012) StrapMaster: a robotic band-strapping system. Seoul, Korea, s.n.
Meisel J et al (2014) Experience and evolution after 10 years of robotics in continuous casting technology. Graz, Austria, s.n.
Miśkiewicz R, Wolniak R (2020) Practical application of the industry 4.0 concept in a steel company. Sustainability 12(14)
Orgeira-Crespo P, Ulloa C, Rey-Gonzalez G, Pérez García JA (2020) Methodology for indoor positioning and landing of an unmanned aerial vehicle in a smart manufacturing plant for light part delivery. Electronics 9(10)
Rathlev F, Meyer B, Juerss S (2012) Innovative technologies for aerial survey of gas pipes. Gas Energy 5:1–5
Ringel M, Taylor A, Zablit H (2015) The most innovative companies 2015: four factors that differentiate leaders. The Boston Consulting Group, s.l.
Ryu H, Jin M, You K-S, Choi C (2012) Development of refractory brick construction robot in steel works. Seoul, Korea, s.n.
Soltani E (2010) An investigation on continuous steel slabs casting line and mechanical design of a 3R robot for sampling from melting arc furnaces. Adv Mater Res 83–86:31–35
Stroud D, Timperley V, Weinel M (2021) Digitised drones in the steel industry: the social shaping of technology. Relat Ind 75(4):730–750
Stroud D, Weinel M (2020) A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology 'effects' in the European steel industry. N Technol Work Employ 35(3):297–313
Turner D (2010) Monitoring vegetation with an unmanned aerial vehicle. s.l., s.n.
Vannucci M et al (2022) Artificial intelligence approaches for the ladle predictive maintenance in electric steel plant. IFAC-PapersOnLine 55(2):331–336

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Industry Perspectives on Industry 4.0 and Workplace Change

The History of the Steel Industry: A Trade Union Perspective from the UK

Anna Mowbray

1 Introduction[1]

The UK steel industry supported 33,400 direct jobs in 2019, a number which has declined over time—there were over 320,000 jobs in the industry in 1971 (Hutton et al., 2021), yet the industry has remained of vital importance to the communities that depend on it. Steelmaking has roots in many regions across the UK: in Scotland, the Northeast, Wales, Yorkshire and the Humber, and the West Midlands. After years of under-investment, many sites have closed, especially those in Scotland and the Northeast, leaving their communities devastated.

This chapter sets out the story of the steel trade union, Community in the UK, from its earliest history to the present day, with a particular focus on the present day and the challenges of net zero and decarbonisation. The UK steel industry has faced successive waves of industrial change, weathering political changes as governments changed between the Conservative and Labour parties, and global changes including wars, climate change and a changing industrial landscape. The lessons of the UK steel industry have implications for national policy (and wider lessons for the UK and Europe) and in particular the approach to and importance of just transition, and the need for coordinated action to support industries and communities.

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2 Early History

To turn iron ore into useful products like food packaging, bridges, and hospital beds, it must be transformed by skilled application of heat, carefully controlling the ration of iron, carbon, and waste material. For the earliest steelworkers, without technology to heat iron to melting point, the challenge was to incorporate carbon into the wrought iron they had smelted to make a stronger material. Evidence suggests they could already do so in the late Iron Age, Roman and early Medieval times (Lang 2017: 863). It took until the eighteenth century to take the first steps towards the European steel industry as we know it today. First, much higher temperatures were reliably achieved through the use of coking coal and with this development the challenge was inverted: how to take high carbon pig iron[2] and reduce the percentage of carbon. Advances[3] such as crucible steelmaking (Fabián 2018) gave greater precision over this balance, and allowed the creation of stronger and less brittle steel, with particular success in the city of Sheffield. A step change came in 1864 when the first Bessemer converter was used commercially, allowing steelworkers to inexpensively decarburize steel (the 'Bessemer process'). These developments made industrial-scale blast furnace steelmaking possible from the middle of the nineteenth century.

As the sector industrialised the nature of work in the industry shifted. No longer could an individual craftsperson (or group of craftspeople) set up for themselves because of the capital required (Pugh, 1951: 9). Whilst work in the steel industry remained skilled the transition led to new demands for workforce organisation (Evans, 1998: 155). In the nineteenth century, the UK steel industry was world-leading, driving the industrial revolution. By 1875 the UK produced almost half of the world's pig iron and 40% of the world's steel (Coats, 2020, p. 35), much of it produced in the Yorkshire region. In this context, unions began to spring up, usually on a small scale. In 1842 an early unionist, John Kane, tried unsuccessfully to form a union of steelworkers (Pugh, 1951: 32). Kane was eventually to succeed at founding a trade union, the Amalgamated Malleable Ironworkers, 20 years later (Pugh, 1951: 11). Early unions were small and specialised and tended to wax and wane as strikes or wage negotiations took place (Pugh, 1951: 11). It was these early unions that were later to become the Iron and Steel Trades Confederation (ISTC).

Conditions in the early steel industry are described by Arthur Pugh where he reflects on his own first job in the industry in 1894, transferring an ingot from the furnace onto rollers:

> '… if by accident one of the narrow wheels of the bogie happened to slip between two of the iron floor plates, there would be a sudden stop, the ingot would fly off the bogie, up would go the handle, and unless the man at the end was smart he would be taken off his feet. The

[2] Pig iron is so named because traditionally the liquid metal was run out into moulds carved into the sand, with a long channel and ingots at right angles to it which resemble a sow nursing her piglets (T. S. Ashton, Iron and Steel in the Industrial Revolution, quoted in Pugh 1951, 7).

[3] In Europe—crucible steelmaking was known in India from around the 1st millennium AD (Lang, 2017, p. 862).

thing to watch was when the handle came back or you might get a bang on the head which, in the most lucky event, would leave a painful impression' (Pugh 1951: 17)

He was paid 4 shillings 6d. a shift for this dangerous work[4] (Pugh 1951: 17). For people working in such conditions (and with the constant risk of wage rollbacks) unionisation was a necessity.

3 The Twentieth Century

A key challenge for the movement as the twentieth century dawned was inter-union competition. Despite typically specialising to represent specific types of workers, unions were regularly in conflict. This drove a desire for unions in the industry to unify. The first step towards this goal came in 1912 when the Steel Smelters' Union and the National Amalgamated Society of Enginemen, Cranemen, Boilermen, Firemen and Electrical Workers fused together (Pugh 1951: 21). Then, in 1916, the British Steel Smelters, Mill, Iron and Tinplate Workers, the Associated Iron and Steel Workers of Great Britain, and the National Steelworkers Association, Engineering and Labour League carried out successful ballots to join into a confederation, known as the Iron and Steel Trades Confederation (ISTC), now Community.

The ISTC had an unusual structure whereby a central association, would exist in parallel to the founding unions. Requests for transfers to the central association were higher than anticipated, and new members—including those in roles that were not traditionally unionised, such as chemists—applied to join the union in significant numbers. By the end of December 1917, there were 49,166 members of the central association, of whom 26,808 were new members, and 22,358 had transferred (Pugh 1951, p. 263). Despite this success, the ISTC did not succeed in attracting all the unions it had wanted to. The Blast-Furnacemen's federation pulled out of talks in 1916, and two other unions failed to secure the majority needed in the ballot.

Meanwhile, the steel industry was stretched by the war effort, facing the imperative to produce as much as possible. Output increased to 10,000,000 tonnes per year in 1918 (Pugh 1951, p. 264). The war also saw shortages of steelworkers as men were called up to the front and an increasing number of women entered into the workforce (Pugh 1951: 266). At that time trade unions were instrumental in improving conditions in the steel industry. A key example is the pathbreaking 1919 'Newcastle agreement' which set out the principle of 8-hour shifts. The steel industry was unusual in that the higher paid men agreed to take a pay cut to meet the costs of the third shift being brought on board (Pugh 1951: 285). Debates about the 8-hour day continued throughout the 1920s, but though there were to be some rollbacks the principle was firmly established, and throughout its history the ISTC would continue to advocate for reasonable restrictions on working time (Upham 1997: 239).

As the war ended, demand for steel was reduced. During the 1920s the union and the industry both struggled. The UK steel industry was facing stiff competition,

[4] Worth approximately £18.46 in 2022s money.

not least because the reparations that Germany was required to pay under the Treaty of Versailles included providing coal for free to France and Belgium (Peace Treaty of Versailles 1919), whose steel industries became significantly more competitive. Though wages in the steel industry were rising from 1921, unemployment was high. Of £112,926 of expenditure by the central association, in the 12 months to December 1920, £102,721 was unemployment benefit[5] (Pugh 1951: 318).

The ISTC participated in the 1926 national strike, in sympathy with locked out coalminers, perhaps reflecting that mining strikes hurt the coal-dependent steel industry. Though steelworkers felt a great deal of solidarity for the striking miners, the ISTC was critical of the leadership of the mineworkers' union (Pugh 1951: 402–403). Government reaction to the strike was severe: the anti-trade union backlash culminated in the Trade Disputes and Trade Union Act of 1927 (Novitz 2007: 494), later described by a Labour MP as 'a vindictive Act, and one of the most spiteful measures that was ever placed upon the Statute Book' (HC Deb (1931) cols 347–348). The act outlawed secondary strikes, made it a criminal offence to participate in unlawful strikes and placed limits on political levies collected by unions.

As the decade closed, the Labour government won a general election in 1929 and sought to rationalise the steel industry. An inquiry was carried out and a delegation visited France, Belgium, Luxembourg, Germany, and Czechoslovakia. The conclusion was that 'in general wages and conditions of employment were inferior in the countries visited' (Pugh 1951: 456) but the committee sought to learn from best practice abroad. Before progress could be made with reorganisation, the pressures of the Great Depression caused the Government to collapse. A National Government, with representatives of all parties, was formed in its place and would remain in place until the outbreak of the Second World War.

Economic conditions improved over the 1930s, in part due to Roosevelt's New Deal Policies in the USA. In 1934 ISTC membership was up a little, from 41,946 in 1931 to 54,540 (Pugh, 1951, p. 503) and a few years later in 1937 the steel industry appeared to be in good condition. However, even with relative prosperity, there were groups left out. In March 1937 an article in the steelworkers' journal, Man and Metal, argued for the sharing of work in the tinplate trade, asserting that 'every possible means of persuasion have been tried to make the men who are working in the fully occupied plants realise that the full employment they enjoy is only possible at the expense of their fellow Trade Unionists who are left derelict outside the closed works gates' (Pugh, 1951, p. 505). Nevertheless, the spirit of partnership with industry for which the ISTC prided itself was demonstrated well in Sheffield in 1939, when the employer Firth-Vickers had visited the USA and been alarmed by the state of competition it would face in the stainless-steel industry. The employer called a meeting with union officials explaining what he had seen—it was reported that the union representatives offered 'intelligent' and 'technical' questions (Pugh, 1951: 543).

[5] In return for their membership fees at this time, trade unionists could expect to receive a form of rudimentary social insurance, with the union paying benefits such as sickness and accident benefits.

4 World War II and Beyond

The steel boom of the 1930s was in part in response to the evidence of Germany's re-arming and fears of war. Consumption of steel was rising, particularly special steels from Sheffield which were used for plane engines (Pugh 1951: 542). The ISTC had 97,476 members by the end of 1940, (still short of peak membership of 124,000 in 1920) but certainly much improved on the depression years (Pugh 1951: 546). When war broke out, the steel industry was classed as essential and protected by reserved occupations. Essential works orders prevented affected workers from changing occupation but did provide them with a guaranteed wage (Pugh 1951: 558). Man and Metal expressed support for this policy and hope for what the post-war era would bring: 'the opportunities the post-war world will offer for social advance will be unique in the history of mankind' (Pugh 1951: 558).

By May 1942 confederation membership of the ISTC exceeded 115,500 (Pugh, 1951, p. 56). There were 15,000 steelworkers from the heavy section alone serving in the army and the steel industry was recruiting women to take on these roles (Pugh 1951: 562). These 'women of steel' remain a source of pride for Community. Questions addressed by the ISTC at the time included the question of whether workers in hot and thirsty jobs should be accorded extra sugar rations for their tea. There was a three-day strike at Llanelli because maintenance workers were not offered the supplementary sugar given to those on hot works (Pugh, 1951, p. 565)—quite the contrast from the subject matter of earlier disputes, but reflecting war-time concerns!

As the war ended, the trade union backed Labour Party won a landslide victory in the 1945 general election and in 1946 a proposal for the nationalisation of the steel industry was put forward. The incoming Labour government also finally repealed the Trade Disputes and Trade Unions Act 1927, although it was not until 1951, when wartime regulations were finally lifted, that the status quo returned (Novitz 2007: 494). In 1949 the Iron and Steel Corporation of Great Britain was formed, nationalising the steel industry. Both union and industry were flourishing. The union was headed by a strong executive which alone could authorise strikes, and to whom officials reported. The most significant problem for the industry at this time was keeping up with demand, high both domestically and internationally (Upham 1997: 6).

From this time, a rather unusual dispute resolution mechanism was developed, which persisted for many years. A 'neutral committee' would be established containing two representatives for either side of the debate. None of the parties involved would work at the firm relevant to the dispute; such transparency quite regularly ensured swift resolution of issues (Upham 1997: 7). These structures, established under a nationalised industry, were retained as the industry came into and out of private hands, resulting in relatively strong and persistent industrial relations structures, in stark contrast to the oscillating ownership structure of the steel industry, which privatized in 1953 (Upham, 1997: 27) and renationalised in 1967. Unfortunately, failure to adequately invest in the industry characterised both models of ownership throughout the twentieth century, concerning steelworkers whose industry was facing increased competition from abroad.[6] Though industrial steelmaking was born in Britain, her dominance of the trade was by this stage long gone.

Roy Rickhuss, General Secretary of Community Union since 2013, argues that debates about the merits or demerits of nationalisation have long failed to account for the constant pace of investment and technological change required in the industry to maintain profitability. In a privatised industry, when the hard times come there are motives to get challenging businesses off the balance sheet. In the public sector, industry must compete for state investment with health and education.[7]

5 Modern History

By the 1970s, the steel unions were negotiating from a position of strength with the British Steel Corporation. But the steel industry itself was not strong, running at a loss. Upham describes a 'long agony of steel' beginning at this time (Upham 1997: 2). In 1979 Margaret Thatcher became Prime Minister of the United Kingdom, bringing an end to the post-war consensus where political parties in the UK were largely in agreement on major issues such as close regulation of industry and the welfare state. Thatcherism advocated free markets, deregulation, privatisation, and sought to make labour markets more 'flexible' including through marginalising trade unions. Thatcher's battles with the coal mining unions are well known in the UK, where there was a yearlong miners' strike from 1984–1985, which was ultimately unsuccessful. Fewer people, however, are aware of her earlier conflict with steelworkers. Though there was a gathering threat to jobs in the steel industry (Upham 1997: 127), when the steel strike broke out it was about pay.

It was the view of the unions that the government had provoked the strikes. Government documents from January 1980 show that Bill Sirs of the ISTC had told the Prime Minister that it 'seemed to him that the Prime Minister and Sir Keith Joseph (Secretary of State for Industry) were repeating BSC's view of the dispute, so much so that it had seemed to him that there might have been a meeting between Ministers and the corporation' (The National Archives (TNA) PREM19/308 f38, 1980). There was a widespread view that the pay offer, in the context of 17.99% inflation (Office for National Statistics, 2022) was deliberately and provocatively low. Many in the industry at the time believed that the Prime Minister herself was not looking for a strike, but that there were others in the Cabinet seeking to provoke action from steelworkers.[8]

The steel strike lasted three months, but steelworkers suffered substantial hardship during that time. The timing of the dispute was not in the workers' favour, as steel was stockpiled over the winter. It's said that Bill Sirs, at the time General Secretary, was in his office in Gray's Inn Road during a demonstration in London. Striking

[6] Interview with A. McDiarmid, 20th August. Oxford.

[7] Interview with R. Rickhuss, 11th August. Oxford.

[8] Interview with R. Rickhuss, 11th August. Oxford.

steelworkers, who believed that the union was not acting sufficiently to represent its members' interests, barged into the office and confronted the General Secretary.[9] At the time questions of solidarity were central; no surprise given the interconnectedness of the steel industry and the mining industry. Whilst such political messages were of paramount importance to the ISTC's staff and NEC (National Executive Committee), the level of importance to the lay steelworker was less significant.

The dispute around pay was eventually resolved with an 11% increase on gross earnings and a 4.5% minimum bonus guarantee (Upham, 1997, p. 147). However, Roy Rickhuss, a young steelworker during the dispute, argues that the conflict had always been more substantial than that, and was fundamentally about restructuring.[10] Though there was a theoretically successful resolution of the dispute, there were plant closures both before and after the strike. This cut the steel workforce dramatically, with deep human cost (Smith, 2018; Beebee, 2020).

The industry was privatised for the final time in 1988, with British Steel Corporation listing publicly as British Steel Plc (Upham 1997: 217–18). However, industrial relations remained broadly well-structured thanks to legacy institutions that continued despite privatisation. As well as strong Dispute Resolution committees, a 'bible' of agreements known as 'The Heritage' gathered together the dozens of agreements that had been made between the unions and the government. This set out a framework upon which industrial relations were conducted.[11]

By the late 1980s, ISTC membership seemed to have stabilised at between 41,000 and 42,000 (Upham, 1997, p. 228), about a third of its peak. But the worst reductions in headcount were yet to come. In the winter of 1989, the first signs of trouble in the economy were sighted. In 1990 a spate of closures struck the industry across all regions including the steel and tube works at Clydesdale in Scotland, FH Lloyd Engineering Steel in the West Midlands, Raine and Co. in the Northeast, and Brymbo in Wales (Upham 1997: 235). Then, in May 1990 British Steel announced plans to shut the Ravenscraig hot strip mill in Scotland, which was once the largest such mill in Western Europe, would lead to a loss of 770 jobs in a steel-focussed community (Upham 1997: 236). However, events were advancing, and market forces placed the whole of the steelworks at threat. In 1992 the Ravenscraig works closed in its entirety (Upham 1997: 237). This was partly driven by the economic climate, but many in the ISTC saw this as punishment by Thatcher for the earlier strike. Ravenscraig represented the end of steelmaking in Scotland, and the loss, not only of livelihoods, but of an industry which engendered a deep sense of identity and pride (Moss, 2001).

Despite this challenging environment, there were some opportunities for the ISTC to grow, including through amalgamation. On the 22nd of February 1991, the Amalgamated Society of Wire workers formally merged with the ISTC following a successful ballot (Upham 1997: 233). The ISTC was also becoming more democratic. In 1993 Keith Brookman became the first General Secretary of the ISTC to be elected by a ballot of the membership (Upham 1997: 248). In 1997 the New Labour

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[9] Interview with R. Rickhuss, 11th August. Oxford.

[10] Interview with R. Rickhuss, 11th August. Oxford.

[11] Interview with A. McDiarmid, 20th August. Oxford.

government swept into power. Whilst much legacy anti-trade union legislation was retained, the Blair government did not bring in further legislation and developed the revised Central Arbitration Committee (CAC) process through which recognition for trade unions could be secured (Simpson, 2007: 289) making it easier for workers to secure representation.

A key development at this time was the merger of British Steel Plc and Koninklijke Hoogvens, a Dutch company, in 1999 to form the Corus Group. The main disputes at this time were around plans to bring together the engineering and production teams. For the unions this caused two kinds of problems. First, management sought to impose headcount reductions, and second, the move created a recurrence of inter-union conflict.[12] Though there were multi-union collective bargaining arrangements, which continue to the present day, team working brought about significant conflict as members from the craft unions would be supplanting production workers under this model.

Other blows also struck the industry, especially in Wales. In 2001, the Heavy End at Llanwern closed for good and in 2002 Ebbw Vale steelworks closed (Stroud and Fairbrother 2012: 655). Though the remaining part of the Llanwern plant has survived, it has done so with a fraction of previous employment levels (Stroud and Fairbrother 2012: 655). A visitor to Ebbw Vale can immediately note the impact the steel industry has had on the town: even the houses were built by the British Steel Corporation. For Roy Rickhuss, without steel, it is 'a town without a heart'.[13] However, some struggling businesses were rescued: for example, in 2003, Allied Steel and Wire, based in Cardiff, which had historically been a private company was bought out of receivership by CELSA, a Spanish company.

In response to plant closures, the Steel Partnership Training scheme was set up. Later renamed Communitas, this arm's length body supported workers as they left traditional industries. The partnership retrained thousands of redundant steelworkers into everything from running their own businesses to horse dentistry. Alasdair McDiarmid, Community's Operations Director, recalls that this approach represented the core of the ISTC's values—even if members lost their jobs the union would not abandon them.[14] Match funding from the European Social Fund meant that the costs donated by companies through paid release from work could be doubled, facilitating high quality training. However, despite these positives, closures of traditional industries meant the loss of unionised jobs with strong collective bargaining frameworks. This innovative approach to the union's learning work was part of the reason for the choice of union name when in 2004 the ISTC merged with The National Union of Knitwear, Footwear and Apparel Trades (KFAT) to create Community, a union which represented people not only in the workplace but also in their communities.

In 2007 Corus group was acquired by Tata who (many believed) overbid for the company in a brutal bidding war with CSN. Tata paid £6.2bn for the company (Bream and Leahy, 2007), valuing it at around 9 times annual earnings. Tata's shares

[12] Interview with R. Rickhuss, 11th August. Oxford.

[13] Interview with R. Rickhuss, 11th August. Oxford.

[14] Interview with A. McDiarmid, 20th August. Oxford.

fell sharply when the news broke, with analysts fearing it would be overextended. Meanwhile, Corus shares boomed as investors expected Tata to deliver cost savings and improved profitability.

In the wake of the 2007 financial crisis, the steel markets were volatile. While the steel industry had always been cyclical, following 2008 business cycles that had previously been measured in years could change over the course of months.[15] This steel crisis left the industry in a state of instability that has not fully abated 14 years later. As a result, most steel companies attempted to restructure their businesses. Restructuring programmes with titles like 'fit for the future' and 'weathering the storm' resulted in extensive job losses.[16] To their credit, union reps managed to achieve the restructures without any compulsory redundancies. Instead, older members approaching retirement took the opportunity to leave on a voluntary basis.[17]

A defining trend in recent years has been fragmentation, as the industry splintered through sell-offs. Whilst fragmentation was challenged at the time, it was apparent that employers were not willing to invest in plants that they did not see as part of their core businesses or strategic long-term vision. Given the pace of change in the steel industry, plants would quickly have become unprofitable without ongoing investment. For Alasdair McDiarmid (Operations Director, Community Union), divestment may realistically have been the only way for surviving plants to continue to get the investment they needed to be profitable.[18] In 2011, the fragmentation of Tata Steel UK began with the Redcar plant sold to SSI. The sale was seen as a hopeful step forward, as in 2009 the plant at Teesside had been mothballed. Rescue seemed secure when the plant was bought by the Thai company SSI, and production restarted.

Then in 2015, crisis hit Redcar. The plant's owner disappeared as the business fell into liquidation and the plant was closed (Arnold 2020). The business model had entailed making steel in the UK and shipping it to Thailand to be rolled. Some commentators argued this was not a sustainable model from the start, but it had worked, for a time, until steel prices fell. Community argued that a rescue could have been attempted by separating the plant in the UK as a standalone and using rolling facilities in the UK. Estimates suggested that for a cost of about £20m the Conservative government could have secured the coke ovens and the furnace.[19] Instead, tragedy struck the community in Redcar in just the same way it had hit plants like Ravenscraig in the past. Steel unions have long warned that communities are devastated when a key employer is removed from an area.

The SSI crash was devastating, showing that even today communities remain dependent on steel. In Redcar, regional salaries fell dramatically—calculations based on ONS data show that median gross weekly earnings fell from £531 before the closure to £496 afterwards, a reduction from 4% below the national average to 15% below it. Serious harm was done to people's mental health and there were many cases

[15] Interview with A. McDiarmid, 20th August. Oxford.

[16] Interview with R. Rickhuss, 11th August. Oxford.

[17] Interview with A. McDiarmid, 20th August. Oxford.

[18] Interview with A. McDiarmid, 20th August. Oxford.

[19] Interview with A. McDiarmid, 20th August. Oxford.

of family breakdown. The jobs that former steelworkers moved into were predominantly self-employment and service jobs, generally un-unionised, and significantly more insecure than the jobs left (Coats, 2020, pp. 42–46). This tragedy occurred despite significant efforts from the government to support workers in the sector—£80 million was invested in reskilling, retraining and redundancy payments (Coats, 2020, p. 46), and there was a good example of the principles of social partnership that unions like Community have been promoting.

Whilst it is not clear that the government fully learned the lessons from the collapse of the SSI site, there is evidence that it wanted to avoid lightning striking twice. Later, in 2016, the Scunthorpe-based long products business was sold to Greybull (British Steel 2020) and the engineering steels business in South Yorkshire was acquired by Liberty in 2017.[20] For the unions, this entailed moving into multiple sets of negotiations and industrial relations structures. But, when the same threat appeared in 2019 in Scunthorpe and it seemed the business was heading like Redcar towards liquidation, the government stepped in to provide an indemnity to the official receiver, which meant they were able to keep the business trading whilst a buyer was found. Eventually British Steel was acquired by the Chinese steel company Jingye (British Steel 2020).

Notably, the steel unions argued that the success of this rescue exposed the lie that no government intervention could have been attempted in[21] Redcar. In subsequent years steel companies have continued to look for opportunities to divest assets, and the legacy of 2008 continues. Yet, for all it has faced in the past, the new set of challenges that the steel industry is facing today dwarf any that it has faced before i.e. decarbonisation.

6 Unions and Steel in the Net Zero Future

Community and the other steel unions have never shied away from acknowledging the urgency of the climate crisis (Community Union, 2021). Human-caused emissions are driving global temperatures up. To stop catastrophic global warming and climate change, it is imperative that the global community reduces its carbon emissions. Since its earliest days, the steel industry has been fuelled by carbon rich materials, charcoal in antiquity, coal since. Now dramatic changes in manufacturing methods are needed to make steel in a way which emits far less carbon.

At the same time, to manage the green transition the world will need steel. Steel will be an essential part of the supply chain for everything from electric automotives to wind turbines (Azevedo et al., 2022). Many of the green industries of the future can simply not be delivered without steel. Decarbonisation of the UK domestic steel industry is thus essential not least because of the emissions associated with transporting steel, the only alternative to domestic production. It has been estimated

[20] Interview with A. McDiarmid, 20th August, Oxford.

[21] Interview with R. Rickhuss, 11th August. Oxford.

that transport costs alone meant that the carbon emissions associated with importing steel from China were fifty times that of steel produced in the UK (UK Steel, 2021: 6).

Significant investment is required to ensure that the industry reaches its net zero targets. The year 2021 represented a pivotal decision point for the UK government and for the steel industry as a whole. In March 2021 Secretary of State for Business, Energy and Industrial Strategy, Kwasi Kwarteng resurrected the Steel Council, which had fallen into disrepute mainly because of a failure to agree on objectives amongst employers.[22] The resurrection gave steelworkers hope that the industry's future would be taken seriously in a year where the UK government's decision to host the COP26 conference placed its own climate policies in the international spotlight. COP itself also created an opportunity, disappointingly not seized, to set out a meaningful plan for the steel industry.

One of the areas of consensus is the importance of competitive energy prices to the future success of the steel industry.[23] Unions and industry argue alike that any of the technologies that will replace the existing technologies will require significantly more electricity than blast furnaces. For many years the UK steel industry has suffered a competitive disadvantage on electricity prices, sometimes paying double the price paid by producers in France or Germany.

Furthermore, the steel industry is the backbone of communities. Lessons learnt the hard way from Ravenscraig to Redcar show the tragic human consequences if steel is lost. The energy price surges of 2021–2022 have stretched the finances of both workers and steel companies to the limits, threatening the UK's Net Zero targets. This is disappointing given that the transition has the potential to create and protect steel jobs. Newer technologies like Hydrogen and DRI (Direct Reduced Iron) steelmaking will require significant investment and strategic thinking about the direction for the UK (Spatari et al 2021). Yet underinvestment has characterised the history of the UK steel industry, so serious change must be made to achieve a result that supports future industrial success as well as protecting good jobs, and communities.

7 Conclusions

Reflecting on the number and variety of challenges UK steel workers have faced over the years, what is remarkable is their great resilience despite continued patterns of underinvestment and failure to protect and support the industry to adapt. As a trade union, we have been proud to put forward workers' voices throughout that history, ensuring that government and employers recognise their impact on people and communities. Without the constant focus of unions on protecting their members, improvements to conditions in the UK steel industry would not have been achieved and efforts to help communities through industrial change would have been weaker.

[22] Interview with A. McDiarmid, 20th August. Oxford.

[23] Interview with A. McDiarmid, 20th August'. Oxford.

As European steel industries continue to face substantial challenges, it's imperative that a co-ordinated effort is directed towards achieving net zero. Lessons from the past must be learnt to ensure communities are not harmed as the economy transitions—no communities should face the fate of Ravenscraig or Redcar. It is more essential than ever that workers' voices are heard, throughout this process and that governments, employers, and unions work together as the industry takes on perhaps the greatest challenge it has ever faced.

References

Arnold S (2020) SSI five years on: former Redcar steelworks site 'now under full local control'. The Northern Echo. https://www.thenorthernecho.co.uk/business/18786656.ssi-five-years-former-redcar-steelworks-site-now-full-local-control/. Accessed 25 Jan 2022

Azevedo M et al (2022) The raw-materials challenge: how the metals and mining sector will be at the core of enabling the energy transition. https://www.mckinsey.com/. https://www.mckinsey.com/industries/metals-and-mining/our-insights/the-raw-materials-challenge-how-the-metals-and-mining-sector-will-be-at-the-core-of-enabling-the-energy-transition?cid=other-eml-alt-mip-mck&hdpid=7236476e-7fa1-41ea-84f8-6f923bcde51b&hctk. Accessed 20 Jan 2022

Beebee M (2020) 2019 labour history review essay prize winner: navigating deindustrialization in 1970s Britain: the closure of Bilston steel works and the politics of work, place, and belonging. Labour Hist Rev 85(3):253–284. https://ore.exeter.ac.uk/repository/bitstream/handle/10871/123869/Beebee_Navigating

Bill (2006) Ind Law J 36(4):492–495. https://doi.org/10.1093/indlaw/dwm034

Bream R, Leahy J (2007) Tata steel wins corus with £6.2bn offer, financial times. https://www.ft.com/content/e8191bda-b0d9-11db-8a62-0000779e2340. Accessed 22 Dec 2021

Coats D (2020) A just transition? managing the challenges of technology, trade , climate change and COVID-19. https://www.ferryfoundation.org.uk/Handlers/Download.ashx?IDMF=d3595d49-cb31-40c3-8a28-d6e7a4846866

Evans C (1998) A skilled workforce during the transition to industrial society: forgemen in the British iron trade, 1500–1850. Labour Hist Rev 63(2):143–160

Fabián O (2018) The legend of Benjamin huntsman and the early days of modern steel. MRS Bull 43(8):637–637. https://doi.org/10.1557/mrs.2018.195

HC Deb (22 January 1931) (1931). http://hansard.millbanksystems.com/commons/1931/jan/22/trade-disputes-and-trade-unions#column_458. Accessed 11 Feb 2022

Hutton G et al (2021) .UK steel industry: statistics and policy. House of Common Library. (7317). www.parliament.uk/commons-library

Lang J (2017) Roman iron and steel: a review. Mater Manuf Process 32(7–8):857–866. https://doi.org/10.1080/10426914.2017.1279326

Moss S (2001) Life after steel. The Guardian. https://www.theguardian.com/g2/story/0,3604,438063,00.html. Accessed 24 Jan 2022

Novitz T (2007) 'The right to strike: from the trade disputes act 1906 to a trade union freedom

Office for National Statistics (2022) Retail prices index: long run series: 1947 to 2021. https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/cdko/mm23. Accessed 25 Jan 2022

Peace Treaty of Versailles (1919) League of nations. https://www.census.gov/history/pdf/treaty_of_versailles-112018.pdf

Pugh A (1951) Men of steel by one of them. The Irons and Steel Trades Confederation, London

Simpson B (2007) Judicial control of the CAC. Ind Law J 36(3):287–314. https://doi.org/10.1093/indlaw/dwm017

Smith T (2018) 'Remembering Corby's hot metal past'. Steel Times Int 42(3):76. https://www.proquest.com/openview/744b14356d65802bb4f41128a23af45a/1?pq-origsite=gscholar&cbl=1056347

Spatari M, McDonald C, Portet S (2021) Decarbonisation of the steel industry in the UK: towards a mutualised green solution. www.syndex.org.uk. Accessed 18 March 2021

British Steel (2020) Where we've come from. https://britishsteel.co.uk/who-we-are/where-weve-come-from/. Accessed 25 Jan 2022

UK Steel (2021) Maximising value: positive procurement of steel. www.makeuk.org/uksteel.

Stroud D, Fairbrother P (2012) The limits and prospects of union power: addressing mass redundancy in the steel industry. Econ Ind Democr 33(4):649–668. https://doi.org/10.1177/0143831X11425542

The National Archives (TNA) PREM19/308 f38 (1980) 'Record of a meeting held at 10 downing street on monday 21 january 1980 at 10.30 AM to discuss the steel dispute. The National Archives. https://www.margaretthatcher.org/document/116071

Community Union (2021) Building a greener future. https://community-tu.org/who-we-are/what-we-stand-for/climate-change/

Upham M (1997) Tempered-not quenched. Lawrence and Wishart Limited, London

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Aiming for Industry 4.0: The Case of the Czech Republic

Roman Ďurčo, Marcel Pielesz, and Dana Sakařová

1 Introduction

The production of base metals is a global industry and in that sense its situation is largely defined by global political, economic and environmental trends. This is a segment that significantly transfers the consequences of world development to local economies and local labour markets. It is, moreover, an energy-intensive industry and therefore dependent on the development of the global energy market. Raw materials processed by the industry are geographically unequally available and are subject to global trade, hence also dependent on non-locally influenced factors. As such, there are significant and varied implications at national and regional levels for metals production, including with the Czech Republic.

The metallurgical industry in the Czech Republic is mostly located in the Ostrava region and its vicinity. Coal, which was discovered under Ostrava and Karviná, started the creation of the lower Vítkovice area—today a national cultural monument—and the establishment of the Vítkovice Ironworks, Nová huť (recently Liberty Steel), Třinec Ironworks (Třinecké železárny), steelworks and tracks production company Bohumín and other firms related to steel production, such as those related to the engineering industry and others similar sectors. Hence, in this chapter, we focus discussion on the Ostrava region, which is called the Steel Heart of the Republic.

Beyond this, the principal focus of the chapter is on the process of automation in the Czech Republic's steel industry, and its very gradual transition to Industry 4.0

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technologies. It represents a case of how the transition is taking place in a much-changed industry since the communist era and accession to the European Union (EU). First, we begin by situating the steel industry in the Republic with a discussion of the emergence of the Ostrava region as the heart of the Czech Republic's steel producing region, and its subsequent decline but also its place as the centre of post-industrial and industrial transformation, and in this sense presenting a case for technological transition, i.e. Industry 4.0.

2 Ostrava: The Steel Heart of the Czech Republic

As usual, those who want to understand today must know the past. In the case of Ostrava, this is doubly true. Its fate was lined up for many decades in the second half of the eighteenth century, when rich coal deposits were found in the Ostrava region. The rapid growth of the agglomeration started in 1828 with the establishment of ironworks in the village of Vítkovice. By the second half of the nineteenth century, Ostrava had already become one of the most important industrial centres of the Austro-Hungarian monarchy thanks to coal mining and ironworks.

However, the greatest expansion of Ostrava did not begin until the communist coup in 1948 and the subsequent orientation of the Czechoslovak economy to the development of mining, steel and other branches of heavy industry. Its massive support led to the rapid swelling of the city. While in 1950 Ostrava had a population of about 215,000, twenty years later there were already 300,000 people living in this city. To illustrate the situation: during the 1980s, the Ostrava industrial area accounted for 86% of hard coal mining, 82.5% of coke production, 66.8% of pig iron production and 60.3% of steel production nationwide. Half of the economically active people were employed in the industry here. The socialist planners anticipated that the North Moravian metropolis should accommodate half a million people and conceived the city accordingly. As the economic geographer Ondřej Slach from the Faculty of Science of the University of Ostrava says, the fundamental problem of Ostrava is encoded in its history, in that "*for some 150 years it was built not for people but for industry*" (Faculty of Science, 2023).

The economic downturn that followed the fall of the communist regimes in Central and Eastern Europe hurt Ostrava in particular. The disintegration of the Council for Mutual Economic Assistance in 1991, and thus the collapse of the market in which these countries traded, led to a drastic decline in the economic output of the post-communist countries. Of course, industrial centres such as Ostrava suffered the most. Workers were laid off in large numbers. If in 1989 OKD mining company employed 112,000 people, six years later the number of employees decreased to 42,000 and by 2003 it had fallen to only 17,500. Today, OKD employs just about 1,200 employees. A similar reduction in the number of employees also affected the company Nova Hut. In 1989 it had 23,000 employees, in 2003 only 12,000 were left and the company currently employs only about 7,500 people. Třinec ironworks underwent similar developments as it reduced employment from 24,000 employees in the late 1980s to currently only about 6,800 employees.

The transformation of the industry to one that was much smaller in terms of workforce became fully apparent after the fall of the communist regimes in Central and Eastern Europe. Gone are the days when miners and steelworkers were a coveted group. It is not for nothing that during the industrial heydays, it was said: "I am a miner, who is more?" The average monthly wage of the miner in 1988 was just under 7,200 Czechoslovak crowns, which corresponded to two and a half times the then country-wide average income. Experienced front-line miners could even earn around 10,000 crowns, which was a lot of money for that time, given that the directors of industrial companies earned an average of just above 7,000 crowns a month at that time. Today the situation is completely different. The miners earn about 30,000 crowns gross a month, but if their wages had grown at the same rate as the average salary in the Czech Republic after 1989, they would be earning more than twice that amount.

3 The Black Lungs of the Republic

After 1989, Ostrava faced a situation for which it was not built. It became an industrial city in post-industrial times, and people started to leave. In 1990, it had about 331,000 inhabitants while today, only 289,000 people live in it. The process of population decline has not slowed down. On the contrary some 27,000 people have left just in the last decade.

This is a big problem for Ostrava in the future. The city was planned for half a million people, and the transport network and the entire infrastructure were designed accordingly: 'The city must learn to manage more efficiently. Although the city's population is shrinking, the infrastructure costs are still the same', says sociologist Lubor Hruška (cited in Kain 2018) head of the scientific team who created a multi-volume monograph on the development of Ostrava called The Industrial City in a Post-Industrial Society.

The most common explanation for the decline in the population in Ostrava is that economic development has stopped and the city has been economically left behind. But according to Slach (cited in Kain 2018), it is more complicated:

> *It is often said that people leave Ostrava for economic reasons, due to deindustrialization. But if you look at the hard data, Ostrava, from an economic point of view, when it measures the unemployment rate, added value per employee, R&D expenditure and several other indicators, it is one of the most successful regions in the Czech Republic. Economic development is not as bad as it is sometimes presented, and the economy is not the only reason why people are disappearing from Ostrava,*

According to Slach, the aging of the population also plays a big role. Like almost anywhere else in the country, birth rates have fallen in Ostrava after 1989 and while the number of pensioners is increasing. If in 1990 Ostrava was by far the 'youngest' of the large cities in the Czech Republic, today it is the ‘oldest’. If nothing changes, according to Slach, an average of 2.4 pensioners per child will live in Ostrava in 2045.

The fact that economic reasons may not have a major impact on the depopulation of Ostrava can also be seen in where people go to when they leave Ostrava. If the reasons for their departure were only economic, they would be completely outside the region, but this is not the case. According to a new analysis of the migration of Ostrava residents, which was prepared by Lexxus Norton for J&T Bank (cited in Kain, 2018) a total of 66.5% of ‘leavers’ remain in the region. This is also confirmed by the data available to Ondřej Slach. Of the total of 42,000 people who have left Ostrava since 1990, about 70% have settled (and remain) in its immediate vicinity.

4 ‘Post-Industrial’ and Industrial Transformation: New Opportunities?

In an effort to find an answer to the question about its future, Ostrava has one advantage. The situation in which Ostrava finds itself is nothing new in the international context. Ostrava thus can learn from other places who have experienced similar developments. The German city Dortmund, for example, which for many decades was one of the country’s largest industrial centres, has experienced heavy industry downturns. In the 1980s, coal mining and steel production became less profitable and 70,000 people lost their jobs due to closure of mines and industrial plants. At that time, the city bet on education, science and research. And it did well. The Technical University, already founded in 1968, flourished and has currently more than 30,000 students. A technology centre for companies focused on biomedicine or nanotechnologies has also been set up nearby, employing almost ten thousand people, many of them highly qualified.

Dortmund tried hard to change its image and get rid of the reputation of a dirty industrial city. A lake (Phoenixsee) was created on the site of the former steelworks, on the shores of which luxury housing has grown. The listed building of a former brewery was renovated for 50 million euros and reopened as a centre for artists. In 2010, Dortmund was even awarded the Capital of Culture of the EU.

Ostrava also has a chance to have a good future if it invests in education and bets on research and development, information and communication technologies, but it should certainly not turn its back on its industrial tradition, as Hruška notes (in Kain 2018): “*Ostrava will probably never just be a city of services, industry will always play a big role here. It will not only be a heavy industry, but it will be a light engineering industry, automated production*”. Slach agrees: “*I am sensitive when someone says that Ostrava is a post-industrial city, because that is not true. The industry still employs around thirty% of the people here. Even reindustrialisation took place here between 2004 and 2008. Industry grew throughout the region.*” According to Hruška, Ostrava would flourish even if Mittal ceased to exist. “*It would lead to a* *further outflow of population, but in general, Ostrava has already taken a different path, the key is for Ostrava to become a modern city with a quality environment based on people who want to achieve something*."

As far as the steel industry in the region is concerned it experienced a significant decline in production in the context of the global economic crisis of 2008–2009. Since then, there has been some gradual improvement in the situation in both the Czech Republic and Europe, but production is around 90% of 2007 levels and production volumes are not expected to return to 2007 levels or higher levels (Steel Union, nda). As in the whole of Europe, the Czech steel industry is characterized by some degree of overcapacity and the situation leads to relatively high pressure to maintain competitiveness, especially in the context of the inflow of cheap steel from China and India. Despite these facts, the recent annual performances, for example, in 2017 and 2018 of the Czech steel industry, are evaluated to be successful (Steel Union, nda). The Czech and European economies showed positive development as demand for and price of steel increased.

A successful strategy seems to be to try not to compete with Chinese and Indian cheap steel production, but to increase the added value of the product in terms of the introduction of modern technologies position (e.g. special wires and heat-treated high-quality bar steel in the case of Třinecké železárny, which thanks to this approach is able to maintain a good market position). This direction requires companies to invest heavily in equipment upgrades, technology development and production greening. In this regard, the role of research and development is irreplaceable, investment in research and development is one of the main global trends in the field of metal production in recent years.

Technological innovation will be key for the industry and those looking to stay ahead will invest in developing these capabilities. This is especially true for industries facing very challenging market conditions. Metal fabrication is a very competitive environment, and research and development is key to keeping businesses abreast. Manufacturers are increasingly aware of the importance of continuous development and innovation, and understanding which new technologies open up new production possibilities and new capacities. Cooperation between metal producers and the metalworking industry is also of particular importance to the success of research and development.

Iron metallurgy is a separate field of intelligent strategy. In this area, research and development is seen as a key element of the path to achieving and maintaining competitiveness. The research activity here should be aimed mainly at new sophisticated products in response to the requirements of the customer industries, especially in the form of higher quality standards, flexible response to the demand for new products and innovation (e.g. offering a lighter material while maintaining the mechanical properties of the original). Other research topics are light alloys, cellular materials and composites, extreme alloys and composites, new and improved steels, advanced superconductors, development of combination alloys, biocompatible metallurgy, metal structures and technological units, metallurgical semi-finished products of copper and alloys, development of new and increasing parameters of existing auxiliary materials (chemicals, oils, etc.), new types of refractory materials, incl. their coatings for casting new types of alloys.

Research and development of new technologies in metallurgy are also supported, which enable an increase in productivity, a reduction in production costs including reduction of energy and material consumption. These new technologies will lead not only to improved product properties but also to cost savings, increased productivity, speed and flexibility, reduced environmental impact and improved workplace environment, including higher work safety. The key to all technologies is a combination of skills in materials science and a deep understanding of the manufacturing process and the technical equipment used. There is a fairly strong awareness among European metallurgical industry leaders that without major investment in innovation, the competitive position of European metal production will continue to deteriorate.

Among other things, this leads to pan-European and national subsidy initiatives to support the development of the sector, especially in terms of research, development and innovation (e.g. the 'Metallurgy Europe' program for the years 2012–2022 or at the national level the inclusion of metallurgy in the areas of intelligent specialization of the Czech Republic within research and development support programs). On the other hand, however, the ever-increasing emphasis on ecological production within the EU (Green deal) creates significant pressure on the industry and worsens its relative competitive position on the world market, and some protectionist measures on the international trade scene, specifically, for example, the introduction of import duties in USA. We need more investment, action and support from the European Union, Member States and companies to make this just transition effective. The transition to a low-carbon economy depends on sustainable and resilient industries.

In short, the industry provides 30 million high-quality jobs across Europe and delivers solutions to decarbonise our economy. However, it requires a supportive policy at EU, national (Czech Republic) and regional levels (Ostrava). A just transition is not free, but the costs of bad transitions are much higher for individuals, regions and society in general. Achieving climate goals in a fair and inclusive way requires higher public spending, but potentially brings long-term savings to society. An important aspect in achieving the transition is the second of the twin challenges (decarbonisation being one): Industry 4.0 and the development and insertion of digital technologies.

5 Industry 4.0

For many years, many developed countries have been engaged in the advent of the Fourth Industrial Revolution or Industry 4.0 (see Fig. 1 below), which is fundamentally changing the nature of industry, energy, trade, logistics and other parts of the economy and society as a whole. The Czech Republic aims to be part of this transition:

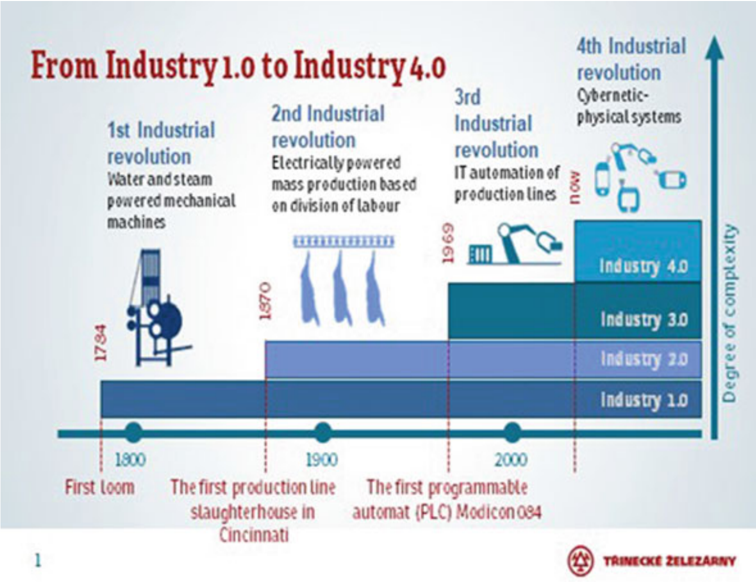

Fig. 1 From industry 1.0 to industry 4.0 [study of Třinec steelworks nda]

> *For Czech Republic and its high dependence on manufacturing industry there is nothing more important than not to let pass the train in something what the Germans called Industry 4.0. We need to develop this comparative advantage as much as possible. In reality we are not missing the money to develop further. But we need to put the money into areas that feed us, where we can do something, and to present it as perishable result".*
>
> (Zámečník 2015).

The aim in this section of the chapter is to provide key information related to the topic of the fourth industrial revolution, show possible directions of development and outline proposals for measures that could not only support the economy and the industrial base of the Czech Republic, but also help prepare the entire society to absorb this technological change. This is the only way to ensure the long-term economic attractiveness and competitiveness of the Czech Republic.

The digitalisation of the economy takes place in a wide range of sectors. These include sectors such as electronics, electrical engineering, machinery and equipment construction, tool manufacturing, automotive, energy, chemical and pharmaceutical production, metallurgy and steel, information technology and telecommunications, industrial automation, radiocommunications, but also maintenance, banking, financial and marketing services, business activity, consulting services, advertising activity, software development, agriculture, environment, health, nutrition and others. Thus, Industry 4.0's goal is to bring a complete digital interconnection of all levels of value-added creation-from product development to logistics. This means radical change and forward-looking investment planning in large and small businesses. Innovation, flexibility and productivity should all be redefined in Industry 4.0.

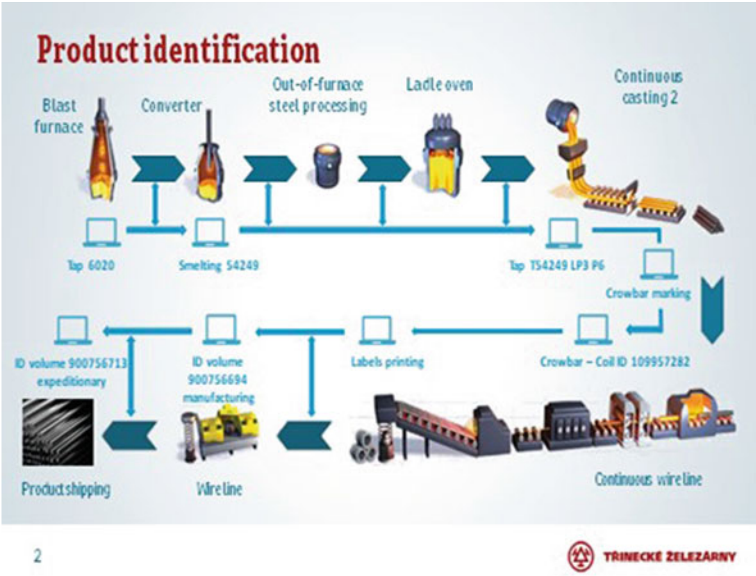

Fig. 2 Product identification-simplified production flow at Třinec steelworks a.s. from primary production to the final product [study of Třinec steelworks, nda]

Industry 4.0 is a term for a set of specific technological trends, which are the result of intensive development in the field of ICT, increasing computing capacity and higher possibilities of interconnection of ICT with physical systems. According to many experts, these trends will completely transform the face of industrial production and this change will also affect the production of metals and metal products (see Fig. 2).

Businesses will be strongly forced to introduce and implement Industry 4.0 technologies due to global megatrends, two of which are a lack of skilled labour and increasing global competition, particularly in terms of prices. These trends will lead the sector to further implement automation, including automation of assembly and setup of machines and parameters and their automatic adjustment in real time, monitoring of product lifetime, etc.

The introduction of Industry 4.0 requires large investments by companies, intensive use of R&D results, investment in state-of-the-art technologies, radical innovation solutions, quality and portfolio optimization of production. As for the future of the monitored industries, it is *expected* that they will move towards higher value-added products and sophisticated products. As such, Industry 4.0 makes claims to bring huge productivity gains and increased flexibility of series size (from individualized 1-piece production to huge series where interconnection allows flexible logistics and communication) [Naujok and Stam, 2017]. In so-called smart factories, which will continuously monitor and regulate the production process using digital technologies, production costs will be reduced (higher work efficiency), waste will be reduced and decision-making processes will be speeded up. One of the key resources in the future will be the know-how for smart factories.

In addition to a direct impact on production processes and technologies, the 4th Industrial Revolution can be expected to affect the production of metals and metal products indirectly through an impact on the demand for metals in terms of certain new features or new use in new segments. The major developments that can be observed at a global level in the metal industry today include automation, introduction of systems using big data, robotics, the Internet of Things, connected factories, collaborative centres, remote monitoring and control and streamlining of complicated processes through data analysis (see Fig. 3).

Data-driven technologies enable higher production accuracy and higher repeatability. Automation, which is already present to some extent in metal production (CNC machines, programmable presses), will continue to gain importance in the form of the Internet of Things. The use of sensors and large data sets allows the implementation of predictive maintenance. All available machine status information will be available at all times and used automatically. Sensors and smart chips are getting smaller and easier to install, which applies to all kinds of products, not just machines. Intelligent tools provide feedback on state and processes, such as vibration, to IT staff who adjust the process. All equipment and tools in the factories will have to be equipped with such features in the future. Together, these technologies will completely map production from start to end. The introduction of real-time process monitoring (sensors and continuous calculations) will allow to regulate parameters (e.g. temperature) in individual phases. To put it simply, it will be enough to insert a piece of metal, program

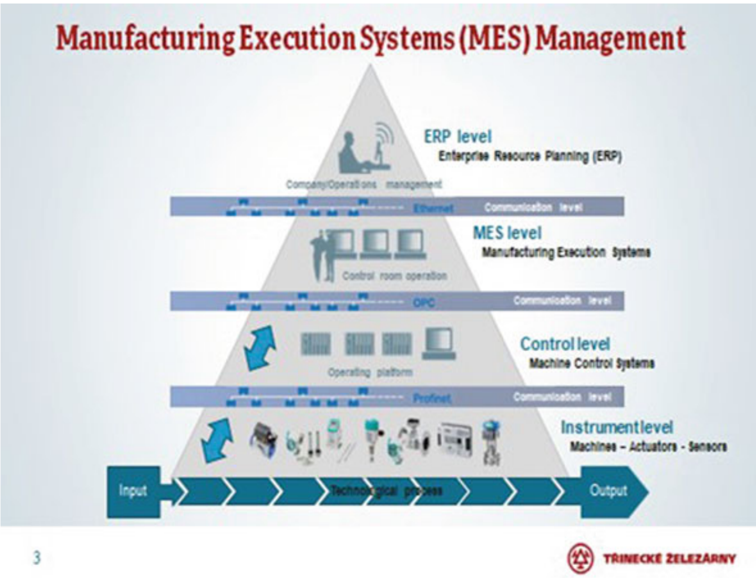

Fig. 3 Manufacturing execution systems management [study of Třinec steelworks, nda]

the device, and at the end the completely finished product falls out according to the specified parameters without the need of manual entry. Automated storage systems for material storage will also play a role—higher storage capacity, density of access and process transparency. Storage systems can be linked to production, where the material is fed automatically. As a result, it is a continuous automatic process from raw material to final product.

The combined effects of Industry 4.0 technology will generally reduce the price of production, reduce material consumption and increase production capacity. In the US, material consumption has already decreased by 4% (waste reduction) in this way, while production capacity has increased by up to 20% in some companies. After-sales services and pre-sales management have also improved with algorithms that better predict customer behaviour. Investing in these areas will enable companies to reduce spare parts costs, increase yield and increase accuracy (part size consistency). It is a realistic precondition for both the production of more advanced products in many ways and a higher adjustment according to customer requirements and customer support.

It is anticipated that such developments will bring more jobs for highly qualified technicians and data analysts and higher wages, but existing employees must also be retrained. However, it is also assumed that the development of digitalisation will to some extent reduce the number of employees (or help to solve labour shortage) in companies thanks to automation, integration of multiple machines, robotics, analytics and the possibility of remote control. The main driver will not be the effort to reduce costs through layoffs or low wages, but the effort to increase reliability, efficiency and productivity that can be achieved with digital technologies.

Trade unions not only in the Czech Republic, but also in the whole Europe should closely follow all these trends and their impacts on employment. New jobs will be for sure created but we should follow where are they created. We do not want to reach the situation that new jobs are concentrated only in some countries or regions while those where original jobs were disappearing are confronted with deindustrialisation, which can lead to poverty or another unbalanced situation within the EU. We fully support the European slogan: "*Nobody should be left behind*". This slogan concerns people/workers; companies, industries/sectors but also EU countries.

6 Industry 4.0 and the Czech Republic

The extent to which businesses in the Czech Republic currently consider the trends in Industry 4.0 to be relevant for them from their point of view is very diverse. It depends on the nature of production, the size of the company and the context of its supplier-customer relations. Large-scale manufacturers usually already have some degree of automation and robotics in place. For producers of small series, for single-piece and custom-made production, the trends have been slow to emerge. Further, a significant part of metallurgical enterprises of the Moravian-Silesian region indicate that a significant proportion of manual labour is irreplaceable in their production also in the future (Association of Industry and Transport of the Czech Republic, nda)

The reality of the vast majority of Czech companies in industry is far from this vision, but these are real concepts that are being discussed extensively in the professional field, especially abroad. Even when they will not be fully developed in the next few years, it is a direction whose timely capture can determine the future competitiveness of the industry as a whole, especially if other competitive advantages (e.g., labour costs) weaken. Some sources mention that for metal production is the connectivity a key for the future, or that the 4th Industrial Revolution may bring a "renaissance" of metal production. Last but not least, digitization has the potential to make the metal and metalworking industry more attractive to younger generations.

The full development of some technologies of Industry 4.0 in production (not only in the Czech Republic) is hampered by the hesitation of companies due to the lack of robust evidence and procedures on how to use the amount of data collected. The whole area is under investigation. Some companies are interested in installing sensors on older equipment they own. Producers of production technologies are therefore hesitant to install sensors. However, as soon as there is solid evidence of benefits and data utilization practices, it is likely that the mainstream will begin to move more strongly in this direction.

The Czech Republic is one of the countries with the longest industrial tradition and our ambition is for its future to remain connected with industry. As example you will find concrete projects implemented in Třinec Steelworks in 2017–2018 (See Fig. 4). The Fourth Industrial Revolution brings a number of challenges, but especially a unique opportunity to ensure the long-term competitiveness of the Czech Republic in a global competitive environment. We live in exceptional times and our ability to seize this opportunity will have an impact on the quality of life of generations.

In what follows we identify a range of issues to be addressed in the context of Industry 4.0 and the future of the Czech Republic steel industry:

- **Readiness of companies to implement robotic technologies is currently weaker in older companies**: Where it is necessary to invest in the renewal of older technologies, little support from the state through funds and guarantees from banks (harsh conditions). New companies are mostly based on new technologies. One of the important conditions for the use of all possibilities of technological development is a sufficiently strong ICT infrastructure, which is evidenced for example, by the speed of the Internet connection available to the company.
- **Research, development and innovation / new materials and technologies**: Investment in research and development is one of the main global trends in metal production in recent years. Technological innovation will be key for the industry and those who want to stay ahead will invest in developing these capacities. This is especially true for the steel sector, which is facing very challenging market conditions. Metal production is a very competitive environment and research and development are the key to keeping companies from falling behind. Manufacturers are increasingly aware of the importance of continuous development and innovation, that new technologies open up new production possibilities and new

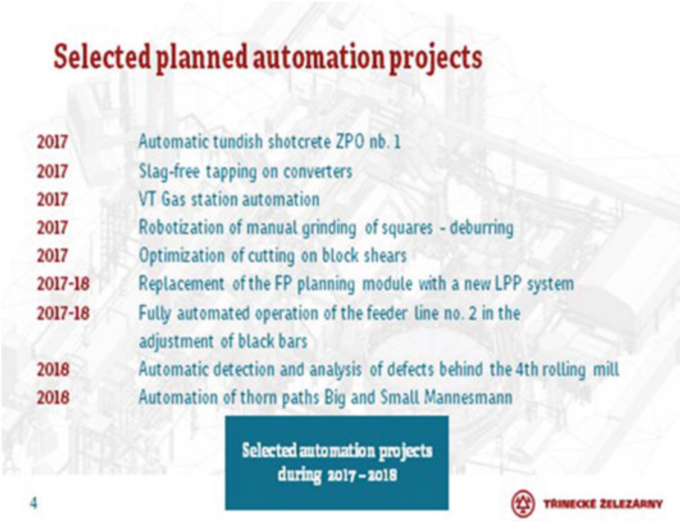

Fig. 4 Selected planned automation projects [study of Třinec steelworks, nda]

capacities. Cooperation between metal producers and the metalworking industry is also of particular importance for the success of research and development.

- **Employment in industry, age structure of employment**: It is a well-known fact that the Czech economy, like almost the whole of Europe, is facing an aging workforce. Industries are even worse off in this respect, as the physical demands of work tend to lead to early retirement and especially heavy industry is failing to attract young workers despite rising wages and the transition to new modern technologies. Demographic development is one of the most frequently mentioned topics in the context of the labour market. The metal industry is one of the first to lose labour due to lower numbers of young people. Many operations have a higher average age and risk leaving outgoing generations of experienced workers with no one to replace. The demographic trend has been compounded in recent years by a record high employment rate, with fewer jobseekers in the labour market than reported vacancies, and the fact that younger generations prefer career choices other than heavy industry or metalworking.
- **Educational structure of employment, education of employees in digital technologies**: Unskilled employees are entering, who need to be retrained for existing professions, and it is also necessary to provide training for existing employees in new technologies, low subsidy programs for training and retraining for companies.
- **Estimation of impacts on professions and skills**: There is a realistic assumption that some professions will disappear during the transformation of the industry, but new professions will also emerge, but with higher qualifications and higher wages.

- **Machine Learning/Artificial Intelligence**: Machine learning and artificial intelligence provide better insight into processes and data for their optimization. Analytical procedures are shifting from more reactive (analysing previous events) in the past to predictive and prescriptive analytics in the future. This allows for higher sophistication of artificial intelligence technologies along with a decrease in the price of sensors and computing power. Based on this data, it will also be possible to make qualified decisions concerning, for example, the strategic position in the value chain. By enabling machine learning to identify the internal processes and activities that contribute most to the achievement of production goals, machine learning will also affect the quality of products and services provided. Artificial intelligence is still in its infancy in metal production and is only being accepted very slowly. However, this type of production is characterized by a number of repetitive tasks that artificial intelligence in combination with robotics can easily take over.
- **E-mobility**: The projected transition to e-mobility is also causing some uncertainty in the sectors under review, which will significantly affect demand of the main consumers of metal industries. Electric motors are simpler than internal combustion engines and contain fewer parts. In general, efforts for lighter cars with lower fuel consumption result in demand for lighter parts and new progressive materials, reducing the need of steel.
- **Environment**: Environmental issues, climate change and efforts to mitigate environmental pollution affect the metal industry in several ways (Green deal and Fit for 55). Climate protection policy in Europe is being transformed into a practical form, for example through emissions trading. The development of their prices is a variable that significantly affects the situation in the steel segment and its competitiveness. If the prices of allowances continue to rise, there is a risk that steel production in the Czech Republic will no longer be profitable and will be moved to third countries outside the EU, where environmentally friendly technologies are used and CO2 production is not limited in this way. Current trends in targeted environmental regulations are described as potentially liquidating for the Czech and European steel industry.

7 Conclusions

The production of basic metals and steel is crucial for Europe and its member states. Today it is defined by global trends and geopolitical developments. Industry 4.0, digitization, the transformation of the entire sector towards greater sustainability and greening is also affecting the steel industry in the Czech Republic. Due to the concentration of steel industry especially in the North Moravian region, i.e. in Ostrava, these global trends have an impact not only on the steel companies themselves, but especially on the employees and their families. The transformation of the steel industry in the Czech Republic and its preservation in a given locality means providing a future perspective to the entire region and its inhabitants, as well as to related sectors.

The steel industry is one of the sectors that has been dealing with issues of its sustainability for many years. Considerable sums are invested in innovation, in research and development, and at the same time, it is and will be necessary to invest in people, in the employees of the future who will have to master new technologies. Considering that it will be a considerable investment, it will be necessary to involve in future educational activities not only steel companies, but also individual states, training and education providers, so that these correspond to the current requirements for an educated workforce of steel and metallurgical companies. At the same time, it will be necessary to introduce concepts of lifelong learning on the part of employees, who will have to continuously respond to new concepts and production changes that are constantly coming.

Even in the future, the steel industry will probably have to deal with unequal conditions on the global market, unfair competition, overcapacity, protectionism, problems with the supply of raw materials, however, thanks to an educated workforce and investments in research and development, which will ultimately lead to the production of green steel in the EU was to maintain a competitive position on world markets. The transformation of the steel industry and our future will therefore depend on a sustainable, stable and resilient EU industry and a skilled workforce.

References

Association of Industry and Transport of the Czech Republic (nda) Survey of Czech firms and industry 4.0 Homepage (sst.cz)

Faculty of Science (2023) University of Ostrava department of human geography and regional development. http://ceskapozice.lidovky.cz/

http://ceskapozice.lidovky.cz/tema/ostrava-chradne-pukne-srdce-mesta-zrozeneho-z-uhli-a-oceli.A180605_100221_pozice-tema_houd

Kain P (2018) Ostrava chřadne. Pukne srdce města zrozeného z uhlí a oceli?

Naujok N, Stamm H (2017) Industry 4.0 in steel: status, strategy, roadmap and capabilities. https://futuresteelforum.com/content-images/speakers/Dr-Nils-Naujok-Holger-Stamm-Industry-4.0-in-steel.pdf

Steel Union (nda) Prediction of Czech steel industry development 2017–2022

Study of Třinec Steelworks (nda) Planning, management and control of production from the study of Třinec steelworks a.s industry 4.0 in the conditions of a metallurgical company

Zámečník M (2015) Euro 47. https://www.tydenikeuro.cz/euro-47-2022/

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Recruitment and Training and the Dynamics of Digitalization

José Ignacio Alonso Osambela

1 Introduction

The current digital and technological transformation affecting the European steel industry is having an impact not only on the industrial processes but also on all the processes related to people. Within this transition, some of the most important aspects are those related to Recruitment and Training. For a simple matter of generational replacement, the candidates and the newcomers on board are coming with dramatically different expectancies than those responsible for hiring decisions. Moreover, the ways these candidates participate in the recruitment processes have nothing to do with what was commonplace not so many years ago.

The hiring process in the 1990s was paper-based. The post was advertised in the newspapers and the candidates had to apply by post. This made the process necessarily manual and much slower than nowadays. At the same time, companies are looking for standardized methodologies that allow them to take the best hiring decisions regardless of the experience of the recruiter. In addition, it is very important what the companies do when the candidates are hired. Not everybody reaches 100% of the requirements from the beginning and, even so, the job function changes and evolves in time. The job's evolution, or even change, takes place faster and faster if we compare it with the last decades, almost at the rhythm of technological changes. As such, we might say, digitalization has come to the world of People Talent Management to improve it.

The demographic evolution is having an important impact on companies' People Departments. What used to be known as the age pyramid is becoming something different because of longer life expectancy and extended working life. According to age distribution evolution, we are moving from a world populated by young people

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to a world where life expectancy is progressively increasing. The consequences of the demographic change have an impact on several fields, such as environment, workforce, and resources. In this chapter, we focus on the workforce.

An important part of the people in our companies are non-digital natives that are slowly being replaced by newcomers born in the age of smartphones and the internet. I say slowly because the evolution of employment in the steel industry has seen in Europe a dramatic decrease in the last 50 years. Nowadays, there are just 327.000 direct jobs in the sector.[1] In this context, it can be assumed that the turnover is low and consequently the ageing is high. According to the data, the challenges are mainly in 2 areas: hiring and learning and development.

First, hire the right people according to our needs in a VUCA world (Volatility, Uncertainty, Complexity and Ambiguity) where the candidates depending on their age may be non-digital natives. If we look at unexperienced candidates, we need to be aware of the formal training that they are currently receiving from the education system (VET or University) and to what extent this education matches with the company's needs. The talent market is a global one now. So, it is necessary to share our opportunities globally. We have to raise the internal awareness of the importance of the Hiring Function in the Steel Industry. The Quality of the Hiring Function is possible throughout robust recruiting processes. Standardization decreases ambiguity, guesswork, and guarantees quality. We need to work with the necessary digital tools. It is about new recruitment versus old-fashioned recruitment processes. Linked to the hiring process, we have to take advantage of social networks to share our Employee Value Proposition, which is related to young people's aspirations towards their jobs.

As regards learning and development, as a starting point, we need to explain clearly to the newcomers what we expect from them. Companies have to develop the skills according to the identified gaps. Every process that we define to assess the performance of the employees according to the identified skills needs has to be done at the right cost considering the budget availability. The development must be done with the best available trainers to guarantee quality. The best trainers of internal talents are normally in-house. Working with the necessary digital tools is another necessity and training and digitalization go hand in hand.

In what follows, I focus on the hiring process itself and the main challenges to be faced by the companies to success in this important field. Second, I focus on the importance of quality and what does that mean in this context. Thereafter, we highlight the learning and development as another priority to take into account.

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[1] *Source* https://ec.europa.eu/growth/sectors/raw-materials/related-industries/metal-industries/steel-sector-careers_en.

2 Hiring: Hire the Right People

"You can train a turkey to climb a tree. But I'd rather hire a squirrel." This saying is true in a world more or less stable. Due to an increased speed of new forms of digitization, there is an evolutionary change in the world of work. As a result, the demands for highly qualified professionals are rising. The question is, how do we find the right candidates that are already sufficiently trained to face our needs in the steel industry?

The current industrial processes and the technology applicable in the steel industry are in a permanent evolution. The training programs formally designed in modern educational centres simply cannot keep up with the speed of this evolution. So, if we cannot meet all our needs with non-experienced professionals, we have to look for candidates currently working in the industry. Considering the demographic changes and digitalization, qualified professionals in the industry are scarce, especially in some departments such as maintenance or engineering. If we look at the market, we could find out that semi-qualified workers need to refresh their knowledge to meet our needs.

Apparently, we could believe that because of the non-digital native issue, this reskilling and upskilling is a difficult job. However, our experience reveals that employees are shifting their perception of reskilling/upskilling from it being a valued opportunity to being an essential step in remaining employable or even to find internal development paths in the current company. Moreover, if we look at the increase in the share of the population using internet it is very clear that in Europe we do not have to be afraid of considering reskilling, especially in digitalization, as a real opportunity that we have to take. In our experience, the employees expect the organization to teach them the new skills that are going to be needed. Thus, it is a Company's responsibility to establish the way to assess the performance and the development needs.

3 Educational Centres (VET / Universities)

The companies are eager to establish partnership agreements with VET institutions/Universities to collaborate in the training of the students consistently with current industrial needs. In turn, the companies are open to help educational institutions to develop the training programs in order to align them with business needs. There is a clear opportunity for improvement in the gap between the current educational programs and the professional functions to be covered. Committed production managers in our company highlight that universities and VET centres are missing opportunities by not working hand in hand with companies, taking advantage of their production lines as actual testing laboratories to put in practise their theoretical lessons.

Universities and VET institutions are full of professionals that when focused on companies needs can do a very good job. Their capacity to gather the concepts and transform them into methodologies and training processes is something really appreciated in the industry. The rhythm in the companies makes it almost impossible to take time to design "how" to develop people´s skills. This is where the educational centres can add more value. The mismatch between formal education and companies' necessities is nothing new. What is probably new is the growing distance between the schools and the companies, because of the speed of digitalization.

There are very important initiatives to address this issue. The European institutions are perfectly aware of this opportunity and consequently, we can see strong programs related to this such as the ESSA project (as a principal focus for this volume—see Chaps. 1 and 2 for more information on the project).

4 Searching for the Candidates

If there is a common scarce resource nowadays, it is time. This is not any different in "People Departments" in any industry, steel sector included. That is why it is normal to think that when we are talking about hiring, we have an important need to do it fast, today better than tomorrow. The pressure that the line managers put on the recruiters is proportional to the speed at which the business is moving. In those circumstances, it is easy to believe that any shortcut can be welcome, but… it does not work. When we are dealing with such an important task, hiring, HR partners must make the supervisors understand the necessity to act in due time, not before.

One typical temptation is to hire in the local labour markets. Depending on the function we are aiming to cover, it can work but in a more and more globalized context, those offering posts and seeking talent might open their minds to candidates located further afield. Searches over greater distances are possible today and much easier than some years ago, when it was much more difficult to find relevant information, and job opportunities were traditionally shared across paper media, e.g. newspapers.

There are many opportunities to explore the internet and the candidates are now more open to work in a different geographical area if the project is worth taking (depending on the culture). Companies need to open their search channels to these digital environments either by learning themselves how to do it or by means of third parties. A recommendation for HR Departments could be to manage these strategic tasks internally if they can. The hiring function is one of the most important ones in our HR Departments, so it makes sense to drive it with internal resources. There are also different ways to do it according to local culture.

The more we enlarge the pool of candidates when we start the hiring process, the more likely will be the success of finding the perfect candidate. It will be more feasible to find a better candidate if we start from a pool of 1000 than if we have to count on just 10 of them in the first stages of the recruitment process. When we share these thoughts with our recruiters, they consider this as something just aspirational, especially in certain geographical areas where mobility is not an option. We need to have our minds open to embrace candidates from unexpectedly far away cities. Young people are moving for different reasons than previous generations and mainly for the sake of the project or the purpose more than for pure geographical matters.

However, there are many barriers to the mobility of people: language, local policies, and economic reasons for instance. Some of them are manageable some others are more challenging. But what is clear is that the world is becoming more and more connected and even now that we have just suffered heavy restrictions because of Covid-19 we can foresee that globalization is not going to stop because of mobility issues. The conclusion then is that globalization can be an opportunity.

5 Quality First

When talking about hiring, excellence should be the standard. The costs of hiring are huge and the costs of bad hiring are even larger. It is not acceptable to hire fast because the business is in a need to cover a position quickly. The HR people must feel comfortable challenging their counterparts if for any reason the priorities are not clear enough for them. In addition, it is not acceptable to face a hiring process without a robust methodology behind it. Some managers used to believe that they were the best recruiters because they had a very good gut feeling, and they trusted their instinct. Obviously, this is a misconception.

We need to consider many things before we face a hiring process. It is fair to know that it takes time. And it is one of the most important decisions in a business context comparable to the decision process of buying an asset of 500.000 € (to compare apples to apples 500.000 € is the investment required when we hire someone who will stay 20 years in the company at a linear gross yearly salary of 25.000 €). The costs of hiring are high; however, they are only the tip of the iceberg, compared with the costs of hiring badly.

Quality is also associated with standardization. It is not fair to treat people differently in a different department or site within the same company. The same is applicable to the recruiting function. That means that the hiring process needs a robust design and better if it is shared throughout the business. To do so it is necessary to involve the right people, namely the future users of the design/system. Adopting agile ways of working implies taking into account the opinions and suggestions of final users (normally the Human Resources professionals) to build the process itself. It will give them a higher sense of ownership and will provide valuable input to the final design.

Cultural change is on top of the aspects that need to be considered when we plan an upgrading of our hiring process. The most perfect process with the perfect training and communication plan, supported by the best tools in the market, can derail if we naively believe that people with different backgrounds, local business needs or different cultural roots will embrace it spontaneously. It is not possible to standardize any process without digitally supported sub-processes. The more data we manage, the stronger should be the digital system that is behind it. It is not only the candidate´s information but also the different stages of the process, and the people that are participating in different moments. This generates more and more data that needs to be available. If we add information to the hiring process, that information must be accessible in the smartest possible way.

In any hiring process, we need to start defining who has to approve it; then, we must follow up with the internal agreement with the line manager regarding what exactly is the request. Once these steps are clear we must first search the market with a clear enough job posting in as many channels as possible. The idea is to build the biggest possible pool of candidates to increase the possibility of finding the best one. The screening process and data generated need digitalization, otherwise it will be impossible to manage. Once we have the shortlist of candidates, the documents generated in the interview phase must be shared in a single storage place available to all the stakeholders. Obviously, this process is a digital one. The final decision-making processes and every support document will be digitally shared, as well as the welcome and induction process.

The recruitment process does not finish once the candidate is on board. The first day of the newcomer's employment is the moment when we are going to check how good we have been in the hiring process. It is possible to measure the unexpected turnover, which is one of the key performance indicators in the recruiting function. If we do not measure what we do in HR Departments, we will not be taken seriously.

6 New Recruitment Processes Versus Old Recruitment Processes

Not many years ago, you could find the following characteristics related to the hiring function:

The process was based on paper (curricula stored in paper in a file cabinet), part of the recruitment process was outsourced (or it all if the company was not big enough), and access to recruitment portals was done outside the company's systems. It was also possible that the hiring request had no specific job description behind it. Regarding the role of Hiring Managers, they could share with the recruiter just a vague idea about their expectancies and not be challenged by the HR Department. Regarding the candidates, most of them were local, thus very little mobility.

The interviewers had no specific guidelines about the interview itself, mainly depending upon their experience and the decisions were taken by one or a maximum of two people. The consequence of this could be a high (not wished) turnover. At the end of the day, the results of these practices were uncertain. Nowadays the best practices in modern companies are based on these new principles: A hiring request with an approval workflow (digitally supported). The existence of the Job Description/Job Profile at the beginning of the hiring process once it has been approved. This Job Description has to be reviewed through a formal contact with the Hiring Manager to fine-tune the search. The publication of the offer internally and externally

(Corporate WEB, Job Boards…) is the next step. The fact that we offer internally every job opportunity is crucial to improve internal talent development and internal opportunities. The screening of candidates in the internal database plus candidates from Job Boards is an important part of the process.

Apart from the interviewers' point of view, it is more than recommendable to count on some surveys (cognitive, values, behavioural and emotional intelligence) to generate data. These surveys will be a powerful tool to compare objectively the different profiles. In the interview, it is necessary to check the competences identified in the profile. All of this will take us to a more robust decision based on different criteria. Last but not least, special relevance has the welcome and induction of the new professional. All these process requirements are possible if HR professionals are granted digital support. There are many solutions in the market to perform the hiring process in the companies. Depending upon the available resources, the systems have a different level of integration, but it is always necessary to do this in a digital way.

When it comes to the hiring request, it is necessary to have a clear idea from the beginning. We have to make the approval process easy and agile. It will be necessary to have the whole database of our people integrated with the hiring process platform in order to make it as smooth as possible. The job description with the competences associated to that function should be available electronically to make a smooth hiring process. Not doing it this way will mean we have to define the job every time we need to hire and this delays hiring.

When we talk about job description, we are not thinking of "rocket science". We need to know "briefly" the mission of the position/function, the main magnitudes associated, the environment of the position, who this professional is going to interact with, the competences associated (just 10 to 15 competences) and of course the accountabilities and educational/experience background requested. The competences in the job description are the base for preparing the interview. We need to explore the candidate´s expertise based on the competences that are relevant. The dialogue with the potential newcomer is about the facts that justify that the candidate has the necessary competences.

If the job description is good enough, we would have done most of the designing part of the hiring process. Otherwise, we will have to fine-tune it with our internal customers to gather the information missing to know exactly what skills we are looking for. The involvement of the hiring manager from the beginning and digital documentation of the briefing about her/his expectancies will save time in the future and will guarantee to do it well at the first trial. To have this conversation as a standard is not a "nice to have" part of our hiring process. HR professionals do not have 100% of the information needed to do the right recruiting. When the hiring manager is aware of the importance of this part, he/she becomes our best ally in this crucial part of our job.

Until this moment, we have not published any offer externally. Each of the previous steps require a robust digital system. All our recruiters or managers involved in the hiring will need to be experts enough to participate without no major headache. Is it possible? It has to be! There is a cultural aspect that needs to be managed.

Moreover, it is necessary to know that this process will be applied for non-specialized professionals and it is necessary to make it accessible.

Talking about the next steps, once we have a very clear idea of what type of professional we are looking for, we need to make it as visible as possible within the organization and outside. It is important not to forget the internal offer: to offer internally first, or simultaneously, all our hiring opportunities is not only good practice but a source of good news many times. It is always important to take into account that the necessity rises when it is urgent. Therefore, the pressure on the recruiters and the push of the hiring managers will be our business as usual. This is not obviously a good practice but it is a matter of fact. A way to avoid this is to include in the Strategic reflection a special chapter related to talent needs. It could be deployed at the most detailed department level and we could plan the talent hiring in advance. The more automated the next steps are, the faster recruitment goes, and the easier we will provide the business with the much-desired candidate.

The job offer should come from a good job description and will reflect what the candidate needs to know about us and mainly the tasks to be done once he/she joins the company. It is not so unusual to see nowadays people that have no clear idea about what the company wants them to do. It is a basic, not only for recruiting but also for development. If we cannot have the job description as the reference, we will never know how to assess the performance of our people and what direction has to be taken to provide development actions.

7 Taking Advantage of the Social Networks to Share Our Employee Value Proposition

Companies are more and more transparent, not only because of the fast way to share information but because of the possibilities offered by the World Wide Web to make them closer to customers or candidates. Facebook, LinkedIn, Instagram, and company portals are normally sites where the main messages have to be shared. Candidates can find out if a company matches with their expectations according to what the company shares about itself on social networks. Good candidates do the homework in advance and study what the company can offer before they formalize their application. The talent is having the opportunity to decide what a company can offer and it is good for everybody.

The company institutional page has to be updated and the follow up of the impact on the market is a must in any communication department. The employee value proposition or even the employer value proposition are powerful tools to develop the appeal of a company. The messages have to be easy to understand and necessarily close to the actual reality. The word of mouth is still alive but in a different channel. There are many possibilities to let society know who we are and recently born functions like Community Manager make it possible. It is not a one-shot deal but a daily activity that has to be integrated as business as usual.

8 Learning and Development

As stated, the ending and starting point of the recruiting process is the first day of employment. It is a must to share with the newly hired workers what the company wants them to do and what they are paid for. This is as simple or as complicated as to have a good job description, which has to be public and easily accessible to the professional but also to everybody else. And this document is not an isolated one. The job description has several links with other parts of the cycle of people's life: recruiting, development, performance, talent and succession. So, it is clear that either it is shared with the same and single point of access or the whole people architecture would not work.

None evolving jobs are a thing of the past. It is necessary to close the skills gaps assuming that they will exist sooner or later. In our VUCA World, the jobs can change so they must be updated. A number of people need to have access to the job description and they need to have the possibility to enrich it collaboratively. Of course, the approval workflows have to be taken into account but it must be open enough to always have a fresh version adapted to the reality. With the job description as the starting point it is necessary to establish a routine of gap analysis between the competences identified and the professional performance. This analysis must be paperless. The system has to work for the supervisors not the other way around. If supervisors have easy access and intuitive tools they will use them.

The tool needs to have all the information at the same moment of the assessment. The supervisor and the professional need all the information available while they hold their assessment interview and discuss about the competences and the grade to which that competence is developed. Once we have identified the development needs, the next step is to design the development plan. Learning is traditionally associated with classroom training activities. In our experience, those types of development actions are less effective. On the job experiences or involvement in projects is by far the main source of development. Coaching and mentoring actions would be the next in order of importance.

We not only rely on the classic learning in a classroom. In our experience, people integrate the learnings better if they do it on the job. If we go for job experiences it is not necessary to be very sophisticated, a simple multiskilling matrix can be a very good tool to guarantee the development of our people and a way to reach our business needs. The day-to-day business requests professionals to be able to work in different roles. A multiskilled team could work smoothly in situations of absenteeism or people dedicated to different projects. What supervisors want is to have the flexibility to arrange the shift easily with the people that they have on board. Programmes such as excel are not the solution, we need tools connected with our previously defined job descriptions to have the possibility to monitor in real-time how our inventory of talent is aligning with the multiskilling matrix.

Coaching has moreover, to be a tool to be spread. There is no better coaching session than in person. Having said this now we know that it is also possible to save time and money by doing it remotely. We could have the best coaches if we are brave enough to start doing it in front of our screens. And the possibilities to explore aggregated information coming from a major database of coaches will provide better raw material to take decisions in development areas. Where are the best available trainers? They are normally in-house. The problem is that our people have the knowledge but they are not the best trainers because of the lack of a "train the trainers" methodology. In a nutshell, we have the best trainers with non-confirmed training skills.

The natural and fast temptation is to outsource this important activity. It means an important investment that has no return for the simple reason that the expertise as trainers is not developed in-house. It can be another interesting action to teach our experts on the methodology of training. That is actually a profitable business. It is not only that we save money in the long term but also an interesting consequence for the development opportunity that we provide to our people, just by showing others how good they are in their respective responsibilities.

And this part is not very digital related, but the opposite. People are starting to miss the traditional training where it was possible to socialize, network and learn with more presence. It is always possible to combine remote training and take advantage of digital communications to create blended programs where part of the audience is in one room while others are split in different locations. Virtual training, synchronous or asynchronous training activities, self-paced development actions, this is becoming more and more the trend in the digitalization of the training activities. It is important to find the right approach and keep face-to-face training when necessary. Some benefits of classic training are difficult to provide with digitalization. It is important then to decide what type of training is good depending upon the development objectives.

Without any doubt, our recent experience with the Covid-19 pandemic has brought some beneficial news. We have learnt to work remotely in an incredibly short period of time. At the same time, we see that we can improve productivity by reducing face-to-face meetings. There are other positive side effects like the possibility to democratize development activities like coaching by doing it remotely. The possibility to launch synchronous or asynchronous training programs for a bigger number of attendees by doing it with social distance (teams, zoom….) is another unexpected positive result. Some of these opportunities need development.

Remote working needs a long-term policy to make it possible even after pandemic times. It has been confirmed that it is good and positive for companies and professionals, so it is worth it to dedicate time to set the principles. With a special focus on digital skills and digital resources, it is necessary to define the polices accordingly (kpi´s, meetings, collaborative work). It is necessary to provide our people with the necessary tools to work in this new context where not everybody is under the same ceiling.

There is one risk: the inflation of non-productive remote meetings. The fact that it is possible to make them easier than ever means that it is necessary to think twice before inviting someone to our meetings. It is like a natural evolution from the analogic way of doing things to the digital one. It was possible before but maybe the pandemic has forced companies to do it in an agile way. What started as a temporary solution is becoming a long-term one. It is incredible the time we are saving by doing things differently. A virtual coach session allows the coach and the coachee to be working in a different task until the very last minute before the session. Just because of that, it is worth it.

A side effect has to be taken into account: The disengagement sensation that can affect remote workers might eventually appear either in a coaching activity or in remote training. Thus, it is necessary to train the coach and the trainer in techniques to keep the people engaged. It is no longer convenient using boring powerpoint presentations with the trainer reading an impossible to see slide with plenty of small characters. Presenting with passion is now more necessary than ever.

9 Conclusion

In this chapter, I have reflected on my experience of the recruitment process within a major steel company and the challenges and opportunities brought by an increasingly digitized human resources process, and a changing steel industry. The ESSA project flags up the latter challenges in terms of skill needs and wider developments of digitalization and decarbonization: the twin challenges referenced often in this volume. It is important that steel companies respond effectively to recruit and train the best talent—we know that the industry struggles to recruit young people because the industry image is poor—and utilize all new digital recruitment developments to good effect.

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The Cold Rolling Industry: Demographic Changes and Further Challenges—Impacts on the Workforce and Current Status of the KaWaGi Project

Martin Kunkel and Nicole Rudolf

1 Introduction: The Cold Rolling Industry in Germany and Europe

The cold rolling industry is a steel manufacturing industry and it has developed into an innovative and modern supplier industry over the past decades. It is primarily characterised by small and medium-sized companies (SMEs) especially in Germany (European Commission 2020), but also in Europe and they are mainly family-owned. *The Fachvereinigung Kaltwalzwerke e.V.*, the German Cold Rolled Narrow Steel Strip Association, and the CIELFFA, the European Federation of the National Associations of Cold Rolled Narrow Steel Strip Producers and Companies, comprises SMEs as three quarters of its membership.[1] The cold rolling industry is of enormous importance for the automotive industry, for mechanical engineering and for general metal processing. The automotive and automotive supply industry alone accounts for more than half of the shipping volume of the member plants of the Fachvereinigung Kaltwalzwerke e.V., followed by general metal processing with a quarter of the total demand for cold-rolled strip steel. About 15% of the production volume flows into mechanical engineering and the electrical industry.[2]

[1] Own calculations of the Fachvereinigung Kaltwalzwerke e.V. based on membership numbers and structure.

[2] Own calculations of the Fachvereinigung Kaltwalzwerke e.V., .

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Cold strip or cold-rolled steel strip is a flat product that has undergone a cross-section reduction of at least 25% by cold rolling and is wound up into a roll (coil). It has a significantly higher stability than untreated steel and enables the production of perfectly fitting precision parts. As a semi-finished product, highly specialised cold rolled strip is an important starting product for a wide range of processing options in the above-mentioned customer sectors. It is used in cars, for example, in seat rails, windshield wipers and as parts in the engine and transmission. Cold strip is also used in construction and furniture fittings, as hinges and as running rails in the construction and furniture industry, to name just a few further possible applications.

A look at the delivery volume of the member plants of the Fachvereinigung Kaltwalzwerke e.V. and the CIELFFA shows healthy growth over the past years. The shipment volume recovered in the years following the steel crisis in 2009, which meant a dramatic drop in demand for the entire steel industry and amounted to around 2.13 million tons for all CIELFFA members in the year 2018. Only the year of crisis in the automotive industry in 2019 and the economic slump in 2020 due to the pandemic led to a drop in the shipment volume for cold rolling mills in 2020 by around 13.5% in 2020 compared to the previous year.[3] With their global orientation and international competitiveness, the cold rolling industry generates a stable export volume, which developed for German mills in the past years with an almost constant share of around 30 to 35% in proportion to the total shipment.[4]

In the following, we first outline the cold rolling industry with its special position in the value chain as well as the challenges it is facing today and in future. We hereby describe the effects of digitisation and demographic changes in cold rolling mills. Secondly, we present the project KaWaGi which has been launched as a response to these challenges. Here we describe some exemplary project results of the age structure and stress analyses, followed by an overview and outlook of possible personnel development projects.

2 Challenges in a Modern Supplying Industry

It is to mention that the cold rolling industry as an independent supply industry has a sandwich position in the market. Especially the automotive sector has very powerful customers with its OEMs (Original Equipment Manufacturer) on the one hand. On the other hand, cold rolling companies buy their raw material mostly from large steel producers. For the predominantly independent and medium-sized companies in the cold rolling industry, this position is often associated with difficulties in asserting their own interests, whether in price negotiations or with customer requirements.

[3] Own delivery statistics of CIELFFA.

[4] Own delivery statistics of Fachvereinigung Kaltwalzwerke e.V.

In addition to this position and the resulting difficulties the cold rolling industry is currently confronted with two problems or challenges[5]:

- The demographic change in the workforce means that the competitiveness of companies must be secured with older employees. Important fields of action are the age-appropriate design of work processes in order to maintain employability and competitiveness.
- Technological development such as Industry 4.0 leads to changes in forms of work and requires new competitive strategies and new customer–supplier relationships. This makes targeted qualification measures necessary, for example.

The challenge for companies is to use the development potential of digitisation and to implement a health-promoting work design. The aim from the cold rolling perspective is to promote the ability of employees to work and to ensure the competitiveness of the cold rolling industry in the face of demographic change.

The cold rolling industry as a supplying industry depends above all on innovative product development and production without friction losses in order to survive on the market. New developments and trends on the market require constant adaptation of the products to market requirements. Here the transformation to electric power trains in the automotive sector for example forces cold rolling mills to adapt products and to develop new applications.

3 The Status Quo in Cold Rolling Mills and the Need for Action

Cold-rolling companies show highly demanding working conditions. Especially in production, working conditions are extremely demanding, physically and cognitively, due to continuous shift systems and the complexity of the production processes. A large part of the employees work in alternating and night shifts as well as in weekend work. At the same time, the industry is characterised by a high proportion of older employees.[6] The demographic change is also and above all evident in the steel industry and steel processing industry (Hans-Böckler-Stiftung 2007).[7] High-quality and innovative products as well as the smooth running of the underlying

[5] Cf. Fachvereinigung Kaltwalzwerke e.V., BIT e.V.: Projektskizze – Die Herausforderungen des demografischen Wandels in der Kaltwalzindustrie gestalten innovative Unternehmen und gesunde Beschäftigte gemeinsam, p.3 https://www.fv-kaltwalzwerke.de/index.php/das-produkt-kaltband.

[6] The proportion of the age group 50 plus is disproportionately high. In two cold rolling member companies, examined as examples, the average age is between 48 and 50 years. The share of those in the age of over 50 is between 57 and 59 percent.

Cf. BIT e.V.: Intermediate results of analysis of exemplary age structures from cold rolling mills, KaWaGi-project, Presentation and Excel-File, 06.05.2021, 30.05.2021.

[7] Cf. BIT e.V.: Den demografischen Wandel in der Eisen- und Stahlindustrie gestalten -– eine Handlungshilfe zur alter(n)sgerechten Arbeitsgestaltung, p.13; Cf. Hans-Böckler-Stiftung (2007): Die Eisen- und Stahlindustrie im demographischen Wandel, Projektbericht, p. 14 et seqq.

processes and services are in turn dependent on qualified employees. Technological developments such as ongoing digitisation processes are leading to a change in forms of work and workloads—causing an increase in the requirements and qualifications of employees.[8]

Against the background of demographic change, the change in work design and the necessary adjustment and expansion of the qualification level of the workforce is under pressure from several points of view[9]:

– The proportion of company top performers is increasingly focused on a growing proportion of older employees in cold rolling mills.
– The participation rate of aging employees in inhouse-company training tends to fall from the fifth decade of life.
– The health burdens in continuous shift systems affect, above all, an aging workforce.
– The comparatively low attractiveness of the industry (the steel industry in general and the cold rolling industry in particular) for young professionals exacerbates the personnel problems in the industry. The challenge of recruiting enough qualified junior staff is made even more acute by the fact that the cold rolling industry is not well known and that smaller cold rolling companies in particular lack professional recruitment strategies.

The challenge for the cold rolling industry is above all to secure the employability and the innovative potential of their aging workforces by personnel development measures which should also focus on semi-skilled and unskilled workers as well as on those with disabilities. In this way, the industrial jobs in this sector are to be preserved in the long term and the locations of the cold rolling mills are to be strengthened as industrial locations. In order to master these challenges the project KaWaGi which is described in the following has been launched. It uses work-scientific knowledge and instruments that have been tried and tested in practice.

4 Project KaWaGi in Cold Rolling Mills

The project KaWaGi[10] is carried out in cooperation with the Vocational Research and Consulting Institute BIT e.V., Germany. The project duration was from April 2019 to September 2022. It is funded by the German Federal Ministry of Labour and Social Affairs and the European Social Fund. Beside several foundries, five German cold rolling mills have been participating in the project. In these cold rolling mills, the age

[8] Cf. Fachvereinigung Kaltwalzwerke e.V., BIT e.V.: Projektskizze – Die Herausforderungen des demografischen Wandels in der Kaltwalzindustrie gestalten innovative Unternehmen und gesunde Beschäftigte gemeinsam, p.4, https://www.fv-kaltwalzwerke.de/index.php/das-produkt-kaltband.

[9] Cf. ibid., p.4.

[10] KaWaGi stands for the German title, **Ka**lt**wa**lz- & **Gi**eßereiindustrie **K**ompetent, **a**ttraktiv und **w**ettbewerbsfähig durch **A**rbeits**g**estaltung und **I**nnovation‘.

structure, the need for qualifications and age-sensitive burdens are to be surveyed and evaluated. The aim is to successfully counter the demographic and technological change in the cold rolling and foundry industry. The following instruments form the basis of the project.[11]

(1) An *age structure analysis* shows how the age of the workforce is developing. It also becomes clear which key personnel are leaving, when it is leaving and which personnel policy measures are necessary in order to keep the practical knowledge in the company. In connection with the qualification requirement analysis, it can be identified whether and which core competencies are lost when older employees are leaving the company. Moreover, the analysis can show whether an unforeseen failure of individuals endangers important production and service processes.
(2) The *skill requirements analysis* is used to determine the current status of the skills of the employees on the one hand. On the other hand, the present qualification requirements and future developments are described and evaluated. Above all, this analysis should also specify the requirements caused by the advancing digitisation. In addition to the need for qualification, it also becomes clear which employee potential is not being used. A workload log is intended to provide information on whether and, if so, which job change could make sense.
(3) A *stress analysis* provides information on physical and mental stress which can have health-endangering effects for the workforce.

The project includes the internal target groups, who bring in their experience and their qualification wishes and concerns, such as employees, executives, human resources managers, specialists in occupational health and safety and members of the works council. There are various fields of action and measures which are important, like health- and learning-promoting as well as age-appropriate and participation-oriented work design with appropriate qualification measures. Furthermore, the project intends to establish and promote an appreciative leadership culture and leadership behaviour on the management level. On the worker's level, an increase in operational flexibility and the ability to change jobs should be achieved by developing new key qualifications and competence resources. Hereby the development of aging and health competence on all levels is relevant too. Therefore, the project also focuses on measures of occupational health promotion. Finally, it must be checked and ensured that measures are sustainable.[12]

[11] Cf. Fachvereinigung Kaltwalzwerke e.V., BIT e.V.: Projektskizze – Die Herausforderungen des demografischen Wandels in der Kaltwalzindustrie gestalten innovative Unternehmen und gesunde Beschäftigte gemeinsam, p.5-6; BIT e.V.: Den demografischen Wandel in der Eisen- und Stahlindustrie gestalten -– eine Handlungshilfe zur alter(n)sgerechten Arbeitsgestaltung, p. 9-10 https://www.fv-kaltwalzwerke.de/index.php/das-produkt-kaltband.

[12] Cf. Fachvereinigung Kaltwalzwerke e.V., BIT e.V.: Projektskizze – Die Herausforderungen des demografischen Wandels in der Kaltwalzindustrie gestalten innovative Unternehmen und gesunde Beschäftigte gemeinsam, p. 6-7https://www.fv-kaltwalzwerke.de/index.php/das-produkt-kaltband.

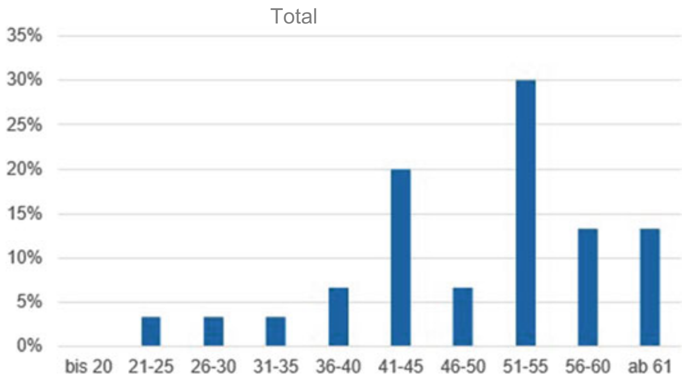

Fig. 1 Total age distribution of all employees in per cent of an exemplary small cold rolling mill

5 Exemplary Age Structures in Cold Rolling Mills

Project results of the *age structure analyses* excellently show the progressing demographic change in cold rolling mills. In the project the age structures of three cold rolling mills have been evaluated, one small company with 30 employees and two medium-sized companies with 61 and 270 employees. The average age in the two examined smaller companies is 48.2 and 49.9 years. The share of those over 50 is 59 or 57% and around one-third of the staff is going to retire in the next five to ten years. This presents a high risk of loss of experience and knowledge and a need for action.

The age structure in the larger cold rolling mill with 270 employees is not as strained as in the other two companies. The share of employees older than 50 is 35% and the average age is 44.3 years.[13]

The following example of one exemplary small cold rolling mill makes the problem of the aging workforce very clear. It shows the age distribution in three selected work shifts in this company. The work area of the company shown below works from Monday to Friday in 15 shifts. The following chart shows the overall age distribution of the exemplary cold rolling company. It has 30 employees, 57% of whom are over 50 years old. The average age amounts to 49.9 years (BIT E.v. 2021a) (Fig. 1).[14]

The following charts show the detailed age distribution in three work shifts (Figs. 2, 3, 4, and 5).

The above-mentioned figures of a small cold rolling mill show a relatively high share of employees older than 50 years. In shift 3 the proportion even amounts to 71%. Due to the aging workforce and the retirement of older people in the near future such a company is working with an extremely tight staffing level. The problem may

[13] Cf. BIT e.V.: Intermediate results of analysis of exemplary age structures from cold rolling mills, KaWaGi-project, Presentation and Excel-File, 06.05.2021, 30.05.2021.

[14] Cf. BIT e.V.: Interim report on the results and activities of the KaWaGi project, 23.02.2022, p.1-2.

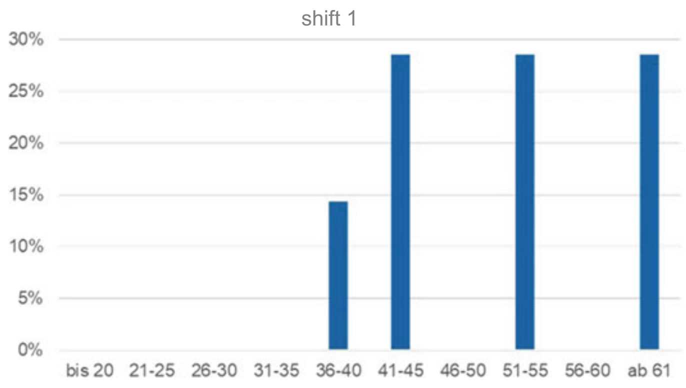

Fig. 2 Age distribution in shift 1

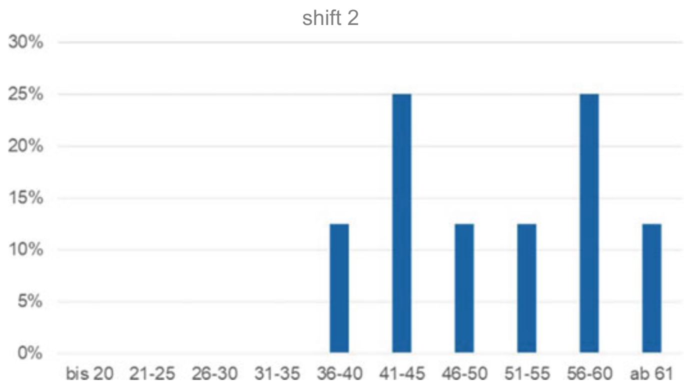

Fig. 3 Age distribution in shift 2

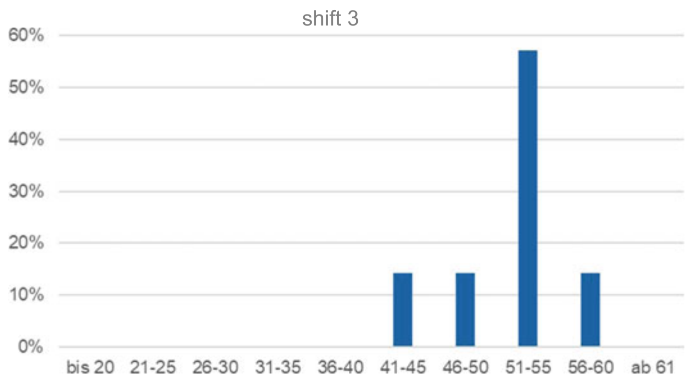

Fig. 4 Age distribution in shift 3

	Shift 1	Shift 2	Shift 3	Total
Proportion of employees older than 50 years	57%	50%	71%	57%
Amount of employees	7	8	7	30
Average age in years	51.6	51.9	51.8	49.9

Fig. 5 Age distribution in three selected work shifts of small cold rolling mill

be compounded as it becomes increasingly difficult to recruit suitable workers. The age structure analysis is a very important instrument and informing fields of action for the personnel planning and development in the company, especially against the background of the demographic change.[15] Cold rolling mills get a comprehensive overview of the composition of their workforce in terms of age. The analysis enables indications of employment risks, possibly also in connection with working days lost due to illness.

6 Relatively High Stress Levels for Older Employees

If employees do the same job for many years, the result is age- and work-related wear and tear. In some examined companies this aspect leads to double-digit sick leave rates, especially in the case of age-centric workforces and due to long-term sickness (BIT E.v. 2021a).[16] In addition, stressors from the working environment (e.g. noise, heat, high temperatures in summer, insufficient lighting, smoke and dust) have a demanding effect. For this reason, companies participating in the KaWaGi project are supported within the project in setting up or optimising an inhouse occupational rehabilitation management[17] or if necessary, in developing and implementing sustainable integration measures for employees who have been ill for longer than 6 weeks. The aim is to offer support at an early stage to people who are already ill and to reintegrate them efficiently into working processes. This is an important contribution to remain competitive also with an older getting workforce.

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[15] BIT e.V.: Den demografischen Wandel in der Eisen- und Stahlindustrie gestalten -– eine Handlungshilfe zur alter(n)sgerechten Arbeitsgestaltung, p. 7, 9.

[16] Cf. BIT e.V., Interim report on the results and activities of the KaWaGi project, 23.02.2022, p.2.

[17] The inhouse occupational rehabilitation management, called BEM – Betriebliches Eingliederungsmanagement in German is legally anchored in Sect. 167 Paragraph 2 of the Ninth Book of the Social Code (SGB IX) in Germany. It stipulates that an employer must offer a BEM to all employees who are uninterruptedly or repeatedly unable to work for more than six weeks within a year.

Cf. Federal Ministry of Labour and Social Affairs, https://www.bmas.de/DE/Arbeit/Arbeitsschutz/Gesundheit-am-Arbeitsplatz/betriebliches-eingliederungsmanagement.html.

Negative aspects of the management culture such as insufficient employee participation in changes at their own workplace, insufficient feedback on the quality of the work ("nothing said is praise enough") or frequent time pressure lead to a feeling of lack of appreciation. Here, too, the KaWaGi project comes into play by providing targeted training for managers and by drawing attention to any leadership deficits. Moreover, tight staffing levels combined with high levels of sick leave increase workload and time pressure. As a result, there is less time for induction, training and qualification of the employees. This in turn has an impact on the quality of the work results and can lead to lower availability of machines and systems (through more time required for troubleshooting e.g.).

7 Holistic Risk and Stress Assessment in Cold Rolling Mill

With the holistic risk and stress assessment, deficits in the working processes that lead to high physical or mental stress on employees and managers become visible. The physical stresses are associated with the individual activities in a cold rolling mill and they are categorised in three risk classes in a workplace register (see figure below). The analysis has been carried out for an exemplary cold rolling mill (BIT E.v. 2021a).[18]

The following risk classes with respective colours and abbreviations are used in the model.

■risk class 1; no overstress/overstress is unlikely

■risk class 2; possible/probable overstress

■risk class 3; overstress is very likely

X no stress in this activity

Assignment to one of the risk classes follows the use of specific analysis tools that are appropriate for the stress under review. Different physical and mental stress categories require different instruments with often unique scales that are used and afterwards translated into the risk classes.

For categories like for example lifting, holding, carrying and moving of loads the amount of the load and the duration of the handling of the load are evaluated. This is done by observations and measurements that lead to an assessment of the stress and the corresponding risk class while other categories like different mental stressors additionally need interviews or questionnaires to capture the amount of stress associated with a work activity and translate the results into a risk class. These results are afterwards recorded in a holistic workplace register.

The following table is an exemplary part of a workplace register where only the stress levels for different physical activities at different facilities are shown. The complete register would show all the physical and mental stressors recorded for every work activity (Fig. 6).

[18] Cf. BIT e.V., Interim report on the results and activities of the KaWaGi project, 23.02.2022.

	furnace	shear	edge profiling	finishing	stacker crane
posture / movement					
lifting, holding, carrying and moving	2	3	2	2	2
pulling and pushing	x	x	x	x	x
manual work processes	x	x	x	x	x
exercising full body strength	2	x	2	x	x
whole body vibrations	x	x	x	x	x
hand/arm vibrations	x	x	x	x	x
forced postures: back strain	x	2	2	2	2
forced postures: shoulder and upper arm loads	x	2	2	1	x
forced postures: knee and leg loads	x	2	2	2	x
locomotion by walking, climbing, crawling	3	x	x	2	x
locomotion when driving with muscle power	x	x	x	x	x
chronological sequence of load types	1	1	1	1	1
load changes within the shift	1	1	1	1	1

Fig. 6 Workplace register in an exemplary cold rolling mill

The figure shows that all five work activities offer enough opportunities for load changes within the shift and a good sequencing of load types. But there are still some high risks associated with operating the furnace or the shear. A high risk from locomotion by walking, climbing and crawling can result from missing opportunities to sit even for a short time during a shift. Operating the shear is associated with high stress due to the manual handling of loads.

8 Results of the Analysis of the Qualification Matrix and from Company Feedback

By evaluating the already existing qualification matrix and by further feedback from the exemplary company, it becomes clear that many activities are semi-skilled activities. Only limited formal qualification is needed for such activities. Employees are often trained on the job while benefiting from the experience collected while executing these activities. This constellation leads to considerable differences between novices and long-term employees in the efficiency and efficacy of execution. Many, especially long-term employees have a wealth of experience due to their many years of work at their workplace. However, the flexibility of these employees, measured by the number of different work activities they can perform, is limited. There are also health-related restrictions of some employees. Overall, the activities are not very conducive to learning and there are hardly any opportunities for development.

In summary, the situation can be described as follows (BIT E.v. 2021a)[19]:

- There is a high average age among employees, especially at the belt furnaces.
- There are some employees with reduced performance and a high level of sick leave.
- There are high individual workloads on several machines and a high physical strain on employees.
- There is further stress caused by the working environment (heat in summer, drafts, dust).
- In general, the work involves little room for manoeuvre and hardly any opportunities for development.
- There is psychological stress (e.g. caused by the lack of participation, the partly low appreciation of work, one-sided feedback on the quality of work).
- Frustration, demotivation and partial resignation of the employees are consequently noticeable.

9 Personnel Development Projects Can Help to Master the Demands of the Future

Working in a three-shift system with high physical and work-related psychological stress and few development opportunities make these jobs less attractive, also for young professionals. However, the companies involved in the project urgently need these younger workers. Regular job rotation can be an approach to reduce one-sided burdens and enabling development careers. In addition, training concepts are developed in the framework of the project that enable new employees to be trained quickly. Personnel development concepts should, initially as a pilot project, reduce one-sided physical strain and lead to flexible use of employees in different activities. It is also being examined to what extent a rotation to related work areas would open up further development opportunities for employees and improve the attractiveness for young specialists and managers. Qualification matrices which are linked to the age structures and tailored to the respective needs of the companies have been developed and adapted within the project. In order to get employees more involved, to appreciate their experience and to promote cooperation on a level playing field with managers, moderated working groups serve to jointly develop and test tailor-made measures to reduce physical stress. Parallel to these activities already described, managers

[19] BIT e.V., Interim report on the results and activities of the KaWaGi project, 23.02.2022.

are supported within the project in reflecting on management deficits perceived by employees and in changing their management behaviour (BIT E.v. 2021a).[20]

Overall, the participating cold rolling mills should learn to master the described requirements themselves in the sense of 'helping people to help themselves'. Internal actors get a holistic view of the interaction of stress and dangers, qualifications and age structures. They gain experience of how stress factors from the work system can be determined and assessed together with employees and managers through questionnaires, interviews and observations. In short: the participating plants are beginning to strengthen their own organisational resilience. The Vocational Research and Consulting Institute BIT e.V. accompanies the plants in this project and process. It qualifies, advises and coaches project employees, managers on different managing levels, the workers' council, specialists for occupational safety, Human Resources managers in the participating cold rolling mills by conducting training courses and workshops on all these aspects (BIT e.V. 2021b).[21]

The described KaWaGi project is a good example how the cold rolling industry is meeting demographic change and the challenges of increasingly demanding working conditions in cold rolling mills. In order to be able to continue to survive in international competition, small and medium-sized companies in particular have to make optimum use of human resources and undertake personnel development measures. Not only does the company benefit from this, but also every single employee, as unused skills and potential are recognised and employee satisfaction is promoted.

References

BIT e.V (2021a) Intermediate results of analysis of exemplary age structures from cold rolling mills. KaWaGi-project, Presentation and Excel-File, 06.05.2021, 30.05.2021

BIT e.V (2021b) Kerstin Pasucha: Organisationale Resilienz: Dient die Gefährdungsbeurteilung psychischer Belastung als Fundament? Ein Konzept zur Selbsthilfe am Beispiel von Kaltwalzwerken und Gießereien, in Stahl + Eisen, No. 3, March 2021, pp 64–65

European Commission (2020) User guide to the SME definition, Brussels

Fachvereinigung Kaltwalzwerke e.V (2023) BIT e.V.: Projektskizze - Die Herausforderungen des demografischen Wandels in der Kaltwalzindustrie gestalten innovative Unternehmen und gesunde Beschäftigte gemeinsam https://www.fv-kaltwalzwerke.de/index.php/das-produkt-kaltband

Hans-Böckler-Stiftung (2007) Die Eisen- und Stahlindustrie im demographischen Wandel. Projektbericht Federal Ministry of Labour and Social Affairs, https://www.bmas.de/DE/Arbeit/Arbeitsschutz/Gesundheit-am-Arbeitsplatz/betriebliches-eingliederungsmanagement.html. 09 May 2022

[20] BIT e.V., Interim report on the results and activities of the KaWaGi project, 23.02.2022.

[21] Cf. BIT e.V., Kerstin Pasucha: Organisationale Resilienz: Dient die Gefährdungsbeurteilung psychischer Belastung als Fundament? Ein Konzept zur Selbsthilfe am Beispiel von Kaltwalzwerken und Gießereien, in Stahl + Eisen, No. 3, March 2021, p. 65.

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Attracting Talents to the Steel Industry

Veit Echterhoff, Peter Schelkle, and Stefan Cassel

1 Introduction

The transformation of the European steel industry is to be led by science, technology and innovation and requires social consensus. To succeed, the industry requires the right people who will drive these changes and ensure their success: the steelworkers of the future. In this decade, the steel industry workforce is undergoing unprecedented demographic change. The age structure in most European steel-producing companies is such that more than 25% of the workforce will leave the industry in the period 2020–2030. To ensure competitiveness attracting talents to the EU steel industry is vital.

In the following, we use the term 'talents' in a broad sense, i.e. we will neither reduce the term to a specific European Qualifications Framework (EQF) level nor age group. Rather, the term describes a group of people usually with high academic attainment that possesses the necessary knowledge, skills or expertise to move any organization forward. Likewise, 'talents' also describes people who have the ability to swiftly acquire new knowledge, skills or expertise if this is required. This definition is oriented by Echterhoff and Schröder (2015) who delivered in their study a corporate-oriented description of the term *talents*. The term refers to a junior manager identified by their company to be promoted within the next two years (by 2025). Usually, these employees are informed of the trajectory program for their personal career and participate in specific development measures.

The following describes at first the challenges for the EU steel industry and secondly workforce labour potential in the EU. For the competitiveness of the

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industry, there is a strong need to attract qualified future employees. Recommendations to attract talents are made against the backdrop of talents' needs and demands, obstacles and success factors.

2 Challenges for the EU Steel Industry

The European steel industry acts in a highly competitive market. The European Steel Technology Platform (ESTEP) describes the vision for the EU steel industry up to 2030 anticipating major changes, many of which will be driven by new scientific and technological developments including digitalization, evolving customer and stakeholder demands, and the industry's response to the ambitious European climate goals leading to new processes and new products (ESTEP 2017).

The ambition of the European steel industry is to become the most advanced steel industry in the world. Having already halved energy usage and CO_2 emissions since the 1960s, the self-conception and mission of the industry is to help the EU to reach its Paris Agreement climate change commitments. With the support of an adequate regulatory framework the aim is to achieve at least 80% of carbon reduction by 2050. This ambition is fully aligned with the EU Green Deal initiative (European Commission 2022). This requires a paradigm shift with regard to the established steel production routes. For the traditional steelmaking route there is, however, no commercially applicable technology currently available to achieve such deep CO_2 reductions. However, promising innovations and demonstration projects aiming to significantly decarbonize steelmaking are under way. Using direct reduction by hydrogen seems a promising approach to reduce CO_2 emissions at a minimum. The way forward will also depend on the further development of supportive and sustainable policy frameworks such as carbon border adjustment mechanism that helps to balance the requirements for deep CO_2 reductions in the European steel industry with global steel trading arrangements.

The mid-to-long-term goal of achieving carbon neutrality is just one source of pressure for EU steel companies. The last two decades were characterized by increasing worldwide steel production capacities that led to growing imports in the EU, which in turn led to overcapacities in the EU steel market. Another source of pressure is the fact that key customers of the steel industry, e.g. the EU automotive industry, are forced to transform their products or business models, which has knock-on effects on the steel sector. Finally, imported raw materials prices for steelmaking have become more volatile in recent years.

The way forward for EU steel companies is ambiguous: due to the high pressure, there is a strong need to reduce costs to remain competitive. Besides the two significant spheres of activity, 'energy transition (costs)' and 'EU legislation', staff costs in the steel industry constitute a significant share of fixed costs compared to some global competitors. It is becoming obvious that the industry will work on reducing fixed costs by permanent rationalizations that will inevitably reduce the total number of workplaces. At the same time, to meet future challenges without ignoring the demographic challenges that the industry is already facing, new highly qualified employees—new talents—have to be recruited.

3 Development of Workforce Potentials in the EU

The European steel industry has seen its workforce decline by 40.000 employees (from ~370.000 to ~330.000) within the last 10 years. (EUROFER 2019). However, due to decreasing fertility rate in the last decades (currently 1.5 in the EU), the age group younger than 45 years will continuously decrease and the share of older people will increase. The organizational demographics within most of the EU steel companies that have been shaped by successive waves of restructuring over the last 30 years, will lead to increasing workforce gaps in the steel industry caused by the great number of employees who will retire in the coming years (European Commission 2021).

A shrinking workforce means losing expertise, which forces the European steel industry into more intense talent attraction efforts. Since the *war for talents* is over—talents have won—the graduates' expectations have to be taken into account more than ever. Losing talents to other industries is a serious threat for steel companies and the aforementioned demographic trends in Europe amplify the threat even more. The analysis of those facts and figures reveals several barriers to the attraction (and retention) of talent, but also sheds light on opportunities upon which this recommendation paper will focus.

4 Needs and Demands of Future Talents

Taking both the scarcity of adequately skilled labour and the strong need for new talents in European companies, including steel companies, into account makes it necessary to focus on the expectations and needs of future talents, and to consider how the steel companies in the EU can meet these expectations and needs. To understand the needs and expectations of new talents, the ESTEP Focus Group 'People' and EUROFER have conducted an EU-wide survey that generated 268 responses from talents already working within steel companies (Echterhoff and Schröeder 2015).

The survey was designed to shed light on the values, ambitions and needs of the survey respondents. The results show that talents prefer individually tailored career development, demand modern company cultures and leadership styles that align with their needs, and value enhanced support in developing managerial competencies. The survey results suggest that to avoid skill shortages in the future, it is essential to proactively respond to talents' needs and expectations and to develop suitable work-life balance models.

Another project, 'Steel Sector Careers' (European Commission 2021) disclosed profound research outcomes concerning the image of steel careers, current skill needs, skills gaps and future skill needs. The project conducted interviews and run questionnaires with 2917 steel stakeholders (i.e. 2000 STEM students on the image of the steel industry, 197 steel industry professionals on current and future skill needs) in 65 steel companies or steel-related institutions across 28 EU member states. The essence of the results is that direct work experience in the steel industry is still key to gain knowledge about the steel industry. Without direct experience outdated perceptions and only little knowledge about the industry is usually predominant. A promising aspect, however, is the fact that a number of respondents have expressed interest in knowing more about it, either through apprenticeships or visits.

5 Obstacles and Success Factors

Looking at the obstacles and success factors for future employee recruitment for the steel industry, it should be differentiated between internal and external factors: some topics can be driven directly by companies; others have a larger, overall societal and political background and thus can only be influenced indirectly.

One of the most important issues in the assessment of success factors and obstacles is the image of the steel industry. Historically, the steel industry has always been associated with a high contribution to air pollution due to carbon dioxide emissions. But gradually, starting with massive efforts to contribute to environmental protection in the last decades of the 20th century, reality has changed. Today, the European steel production is much cleaner thanks to state-of-the-art filter methods. Even the product ‘steel’ has developed into a high-tech product with completely new application possibilities. In particular, this was achieved by investing heavily in research and development, which has also created a large number of attractive and innovative jobs. Unfortunately, these developments in the steel industry towards high-tech products and modern employers have not always been sufficiently communicated. Public perception is generally characterized by a mix of an obsolete old image and a lack of knowledge, which acts as an obstacle to hiring new employees.

Another obstacle is the decreased number of employees in the European steel industry. This has mainly been caused by declining production rates in the EU due to global overproduction. Moreover and unfortunately, industry downturns seem more appropriate to catch the attention of public media.

With a negative public image and an uncertain economic future, the steel industry in the EU does not look like a prospering and attractive place to work to potential future employees even if they have a personal affinity to steelmaking because a secure job and a good economic outlook are important criteria when choosing an employer.

With these obstacles in mind, it is particularly important to highlight the positive opportunities and chances for a career in the European steel industry, to counterbalance and hopefully change negative public perceptions about it. Thus, the steel industry needs to step up its efforts in communication with the public and with potential candidates and to send a clear message: The European steel industry is a high-tech employer with state-of-the-art production facilities, strong research and development departments, and develops sustainable solutions for its customers. For better and more sustainable products in our future world, steel, due to its complete recyclability and versatile properties, is and will remain indispensable.

The European steel industry has a great opportunity to create exciting and innovative jobs and to communicate the upcoming innovative technological developments. The steel sector has much to offer: the production plants are already largely fully automated. At present, significant investments are made to digitize production processes. Digital control, digital tracking and predictive maintenance are just a few examples. The resulting job and development opportunities offer an extremely attractive working environment, especially for IT graduates, who rarely think of the steel industry as a potential employer.

Another starting point for emphasizing the opportunities in the steel industry is the changeover in the blast furnace to the injection of hydrogen and the associated production towards carbon-free steel. This offers a clear opportunity to speak directly to STEM graduates who prefer to work in sustainable 'green' companies. It can also contribute to shed the public image of the steel industry as 'dirty'.

More generally, steel companies need to improve their communication with the target group of potential new talents. To overcome these negative perceptions it is observable that visits and internships of students and other target groups at steel production are a promising approach. Changes in mindsets and heightened interest in the industry can be seen during such visits and visitors are more likely to leave with a much more positive image of the steel industry. Anyway, in that context, it is worth mentioning that the steel industry offers various opportunities e.g. by providing vocational education in several professions leading to individual career paths.

This direct engagement and communication with STEM talents that centres on the use of the production facilities as showcases of innovation is definitely a promising approach to present the opportunities of the steel industry. As an 'internal' success factor, the European steel industry can implement this form of talent engagement on its own.

6 Concluding Recommendations

Attracting talents to the EU steel industry is vital for the future of the industry. Considering the present analysis, recommendations can be made on different levels. Within companies, we see opportunities to turn existing employees into talents through personnel development and to retain existing talents. As the labour market turns more and more into an employee market, in which potential talents are scarce and they can choose their future employers, it is paramount for steel companies to be attractive employers for future talents. This situation has evoked the concept of Employer Value Proposition (EVP). EVP is used for employer branding and is the magnet that attracts job candidates. The direction of employer branding is outside the organization and to attract potential talents.

Company Level

Company culture: The big question is whether the company culture fits the needs and aspirations of talents and potential talents. Hence, attention needs to be paid to company culture. Company culture is a generic term that describes the development and status quo of leadership, decision-making, internal processes, relationships between colleagues and groups, its originated values and attitudes furthermore reflected in terms of corporate social responsibility. It is not easy to obtain an unbiased picture of the existing company culture, although it is crucial to understand contexts and situations. Changing company culture is even more difficult and, if it is to be done, changes need to be implemented carefully and sensibly.

Leadership: The available evidence suggests that talents prefer to assume responsibility, like to be visible within the organization, favour working on projects, and wish to receive constant feedback (Echterhoff and Schröder 2015). To attract and retain talents, the leadership style within a company should accommodate and reflect these aspirations.

Working conditions: Work-life balance and individual health have become more and more important in recent years. Future-oriented forms of work, e.g. mobile work and flexible working time are becoming more and more usual and accepted. Recently, intensive mobile or home working during the corona pandemic was eye-opening for lots of former mobile work critics to see and learn that it can be a way to go for administrative employees without experiencing reduced outcomes. Besides transparent compensation and benefits on the market level, personnel development/learning programs and career opportunities are appreciated when they reward individual performance.

Digital skills: Digital skills are an integral part of almost all job profiles on the shop floor and the production process of steel is high-tech and supported by state-of-the-art technologies that involve big data streams. Besides recruitment strategies for new staff, also up- and reskilling of the existing workforce (e.g. by using the gamification paradigm) should be considered, including identifying talents with a lower formal qualification (non-academics) but high workplace experience.

The regional eco-system approach: Another priority is to re-establish, or reinforce, the attention of steel companies towards local communities. Without being nostalgic, the steel companies should become the employer of choice for local youngsters again. Looking at the growing importance of work-life balance and sustainable transport solutions (commuting at near 0 km), living in the proximity of the workplace will be of great importance in the near future. This, however, implies solving significant environmental and behavioural issues, not only in terms of Carbon emissions. Finally, the concept of "fidelity to the company" and vice versa "fidelity to the workers" should be considered again.

Cooperation with schools/universities: It is promising to build up a network with universities and even schools to have direct access to future talents while raising the corporate image. Through direct contact or through contact via social media, it is possible to attract and engage the target group. This contributes to the reduction of prejudices and can raise awareness, especially when the target group participates in company events or visits production sites.

Sponsoring and external communication: It is well known that the decision where to apply for a job is influenced by family, friends and the peer group of job seekers. As the public perception of the steel industry requires improvement, external communication and sponsorships are important channels to attract attention to steel companies as future workplaces. For example, in recent months many EU steel companies have communicated their approach to and contribution towards carbon-neutral steelmaking. This has already had a big impact on the image of the steel industry that we have not seen for a long time.

Steel Association and Organization Level

Steel-related associations and organizations are important players to support the attractiveness of the industry:

Work on a better image: Steelmaking is on a transformational pathway. Production processes will increasingly decarbonized in accordance with the European climate goals. Furthermore, steel is of infinite recyclability and the basis of various high-tech products such as electric cars and wind turbines that Europe wants to keep producing. Steel associations and organizations are important actors that can play a vital role in improving the public perception of the steel industry.

Addressing policy makers: European youth is influenced by the 'Fridays for future' movement. It is of utmost importance for associations and organizations to engage European and national policy makers to raise awareness that the steel sector can contribute sustainably and ecologically to the European value chain. Policy makers need insights in order to promote the steel industry as a choice for talents.

Working together and build up networks: Associations therefore need to keep in touch with the European steel companies, R&D organizations and other partners to build up networks. Working together can generate new views and ideas that can help to overcome organizational blindness and inertia. Therefore existing networks like the European Steel Skills Alliance (ESSA)[1] or the Skills Alliance for Industrial Symbiosis in the Process Industry (SPIRE-SAIS)[2] and projects (like the previously mentioned Steel Sector Careers project) can be used as a platform to be further extended.

[1] Refer to Chaps. 1 and 2 for a brief overview of the project.

[2] The SPIRE-SAIS alliance will address possible skills shortages in the Energy Intensive Industries while providing EU citizens with the necessary skill sets for future job profiles. The project will address updating of the curricula, qualifications, knowledge and skills that are required to support essential cross-sectoral collaboration and Industrial Symbiosis activities (Processes Planet Research Association 2022).

Sponsoring of students for events: Talents need to get in touch not only with the steelmaking process but also with steelmakers and industry representatives. Engineers from steel companies are usually best placed to attest and explain the attractiveness of steel and the steel industry as they are able to fluently recapitulate the high-speed development of process efficiencies over the last decades or to describe a future hydrogen scenario. Thus, associations can serve as platforms of exchange between students and engineers, bringing together those who are passionate with those who are interested. In that context, it could be worth sponsoring students e.g. by distributing 'wild cards' to participate in steel events free of charge.

References

Echterhoff V, Schröder A (2015) Retaining talents in the European steel industry. ESTEP, Brussels. https://www.estep.eu/assets/Uploads/ESTEP-WG5-Report-TalentSurvey.pdf. Accessed 27 May 2022

ESTEP (2017) Strategic research agenda, ESTEP, https://www.estep.eu/assets/SRA-Update-2017Final.pdf. Accessed 27 May 2022

ESTEP (2020) Attracting talents to the steel industry, ESTEP, Brussels, https://www.estep.eu/assets/Uploads/20200302-attracting-talents-to-the-steel-industry.pdf. Accessed 27 May 2022

ESTEP (2022) ESSA at a Glance. https://www.estep.eu/essa/essa-project/. Accessed 03 June 2022

Eurofer (2019) European steel in figures. Brussels 2019

European Commission (2021) Blueprint for sectoral cooperation on skills: towards an EU strategy addressing the skills needs of the steel sector. European vision on steel-related skills and supporting actions to solve the skills gap today and tomorrow in Europe. Brussels 2021

European Commission (2022) A European green deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Accessed 27 May 2022

Process Planet Research Association (2022) Skills alliance for industrial symbiosis–a cross-sectoral blueprint for a sustainable process industry. https://www.aspire2050.eu/sais. Accessed 03 June 2022

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New Skills Requirements, Training, and Recommendations

Preparing for a Digital Steel Industry: What Challenge for Skills Formation Systems?

Luca Antonazzo, Dean Stroud, and Martin Weinel

1 Introduction

Since the beginning of industrial society, innovation has always been central to industrial revolutions. What is currently considered to be the 4th industrial revolution (also referred to as Industry 4.0) relies on innovations such as ICT and robotics (bridging the 3rd and 4th revolutions), and recent concepts, such as the Internet of Things, Cyber-Physical Systems, Cloud Computing, Big Data and Artificial Intelligence.

Although Industry 4.0 has a core production dimension, it is also a social phenomenon and is changing the way work is organised, along with how goods and services are produced and supplied. While there is perhaps a consensus within politics, industry and academia that these technological and organisational changes have profound implications for the kind of skills, competencies and qualifications that are needed in the future, there is less agreement about what the future of work is going to look like and how jobs are going to be changed. As Martinaitis and colleagues (2021) pointed out, three scenarios have coexisted in the academic literature: deskilling (Braverman 1974), upskilling (Acemoglu 2002; Goldin and Katz 2008) and polarisation scenarios (Goos et al. 2014; Autor 2015). While the first suggests that segmentation, standardisation and automation of work have gradually caused a deskilling of labour across occupations, the second scenario offers a

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much more optimistic view where technological progress results (almost deterministically) in a higher demand for skills and qualified workers (Skill-Biased Technological Change or SBTC). The third scenario maintains a less monotonic relationship between technology and skills, offering evidence that the mid-skills segment is the one most affected by technological substitution, consequently increasing relative opportunities in the low- and high-skills end.

The divergence in the literature highlights how the exact outcomes of these processes are still uncertain and open to investigation. However, it is largely undisputed that as industries adapt to extensive automation and digitalisation, the composition of jobs will gradually change. With polarisation or upskilling being the most likely effect, workers will be required to possess wider and qualitatively different skillsets from what was the case in the past.

In this chapter, we discuss the implications of such processes for the European steel industry and the response of vocational education and training (VET) systems to emerging skill demands. This chapter draws on the findings of the Erasmus+ project 'Blueprint "New Skills Agenda Steel": Industry-driven sustainable European Steel Skills Agenda and Strategy (ESSA)' (please refer to Chaps. 1 and 2 of this volume for an overview of the project) and on the discussion of institutional models and response types previously elaborated in Antonazzo et al. (2021).

The ESSA project had a Europe-wide focus and primary data were generated through semi-structured interviews and questionnaires in five countries (Germany, Italy, Poland, Spain and the United Kingdom). Overall, we collected 60 responses from steel companies' representatives (HR managers, production managers, training centre managers), VET providers, trade union representatives and steel industry experts. The interviews were conducted between April 2020 and March 2021. Due to the Covid-19 pandemic, the interviews were conducted remotely and usually lasted between one and two hours.

In the remainder of this chapter, we first introduce the concept of institutional models and institutional complementarities (Hall and Soskice 2001; Amable 2009), and then we present our findings on emerging skills needs in the ESSA case study countries. Finally, we look at recent reforms introduced in three of the ESSA case study countries (Germany, Italy and the United Kingdom) to respond to skills challenges. In doing so, we aim to draw attention to the fact that to support the steel industry's transition to 4.0, VET policies need not only to address skills gaps but also to consider the interplay between the reforms newly introduced and pre-existing institutions. This interplay can result in a disconnect between policy expectations and outcomes, as we will try to show.

2 Why Do Institutions Matter in VET?

In the social sciences, an institution is understood as 'a set of behaviours patterned according to one or more variously codified and differentially enforced rules' (Burke 2011, p. 321). Within the Varieties of Capitalism (VoC) framework adopted here (Hall and Soskice 2001), institutions are described as ‘a set of rules, formal or informal, that actors generally follow, whether for normative, cognitive, or material reasons’ (Hall and Soskice 2001, p. 9).

Societal institutions are shaped by their historical path. Once considered in their joint combination (this concept is referred to in the literature as ‘institutional complementarity’), institutions are deemed to make up coherent models, which can differ deeply from one another. The idea of institutional complementarity entails that, in such coherent models, the presence of a specific set of institutions in one sphere of the economy can raise the returns from corresponding institutions in other spheres (for instance, consider the relationship between labour market regulation, industrial relations and skills formation).

The concept of institutional complementarity is at the core of VoC. Hall and Soskice distinguish between Liberal Market Economies (LMEs) and Coordinated Market Economies (CMEs). The first, exemplified by countries like the United States and the United Kingdom, is characterised by the primary role of market competition in regulating the relations between firms, and in other spheres of the political economy. This is argued to lead to short-termism in economic strategies, investments seeking high returns and short payback and to be associated with low levels of trust between firms (and between firms and other actors). CMEs, usually exemplified by Germany, are characterised instead by a more pervasive regulation and strategic interaction over economic dynamics. Here, firms are strongly linked with one another through sectoral associations and engage in more strategic forms of interaction with social partners. Opposite to LMEs, the institutional setting of CMEs encourages companies to adopt longer-term strategies and to be less dependent on financial markets and their fluctuations.

From a skills perspective, it is maintained that employment protection and coordinated wage bargaining in CMEs tend to encourage workers to commit to a lifelong career and to develop more specialised skills. In LMEs, instead, the absence of such institutions seems to incentivise workers to invest in more general and portable skills to better cope with the risks of market fluctuations and job loss. In parallel with this, it is argued that companies tend to adapt their business strategies to the pool of skills available to maximise their competitive edge (Estevez-Abe et al. 2001). In this way, while firms located in LME would tend to rely less on technology requiring specialised skills, firms in CMEs would engage more in production that requires skilled labour thanks to its availability.

VoC is a dichotomic framework contrasting LME and CME, which presents its limitations when applied, for instance, to Mediterranean or Eastern European countries. Thus, scholars have worked on widening the research on Comparative Capitalism (CC) by proposing more nuanced typologies. One such typology includes indeed Mediterranean capitalism (Amable 2009), exemplified by Italy and Spain, and described as based on more employment protection and less social protection than CMEs (Amable 2009). The Mediterranean model is deemed to rely on ‘a large set of family-based small firms, cross-participation in firms’ governance and the prominent role of the state in the economy’ (Vallejo-Peña and Giachi 2018, p. 24). Product market competition is considered to be relatively low here, and the workforce to possess limited skills and level of education, which does not allow for the implementation of a high-skills/high-wages industrial strategy (Amable 2009). Overall, this institutional model is deemed to provide scarce incentives for upgrading the skills of the workforce, thus hindering potential pathways for innovation.

3 An Overview of Emerging Skills Needs in the Industry

As other chapters in this volume well illustrate, it is becoming evident that the European steel industry is progressively moving towards Industry 4.0 (Estep 2017) with firms starting to employ (although at a different pace) IoT, sensors and big data analytics to improve energy efficiency and resource management, as well as for quality monitoring and defects detection (Murri et al. 2021). Such developments are confirmed by the interviews we collected from the five case study countries (Germany, Italy, Poland, Spain and the UK). A Head of a company training centre in a German steelwork, for instance, underlined the advantage given by extensive generation, storage and analysis of data to act and improve processes or plan a recurring intervention on machinery based on sensor data and computer simulation.

Such developments are reflected in qualifications requirements and expectations regarding workforce skills. While perhaps not at the forefront of Industry 4.0, expectations concerning future competence and skills requirements resurface repeatedly in steel-sector-specific research (e.g. Evans and Stroud 2016; Stroud and Weinel 2020; EC 2020) as they do in our interviews with steel industry representatives. There is, indeed, an expectation that change is both continuous and accelerating, with consequences for vocational education and training:

> Back in the day, apprentices were referred to as *Ausgelernte* which literally means “someone who has completed his/her learning”. Nowadays, apprentices are referred to as *Ausgebildete* which means ‘someone who has been trained’. The term *ausgelernt* suggests that you are done, finished learning and the rest of your work life is applying what you have learned. Today, an apprenticeship is just your ‘initial qualification’, one that will be added to throughout your working life (HR manager, Germany).

> Technical progress and process automation require employees to learn and improve their qualifications practically continuously throughout their professional career [...] the employer will expect employees to have the skills to continuously improve their professional qualifications (HR officer, Poland).

The data collected allowed us to identify a list of the ten most common skills and competence needs, grouped in three categories, that resurfaced in the five ESSA case study countries, and which can offer an illustration of what industry representatives think needs to be tackled by current (and future) VET programmes (Fig. 1).

Transversal skills appear to be an important concern for the industry as it counts five skills out of the ten most cited. To start, adaptability appears to be critical in the context of a transforming industry:

> This is probably an internal thing; it is about people adapting to change. It’s a key thing for us [...] the change in the mindset (Training advisor, United Kingdom).

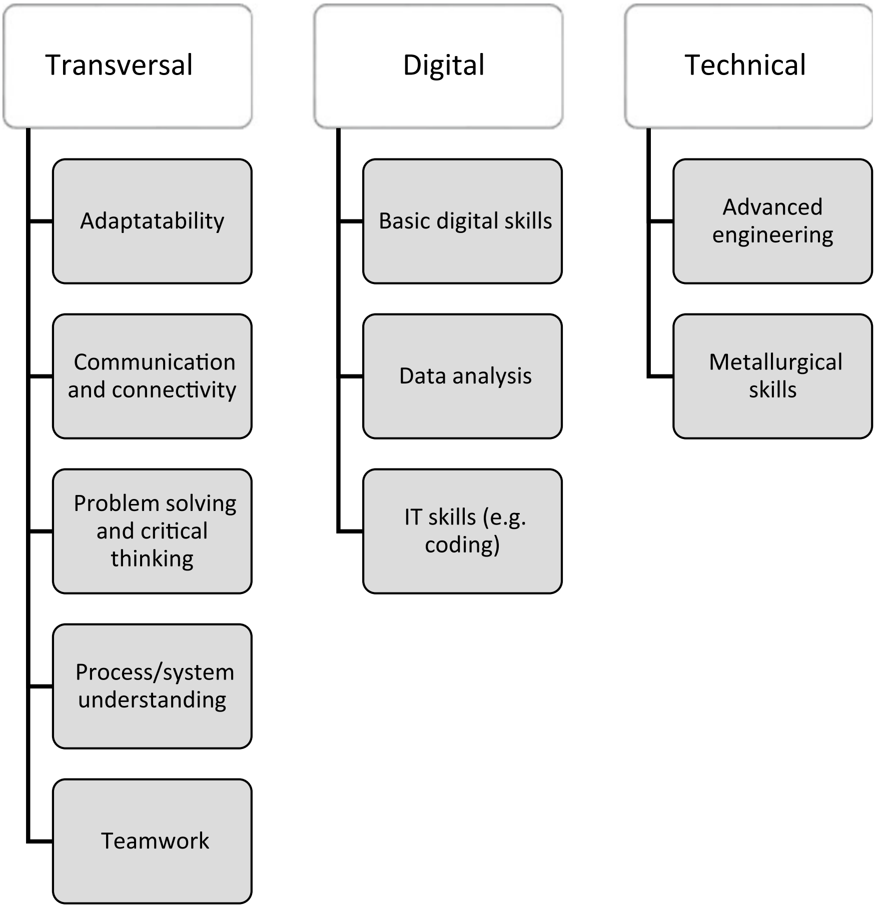

Fig. 1 Ten most cited skills and needs in the ESSA case study countries

There is an increased importance of process and system understanding, which stems from the increasingly integrated character of production processes and the use of digital technologies that render processes less visible and harder to grasp (Zinke 2019). In a more complex and interconnected environment, process and system understanding becomes more important to ensure the smooth running of production processes:

> [they] ensure that apprentices have a contextualised understanding and get the plausibility of what is happening. […] Normally metal workers will not learn PLC [Programmable Logic Controller], it's not their world, nonetheless, we have been asked to please introduce metal workers to PLC so that they will understand what electricians are actually doing and so that they can talk about it […] The point is not to educate them deeply in these areas. Rather, the point is that they have what I call 'overview knowledge' (Training centre manager, Germany).

> They need to acquire general process knowledge, they need to know first of all the overall processes and what are the different outcomes of these before starting to manipulate the real controls of machinery and interface (Training officer, Poland).

The importance of understanding wider processes and how systems operate is crucial also for understanding knock-on effects down the production line:

> [what is important is] people's understanding and knowledge of the knock-on effect down the line in the process. So, if you were producing coke for the blast furnace, and you're producing poor quality coke [...] what effect is that going to cause to my customer? Because it's a chain at the end of the day (Training advisor, United Kingdom).

The increased importance of personal and social skills is another recurrent theme in the data. Skills such as problem-solving, decision-making, communication and teamwork appear to be highly valued in the modern steel company:

> Decision-making process and problem-solving are always key things for us. And I think the two go sort of coupled. […] Especially with the structures we have now, a lot flatter. The teams are more flexible (Training advisor, United Kingdom).

> Technical competencies will be very important […] But also, we realised in our company that we need to offer some training on soft skills, such as communication, problem-solving, team-working…because they work in a team and well-managed interaction is very important to work properly (Training officer, Poland).

In light of the need for continuous and smooth upskilling of workers, skills such as literacy, numeracy, comprehension and logic, play a crucial role, as they are deemed to provide the grounds for continuous learning:

> But the core, and this is the core of occupational education, is to develop personal and social competencies. Because if we have developed those then people are in a good position to acquire other kinds of competencies, knowledge and skills on their own (Head of training, Germany).

Certainly, digital skills will be of unquestionable importance for metal and machinery workers (Cedefop 2019), and will need to be constantly updated, in parallel with technological advancements. A UK union representative commented on the importance of digital skills for the industry but warned that these need to be built on top of robust foundational skills:

> Digital skills in the UK, you know, the amount of people who do not have basic communication skills, the basic five digital skills,[1] is really concerning actually […] I think that it will be a key barrier to participation in technology in the future […] So, [the problem of] digital skills is massive for me; but also without forgetting that millions of workers in the UK still don't have basic literacy and numeracy skills. So, if they do not have basic literacy and numeracy, how will they then be able to replicate it digitally? (Trade union representative, United Kingdom).

[1] The UK's 'Essential digital skills framework', designed to support providers, organisations and employers who offer training for adults, lists the following five essential digital skills for life and work: communicating, handling information and content, transacting, problem solving, being safe and legal online.

Analytical skills seem also to be of great importance in modern steel companies. In a digitalised environment data are produced continuously and in great volume, and workers at any different level should be able to make sense of them, translate data into real-world situations and act upon them:

> In production, data analysis is fundamental […] In the rolling mill or the smelting furnace everything is automated and what the worker has to do is a good analysis of the data. And then, with this data analysis, he has to transfer the solutions to unforeseen events and problems (Trade union representative, Spain).

In addition, and not surprisingly, there is also an increasing demand for more advanced engineering and IT competencies:

> [We need more] highly specialized technicians, mechatronics, with bases of computer, mechanics and electronics that are precious on the market (HR manager, Italy).

> IT people, for instance, I think we don't have enough skills there, because even nowadays it is difficult to find good IT people, and they earn a lot of money because they are in shortage (Industry expert, Poland).

While there is much focus on new emerging skills and competencies, this does not mean that traditional job- or occupation-specific technical skills lose their importance:

> And even in 2030, we will educate apprentices in the basics of sawing, filing and welding, and so on. Because, in the end, we need people who can change a pressure roll, who can weld something that needs welding and so on (VET trainer, Germany).

> The most basic one for me would be steelmaking knowledge in general. So, the actual process of steel. We probably cover every role, you can imagine [...] but for me, the fundamentals have to come from the basics of steelmaking (Training advisor, United Kingdom).

Finally, some amount of on-the-job training is also considered necessary to consolidate and refine the knowledge and skills taught in class or workshops:

> I remember the time when my colleagues were in professional secondary schools, it was like three days teaching in school and two days of real shop floor practising […] And after three years, they were the young professional workers with skills to use a lot of up-to-date machines and technologies. […] the real industry practice is necessary (Industry expert, Poland).

> Anyone also from other sectors, like automotive and shipbuilding, will tell you that we need to recover what used to be called apprenticeship schools in Spain. Basically, these worked as if companies assumed the training of the workers (Trade union representative, Spain)

These findings align with those of another recent European project, 'Steel Sector Careers' (EC 2020), which underscored that steel companies would benefit from a more holistic approach to occupational training. There increasingly appears a need to adopt a 'T-shaped' skills approach, including 'an area of speciality complemented with a series of transferable skills, which can be grouped in three overarching categories: general technical skills, digital skills and soft skills' (EC 2020, p. 56).

As requirements like those we described have become more pressing, countries have responded by reforming their VET systems to cope with the new challenges. In the following section, we illustrate recent VET reforms in three of the five ESSA case study countries (Germany, Italy and the United Kingdom) for clearer contrast, and we discuss them in light of their embeddedness in wider institutional models and their potential implications for the industry.

4 VET Reforms in UK, Germany and Italy

In Europe, VET policies appear to have gone in and out of fashion over time but, increasingly, VET systems have been called upon to address societal challenges stemming from economic and technological transformations. Such challenges have often been tackled by importing 'best practices' from other countries and this is argued to have resulted in some (nominally) common patterns in VET reforms across the EU (Cedefop 2018). Common reforms have consisted of strengthening the links between VET and the labour market, involving employers more in training provision, relaunching apprenticeship schemes, incorporating more elements of transversal skills into the curricula, and extending VET provision at post-secondary and tertiary level.

Turning to our case study countries, the United Kingdom's VET system has been criticised for being fragmented and complex (OECD 2015). The system experiences constant renovation and reform (Pring 2013) and often finds itself at the centre of government rhetoric on skills. Recent VET reforms (also driven by the Industry 4.0 agenda) include England's apprenticeship frameworks being replaced in the period 2018–2020 by new apprenticeship standards developed by sectoral panels of employers. The new standards are occupation-focused, rather than qualification-led, and combine on-the-job training and study. Standards must include a work contract, and at least 20% off-the-job training. The unit-based structure of the previous apprenticeship frameworks has been replaced with a holistic end-point assessment. New standards for metalworkers comprise English and mathematics, subject-related theoretical knowledge (also including environmental and data regulation where relevant) and technical abilities, as well as soft skills such as communication, problem-solving and teamworking.

In addition, the Department for Education rolled out in September 2020 new technical study programmes called 'T levels', aiming to simplify the national VET system and to enhance the credibility of technical qualifications. T Levels are 2-year courses based on the same standards as apprenticeships, designed by employers and approved by the Institute for Apprenticeships and Technical Education. They include compulsory elements such as core theory, concepts and skills for an industrial area, alongside specialist skills and knowledge for an occupation or career. T Levels have been developed to meet the needs of industry and prepare students for entry into skilled employment, further training, or further study. The programme offers a mix of classroom learning and 'on-the-job' training during an industry placement, so meeting employers' demand for earlier work experience. T Levels curricula such as 'Engineering, manufacturing, processing and control', 'Digital production, design and development', 'Digital support services' seem relevant to the needs of the future steel industry.

Quite different from the UK, the German VET system is well-known for its dual training and the embeddedness of social partners and stakeholders in its governance structure (Clarke and Winch 2006). The German approach to recent VET reforms appears to be rather incremental (or 'adaptive', see Antonazzo et al. 2021). Regarding steel sector vocational qualifications, recent changes were oriented towards filling skill and competence gaps, increasing flexibility within occupational qualification offers and improving the permeability of the system to increase re- and up-skilling opportunities. An example of this type of incremental reform is the updating of the curricula of 11 metalworking and electrical qualifications to meet the new industry and market challenges. The training regulation for qualifications such as 'Mechatronics fitter', 'Production technologist', 'Plant mechanic', 'Electronics technician for devices and systems' have been reviewed and subsequently updated with the involvement of the relevant social partners. In addition, a training 'module' titled 'Digitalisation of work, data protection and information security' (*Digitalisierung der Arbeit, Datenschutz und Informationssicherheit*) has been introduced.

Metalworking occupations have also been updated with training on process integration, system integration, IT-based plant modification and additive manufacturing. Such additional contents were introduced to react flexibly to the different needs of companies and so they are not mandatory for apprentices, but have legally regulated minimal standards that assure quality and transparency across the VET system. More recently, emerging skills gaps related to digitalisation and environmental sustainability have been plugged across all dual apprenticeships by introducing completely new 'standard modules' and by updating and modernising existing modules on labour law and collective bargaining, as well as on occupational health and safety (BMBF 2020).

In Italy, upper-secondary and post-secondary VET programmes were reorganised starting in 2008. As part of a review of the school system, it was decided in 2008 the redefinition and rationalisation of existing curricula. The regulations on the reorganisation of upper secondary schools were subsequently adopted in 2010. Upper secondary technical and vocational schools' curricula were rationalised significantly reducing their number and the overlap between similar ones, and job placements were introduced. Vocational school curricula were further updated in 2017. Curricula such as 'Mechanics, mechatronics and energy', 'Electronics and electrotechnics', 'ICT' and 'Maintenance and technical support', seem to fit well the emerging needs of the steel industry. Technical and vocational schools have also been granted the possibility to customise part of the curricula (20% of the allocated hours) to better tackle the demand of local labour markets.

At the post-secondary level, a new higher technical training programme (*ITS*, *Istruzione Tecnica Superiore*) was established in 2008. This is collectively organised and run by schools, vocational centres, universities and companies. ITS responds to companies' demand for new and high technical skills to promote innovation. They represent a novelty in the Italian training system as a new strategy connecting education, training and labour policies with industrial policies. This programme is organised around training areas such as ‘Energy efficiency’, ‘New technologies for made in Italy’ and ‘ICT’, it makes use of I4.0 enabling technologies, and job placement is a mandatory part of the training (at least 30% of the course duration). In addition to this, a 2015 reform established the opportunity for learners to obtain a vocational qualification or a diploma in a dual-training mode (similar to the German dual training) to fill the gap between formal VET and companies and tackle youth unemployment. As regards the vocational qualifications issued at the regional level (*IeFP*, *Istruzione e Formazione Professionale*), the profiles and curricula of these were updated and integrated in 2019 after a two-year review process. This has resulted in strengthening foundational skills across the IeFP curricula and in the addition of new occupational profiles (e.g. ‘Digital modelling and production technician’ and ‘Renewable energy technician’). The Regions also collectively agreed to incorporate personal, social, learning and entrepreneurial competencies into the curricula.

5 Meeting Skill Needs: Different Models, Different Outcomes

To a large extent, the skills and training needs identified within the industry would appear to be addressed by the reforms presented. What we argue, however, is that the outcome of such reforms can only be assessed when considered in their institutional context.

An important debate within the institutional literature concerns the degree of fit between institutions. VoC (Hall and Soskice 2001) assumes that institutions fit tightly and produce coherent and solid economic models (LME and CME). This implies that any reform based on imported institutions (what is referred to in the literature as ‘hybridisation’) would compromise the stability and coherence of the model and its comparative advantages. While some scholars remark that actual institutional models are more ‘slack’ than what is maintained by theories like VoC (Amable 2016), there is still agreement on the value of such conceptual lenses in investigating real-world phenomena.

The tripartite arrangement typical of a CME makes it difficult to implement radical changes and adapt quickly to market conditions in Germany. Employers have sometimes expressed concerns on this matter and advocated for some degree of ‘hybridisation’ of the VET system to enhance its flexibility and better cope with the dynamism of the market. Nevertheless, the German approach is still largely incremental and adaptive. The ‘adaptivity’ of German VET to industry 4.0, as shown by the example of the metalworking and electrical qualifications, relies on a circular process of reviewing the curricula, identifying changes in processes reflected in occupations, and integrating the contents and skills needed. This type of adaptation can be slower and less flexible but avoids the risk of institutional inconsistencies. The steel companies and the unions’ perspectives are brought to convergence through consultation mechanisms that are typical of CMEs, and the regulations for the occupational profiles have been revised and integrated accordingly. This, we believe, can support long-term upskilling strategies which are critical in light of Industry 4.0 and from which the steel industry and the workforce could both benefit.

Typical of LMEs, the UK is characterised by market-driven VET provision, lack of meaningful trade union involvement, fragmented governance and a tendency to embrace a more radical approach to reforms. Under the pressures created by digitalisation and Industry 4.0, the reforms introduced in the country seem to follow this same pattern. The UK governments have mostly reacted to exogenous pressures when these have become too urgent to be ignored (see Bosch and Charest 2008), often borrowing 'best practices' from other contexts and resulting in institutional hybridisation. This practice has been questioned. For example, some have expressed doubts about the capacity of the new T Levels to engage employers on a larger scale (Williams et al. 2020). This is consequential to the absence of an institutional tripartite arrangement. Where inter-firm relations are characterised more by competition than cooperation, occupational standards defined by a panel of employers might not be widely recognised. Furthermore, as LMEs are associated with a higher heterogeneity of interests, employers' panels are likely to represent the interests of large companies, over those of SMEs.

The new apprenticeship standards in England attempt a shift from qualification- to occupation-based training and to reach some level of coordination between government, employers and VET providers. In this respect, this seems an attempt to shift away from LME's typical market-driven VET. However, the reform lacks the trade union component, which plays an important role in CMEs (see Turbin 2001). This results in an imbalance of employers' influence over VET contents. Such an imbalance could lead to a proliferation of narrow occupational standards, limiting the breadth of learning that would afford protection and resilience to workers (Cedefop 2018). The reforms would require the government to play a more active role in harmonising employers' and workers' expectations, as well as the involvement of trade unions in a tripartite mechanism. Overall, while the reforms described for the UK (particularly England) seem to move in the direction of meeting Industry 4.0 requirements, their actual implementation runs the risk of low engagement both on the side of employers and workers. In turn, this risks undermining the capacity of the UK steel industry to stay on track with the technological changes and cause an imbalance between skills demand and supply.

As regards Italy, the country's approach to VET reforms seems to be mostly incremental with some limited structural changes happening over the last 15 years. The organisation of vocational education and training has not undergone major structural reforms, except for the introduction of the new post-secondary ITS programme in 2008 and the dual training experimentation in 2015. These reforms created some hybridisation since co-delivery and dual training are not typical of the Mediterranean model (where education and training have been tendentially school-based). As regards the review and updating of national standards for the regional IeFP qualifications, this can be considered an example of incremental reform, which has assured that curricula remained fit for purpose and that the IeFP programme maintained its consistency and recognisability within the national VET system.

The fact that ITS courses are more present in the north still reflects a divide in the country. The same geographical asymmetry has been observed for dual apprenticeships (INAPP 2018). Consistently with the Mediterranean model, Italy has long relied on the central and regional governments in regulating and running general education and VET. The introduction of higher technical programmes collectively organised and co-delivered at the regional level by schools, universities, companies and local authorities, brings into the Italian institutional architecture new arrangements. ITS programmes and dual training apprenticeships appear to work better in those regions with a dense industrial population, more established social dialogue and long-standing VET tradition. In other regions, school-based secondary VET remains the most popular choice. Thus, the post-secondary and dual training reforms in Italy appear to serve well the steel industry transition to Industry 4.0 in those northern regions in which the local institutional environment better supports the hybridisation brought in by the new arrangements. This risks widening the divide between the innovation potential of companies located in the north and the centre-south with regard to access to a highly qualified workforce.

6 Conclusions

As the European steel industry faces major transformations, it becomes evident that workers need to possess a wider and more varied skill set. Over the last few years, scholars in different fields have offered consistent insights into the changing nature of manufacturing work due to technological innovation, and how skills and competence needs are changing accordingly (Liu and Grusky 2013; Hecklau et al. 2017; Kazancoglu and Ozkan-Ozen 2018; Spöttl and Windelband 2021). Such insights match with the ones presented in this chapter regarding the European steel industry and they could be summarised in the remark that the mix of technical and soft skills and competencies is changing, with digital and soft skills increasing in their relative importance and catching up with technical and sector-specific ones.

It appears that along with Industry 4.0, a new vision of worker is emerging, which has been labelled and defined in several ways, Human Capital 4.0 (Flores et al. 2020), Operator 4.0 (Romero et al. 2016), Workforce 4.0 (Estep 2017). This scenario reinforces the call for a ‘holistic shift’ (Flores et al. 2020) in vocational education and training to enhance workers’ adaptivity to technological change, as well as companies’ innovation potential, sustainability and resilience. Skills formation institutions are expected to keep up with these transformations, resulting in VET reforms like the ones we considered for Germany, Italy and the United Kingdom.

What we aimed to show, however, is that reforms do not happen in a void and nominally similar arrangements (for instance, dual training) might not produce the same outcomes when introduced in a different institutional model. Thus, the way reforms fit in with pre-existing institutions plays an important role in shaping their outcomes. VET is embedded in a wider national institutional architecture, which is characteristic of certain models (e.g., CME, LME, Mediterranean capitalism), as we have shown. These aspects need to be accounted for by policymakers when they aim to support national industrial strategies by reforming VET provisions. Supporting the steel industry across European countries results in not just a challenge of training for the right skills and competencies, but also of reforming systems in a way that optimises existing institutional complementarities and maximises the return for workers and businesses alike.

References

Acemoglu D (2002) Technical change, inequality, and the labor market. J Econ Lit 40(1):7–72

Amable B (2009) Structural reforms in Europe and the (in)coherence of institutions. Oxf Rev Econ Policy 25(1):17–39

Amable B (2016) Institutional complementarities in the dynamic comparative analysis of capitalism. J Inst Econ 12(1):79–103

Antonazzo L, Stroud D, Weinel M (2021) Institutional complementarities and technological transformation: IVET responsiveness to industry 4.0–meeting emerging skill needs in the European steel industry. Econ Ind Democr 44(1):25–46

Autor DH (2015) Why are there still so many jobs? The history and future of workplace automation. J Econ Perspect 29(3):3–30

Bosch G, Charest J (2008) Vocational training and the labour market in liberal and coordinated economies. Ind Relat J 39(5):428–447

Braverman H (1974) Labor and monopoly capital: the degradation of work in the twentieth century. Monthly Review Press, New York

Bundesministerium für Bildung und Forschung (2020) Digitalisierung und Nachhaltigkeit—was müssen alle Auszubildenden lernen? https://www.bmbf.de/de/digitalisierung-und-nachhaltigkeit---was-muessen-alle-auszubildenden-lernen-12244.html

Burke J (2011) Institution. In: Ritzer G, Ryan JM (eds) The concise encyclopedia of sociology. Wiley-Blackwell, Chichester, pp 321–322

Cedefop (2018) The changing nature and role of vocational education and training in Europe. Volume 3: the responsiveness of European VET systems to external change (1995–2015) (Cedefop research paper No. 67). https://www.cedefop.europa.eu/en/publications-and-resources/publications/5567

Cedefop (2019) Skills panorama—metal and machinery workers: skills opportunities and challenges. https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/metal-machinery-workers-skills-opportunities-and-challenges-2019-update

Clarke L, Winch C (2006) A European skills framework?—But what are skills? Anglo-Saxon versus German concepts. J Educ Work 19(3):255–269

Estep—European Steel Technology Platform (2017) Strategic research Agenda (SRA). https://www.estep.eu/library/publications/2017-sra/

Estevez-Abe M, Iversen T, Soskice D (2001) Social protection and the formation of skills: a reinterpretation of the welfare state. In: Hall PA, Soskice D (eds) Varieties of capitalism: the institutional foundations of comparative advantage. Oxford University Press, Oxford, pp 145–183

European Commission (2020) European vision on steel-related skills and supporting actions to solve the skills gap today and tomorrow in Europe, Publications Office of the European Union, Luxemburg. https://data.europa.eu/doi/org/10.2826/2092

Evans C, Stroud D (2016) Greening steel work: varieties of capitalism and the ‘greening’ of skills. J Educ Work 29(3):263–283

Flores E, Xu X, Lu Y (2020) Human capital 4.0: a workforce competence typology for industry 4.0. J Manuf Technol Manag 31(4):687–703

Goldin C, Katz LF (2008) The race between education and technology. Harvard University Press, London
Goos M, Manning A, Salomons A (2014) Explaining job polarization: routine-biased technological change and offshoring. Am Econ Rev 104(8):2509–2526
Hall PA, Soskice D (eds) (2001) Varieties of capitalism: the institutional foundations of comparative advantage. Oxford University Press, Oxford
Hecklau F, Orth R, Kidschun F, Kohl H (2017) Human resources management: meta-study-analysis of future competences in industry 4.0. In: Rich M (ed) Proceedings of the 13th European conference on management, leadership and governance. London, pp 163–174
INAPP (2018) L'apprendistato tra continuità e innovazione. XVIII rapporto di monitoraggio. http://oa.inapp.org/xmlui/bitstream/handle/123456789/435/Inapp_ExecutiveSummary_XVIII_Rapporto_Apprendistato_2018.pdf
Kazancoglu Y, Ozkan-Ozen YD (2018) Analyzing workforce 4.0 in the fourth industrial revolution and proposing a road map from operations management perspective with fuzzy DEMATEL. J Enterp Inf Manag 31(6):891–907
Liu Y, Grusky DB (2013) The payoff to skill in the third industrial revolution. Am J Sociol 118(5):1330–1374
Martinaitis Ž, Christenko A, Antanavičius J (2021) Upskilling, deskilling or polarisation? Evidence on change in skills in Europe. Work Employ Soc 35(3):451–469
Murri M, Colla V, Branca TA (2021) Digital transformation in European steel industry: state of art and future scenario (ESSA project report). https://www.estep.eu/assets/Uploads/ESSA-D2.1-Technological-and-Economic-Development-in-the-Steel-Industry-Version-2.pdf
OECD (2015) Reviews on vocational education and training. Key messages and country summaries. http://www.oecd.org/education/skills-beyond-school/OECD_VET_Key_Messages_and_Country_Summaries_2015.pdf
Pring R (2013) Another reform of qualifications—but qualifying for what? Polit Q 84(1):139–143
Romero D, Stahre J, Wuest T, Noran O, Bernus P, Fast-Berglund Å, Gorecky D (2016) Towards an operator 4.0 typology: a human-centric perspective on the fourth industrial revolution technologies. In: Proceedings of the international conference on computers and industrial engineering, 29–31 October, pp. 1–11
Spöttl G, Windelband L (2021) The 4th industrial revolution–its impact on vocational skills. J Educ Work 34(1):29–52
Stroud D, Weinel M (2020) A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology 'effects' in the European steel industry. N Technol Work Employ 35(3):297–313
Turbin J (2001) Policy borrowing: lessons from European attempts to transfer training practices. Int J Train Dev 5(2):96–111
Vallejo-Peña A, Giachi S (2018) The Mediterranean variety of capitalism, flexibility of work schedules, and labour productivity in Southern Europe. Region 5(3):21–38
Williams J, Newton B, Takala H, Gloste R, Alexander K (2020) Process evaluation of support for T level industry placements: research report, Institute for Employment Studies (Government Social Research—Department for Education)
Zinke G (2019) Berufsbildung 4.0—Fachkräftequalifikationen und Kompetenzen für die digitalisierte Arbeit von morgen: Branchen- und Berufescreening. BiBB Wissenschaftliche Diskussionspapiere (Heft-Nr.: 213). https://www.bibb.de/veroeffentlichungen/de/publication/download/10371

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The Effects of Industry 4.0 on Steel Workforce: Identifying the Current and Future Skills Requirements of the Steel Sector and Developing a Sectorial Database

Tugce Akyazi, Aitor Goti, and Félix Báyon

1 Introduction

The European steel sector is going through continuous and considerable changes due to the emerging digitalization of steel production and strong demands to put the sector on a more environmentally sustainable footing. The manufacturing models are altering with the adoption of smart technologies such as Internet of things (IoT), Artificial Intelligence (AI), robotics, etc. The use of digital technologies results in a new stage of automation, which enables more efficient and creative processes, products and services (Jagannathan and Maclean 2019; German National Academy of Science and Engineering 2016). Even though the steel industry has been recognized as a matured sector with minor technology updates, the sector is already participating in Industry 4.0 evolving into a smart industry. The steel companies are digitizing their manufacturing processes by integrating the 4.0 technologies into the melting, casting, rolling and finishing sub-processes (European Commission Executive Agency for Small and Medium-sized Enterprises 2019). The interconnected, flexible and complex processes have potential to completely change the organizational structure, job profiles and skills requirements of the steel industry. Nevertheless, most of the workers with experience in metallurgy do not have the required technological skills (European Commission Executive Agency for Small and Medium-sized Enterprises 2019).

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As a result, the steel sector is in urgent need of a multi-skilled workforce which is qualified enough to manage the implementation of the smart technologies, contemporary business models and organizational structures. Building this competent labour force is only possible through upgrading the skills, knowledge and credentials. A workforce with updated skills is key for the steel sector to keep up with the growing digitalization, and to adapt to novel working systems. The initial step of the continuous re-skilling and up-skilling of the workforce is addressing the current skills needs and trends as well as foreseeing the future ones. This chapter aims to accomplish that objective through performing a detailed desk analysis and creating a sectoral occupational database. Once the anticipated evolution of skills needs is identified, a long-term skill implementation methodology may be established for reducing the skills gap between the industry expectations and the current workforce. Such a methodical approach would ideally provide tools for the recruitment of new talents, as well as introduce well-developed education and training programs for the current workforce, and redesign work processes.

Accordingly, the steel sector critically demands a roadmap guiding the sector to identify the current and future skills needed by the workforce and tools to implement them. Additionally, a sectorial guideline is needed for education policy makers to facilitate the relevant education programs, degrees and subject-matter syllabuses being compatible with the industry's skills needs. This chapter is developed in response to these needs.

This chapter describes step-by-step the methodical process applied to the steel sector. Initially, we have performed detailed desk research to identify the current steel sector skill trends. Then, we present the development of a sectorial occupation-skills database, through determining the actual and future competences requirements. To achieve that goal, principally we analyse the strategies for the implementation of competences followed by other sectors (e.g. machine tool, construction) and develop a methodology—adjusted from a broad spectrum of European sectoral and cross-sectoral frameworks, projects and scientific articles—to describe the steel industry requirements related to future skills. During the generation of the database, we identify the current and future competences needed by the steel sector occupations (engineers, operators and managers).

To define the relevant steel sector occupational profiles and identify the competence needs of each profile, we use the database of European Skills, Competences, Credentials and Occupations (ESCO). Then, we create the occupation-skills database in an automated excel format using Visual Basic for Applications (VBA) through the integration of the selected occupations and their current skills needs.

To support the development of future competences, we analyse the occupational profiles which are present in the database one by one and pick the ones that will be transformed through the sector's digitalization. For this purpose, we again utilized notable European references related to the subject: numerous strategic inter-sectoral and sectoral European frameworks and projects. Once the future competence needs of each profile are identified, they are integrated into the database to finalize the update process. Eventually, we generate an automated database incorporating the present and future competences needs of the steel sector job profiles. Finally, in the last section, the main conclusions are discussed explaining the potential importance of our research for companies, training centres, policymakers and researchers.

We envisage that the sectoral database can serve the steel industry as a fundamental tool for all the future technological and organizational transformations. The target end-users of this database are steel manufacturers, universities, training and education centres who are responsible from the development and delivery of training programs. We believe that this work has a potential to be used as a framework guiding the sector for building a competent and multi-skilled workforce.

2 Identifying the Current and Future Skills Requirements for the Steel Sector

This section focuses on identifying the (current and future) competence requirements of the steel workforce. When we talk about the "future" skills, we refer to the foreseen skill needs for the next 10 years (till 2033). To this end, firstly, we evaluate the most recent skills trends affecting the steel industry performing desk research. Secondly, we demonstrate the development of the sectoral occupation-skill database step by step, presenting the methodology and the results (Sect. 3). The key condition for achieving a relatively accurate perception of the evolution of skills is to have a general idea about the future steel industry. This is only possible through examining and determining the outcomes of the ongoing and future industrial changes on the steel workforce.

As for all industries, the steel sector has been tremendously affected by the COVID-19 pandemic. The main consequence of the pandemic from an industrial and business perspective is the accelerated adoption of digital technologies which enable agile and flexible operations. Industrial digitalization has accelerated greatly across the whole manufacturing industry through adopting existing and new technologies related to Industry 4.0 (Naselli 2020; Agrawal et al. 2021). Therefore, the top strategic priorities of the industry have been the integration of smart technologies and the upskilling and reskilling of the workforce accordingly (Agrawal et al. 2021).

On the other hand, during the last decades in the EU, the job loss for workers with low-skilled routine in manufacturing has been observed to increase and it is anticipated to increase further as a result of the automation of the tasks carried out by these job profiles. The upskilling and reskilling of low-profile workers can keep them still useful for the industry (Madl 2021).

Along with digitalization, the steel industry is looking for solutions that make it possible to use resources efficiently and reduce CO_2 emission levels while keeping up competitiveness and economic development. Therefore, both policymakers and companies are constantly integrating the concerns about sustainability into their agendas. Moreover, their strategies focus not only on optimal consumption of resources, sustainability and energy efficiency, but also safety and well-being of employees (Spire-SAIS 2020). Digital technologies facilitate the steel manufacturers to carry out more energy and resource efficient and less environmentally damaging processes. Sustainability establishes the background for Industry 4.0 (Gajdzik et al. 2020). Even if we cannot separate one from the other as an element in a distinctive way, Industry 4.0 and sustainability are emerging as two main factors that drive the evolution of skills in the steel industry (European Commission Executive Agency for Small and Medium-sized Enterprises 2019). These two drivers result in an acceleration of skill shifts compared with historical trends and also push the sector to improve the quality of skills to fulfil the needs of the industry.

The technological developments are altering the tasks performed by the steel professionals and therefore changing the skills needed to execute these tasks (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Ellingrud et al. 2020). First of all, the workers will be able to make more informed decisions in shorter periods of time and deal with complicated circumstances due to the real-time data developed by the automated and smart production systems (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Branca et al. 2020; Schlegel et al. 2018). The majority of the workers will be executing their day-to-day operations beside robots and machines. Collaborative robots will become more autonomous and tackle the plain and repetitive tasks, while operators will perform more complex tasks and make critical decisions (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Akyazi et al. 2022). Therefore, the importance of decision-making skills will increase substantially.

Additionally, the relationship between machines and humans is being altered by 4.0 technologies (Gajdzik and Wolniak 2021; Tihinen et al. 2017; Ten and St 2015). **New technologies are minimizing physical human work**. Since the high degree of automation will decrease the human intervention in routine production tasks, the workers will be mainly gathered in control rooms operating remotely. Many tasks performed physically by the workers will be operated using computers, monitoring data and providing oversight.

On the other hand, new skills are expected from the workforce to control the new technologies, to supervise the automated processes and execute more qualified work (Gajdzik and Wolniak 2021) (Romero et al. 2016). For example, thanks to the self-learning productions systems (made possible by AI) **operators will be able to supervise the work** of machines remotely (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Gajdzik and Wolniak 2021; Bokrantz et al. 2017; Wang et al. 2018). Concurrently, human intervention will become more essential not only during the supervision of the machines but also during maintenance activities (European Commission Executive Agency for Small and Medium-sized Enterprises 2019). Also, capability of online supervising can lead the operators to home office working. The integration of artificial intelligence will cause the organizations to be more **team-oriented** and **top-down hierarchal structures with bureaucracy, collaboration and communication barriers are likely to lose influence** (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; European Centre for the Development of Vocational Training 2009). Teamwork not only between co-workers, but also between the automated systems and co-workers will become more important (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; European Centre for the Development of Vocational Training 2009).

In general, the job profiles of the steel industry are not expected to be replaced entirely, instead they are expected to **execute more tasks in various departments**. Therefore, workers will be demanded to have a **wider knowledge in different subjects and higher qualification**. Multitasking will become a significant skill for the workers (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Akyazi et al. 2022).

The major consequence of the aforementioned transformation is the **growing demand for the digital skills** as the steel companies adopt smart technologies (Madl 2021; Deming 2015). Therefore, the workers will be expected to have not merely basic digital competences, but also advanced digital competences related to IoT, AI, robotics, Machine Learning, AR, Big Data Analytics, Cloud Computing, Digital twin, simulations, Predictive Maintenance (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Branca et al. 2020; Gajdzik and Wolniak 2021; Neef et al. 2018; Fragassa et al. 2019; Hanoglu and Šarler 2019; Colla et al. 2021). Due to this demand, data safety and protection will become crucial to increase the trust in new technologies.

The adoption of digital innovation demands not only digital skills but also require **social and emotional skills**—which machines will not capable of learning in the near future—from the steel sector workers (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Akyazi et al. 2022). Due to increasing automation, workers will be responsible for more significant tasks which require solid literacy, numeracy, ICT along with some **soft skills** such as collaboration, initiative taking, problem-solving and teamwork (Deming 2015; Industry-driven sustainable European Steel Skills Agenda and Strategy 2019). Flexibility and transferability will become more important as the workers are expected to execute varied tasks (German National Academy of Science and Engineering 2016). Also, because of the growing automation basic cognitive skills will lose importance as higher cognitive ones such as creativity, lifelong learning, teamwork, problem solving, decision making will become more significant (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Gajdzik et al. 2020; Industry driven sustainable European Steel Skills Agenda and Strategy 2019). Critical thinking, independent problem solving, managing complexity, complex information processing, cross-functional process know-how, interdisciplinary thinking and acting will be crucial in the future industrial environment (Schlegel et al. 2018; Deming 2015). The demand for communication and negotiation skills will also increase (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Schlegel et al. 2018). Despite of the decreasing demand, manual and physical skills will continue being the largest category of skills (Gajdzik et al. 2020; Schlegel et al. 2018). This category of skills will be updated for each occupation depending on the level of automation of the profile.

Moreover, **green skills** are acknowledged as vital in order to sustain the competitiveness of the European manufacturing industry (including the steel sector) due to the growing focus on environmental awareness, sustainability and energy efficiency (European Commission Executive Agency for Small and Medium-sized Enterprises 2019; Organisation for Economic Co-operation and Development 2014). The relevance of green skills can also be explained by the fact that EU countries have agreed to reach certain legally binding environmentally targets by 2050 (Spire-SAIS 2020; Organisation for Economic Co-operation and Development 2014). Not only managers, but also operators will be expected to have knowledge in resource efficiency, recycling and material reutilization in the near future (ESSA 2019). Some of the green skills needs relate to environmental awareness, environmental monitoring, sustainability, circular economy, industrial symbiosis basic understanding and methodologies, field experience, waste management, waste reduction and prevention, resource, reuse and recycling, eco-design of product, technology and process, water conservation, sustainable resource management, product life cycle assessment, energy management of equipment and plants, developing and installing analysis systems for energy use, manufacturing principles to reduce energy consumption, monitoring and investigating energy use, selection and use of monitoring equipment for energy consumption, energy data collection and analysis, industry field experience, general regulatory awareness, legislative and compliance requirements, legislation about waste management and CO_2 emissions (Spire-SAIS 2020; Organisation for Economic Co-operation and Development 2014; INSIGHT Industrial Symbiosis Facilitator 2020).

In conclusion, the future steel workforce is expected to have cognitive and social skills that enables them to work alongside increasingly automated technologies, such as critical thinking, communication, team working and lifelong learning. The steel sector also demands from its labour force to have basic and complex digital skills to handle the digital transformation smoothly and effectively. In addition, green skills present key importance for the workforce to manage European regulations and policies about the sustainability, energy efficiency and environment, which is one of the current focuses of the European steel industry.

3 Generation of the Sectorial Database

This section demonstrates the main objective of the chapter: the generation of the database incorporating competence needs (present and near-future) for the steel sector professional profiles. We firstly explain the development of the methodology (Section "Materials and Methods") and later, present the results (Section "Results and Discussion").

Materials and Methods

The methodology incorporates broad desk research of international publications, inter-sectorial European projects and frameworks, with the opinions of ESSA (Industry-driven sustainable European Steel Skills Agenda and Strategy) subject matter experts about the future skill demands of the steel sector workforce. A similar methodology underpinned previous research on other sectors undertaken by our team (Akyazi et al. 2020a, b, c, d, 2022; Arcelay et al. 2021).

The two main data sources that we used for the generation of our database were: (a) the database of ESCO (created by the European Multilingual Classification of Skills, Competencies, Qualifications and Occupations (ESCO) association—cultivated by the European Commission) and (b) Industry-driven sustainable European Steel Skills Agenda and Strategy (ESSA) project aiming to establish a Blueprint for "New Skills Agenda"—an EU project that we are directly involved in (ESSA 2019). ESCO could be considered a dictionary that classifies skills and professional occupations essential for education, training and labour markets in Europe (European Commission ESCO European Skills/Competences Qualifications and Occupations 2022). It is a European multilingual categorization of occupations, competences and skills. The ESCO database is based on the "International Standard Classification of Occupations" (ISCO-08) framework developed by ILO (International Labour Organization); it enables the ESCO database to be directly linked with a wide range of international occupational group categorizations established by ILO.

The other main source, the ESSA project, has been initiated to develop a Blueprint for a sustainable, steel industry-driven and coordinated European Steel Skills Agenda (ESSA) and to present a strategy for an ongoing and short-termed implementation of new skills demands. The project aims to pilot this by the development of modules and tools for building awareness and implementing new skills for a globally competitive industry, ready to anticipate new skills demands and to develop pro-active and practical activities to meet the future requirements of the evolving job profiles of the steel industry ESSA 2019).

Moreover, the desk research that we executed during the development of Sect. 2 for identifying the general skills trends for the steel sector contributed immensely to the development of the database. The literature was carefully selected from the high impact journal articles, reports published by European Commission and McKinsey consulting.

Furthermore, the "European ICT System of Professional Role Profiles Framework" created by the "Council of European Professional Informatics Societies (CEPIS)" and the "European Committee for Standardization (CEN)" was used as a significant reference to identify ICT-related skills needs of the steel sector. CEPIS is the representative party of national informatics associations in Europe. It is a non-profit organization that not only represents IT professionals in 28 countries but also addresses the development of prominent standards among IT professionals through recognizing the effect of IT on industry, society and labour market (Council of European Professional Informatics Societies 2020).

Furthermore, CEN is the association that combines the National Standardization Entities of 34 European countries supporting standardization activities in a broad range of areas and sectors (European Committee for Standardization 2022). The two aforementioned organizations worked together to develop the "European ICT Professional Role Profiles Framework" supporting the generation of a common European reference for the management, planning and progress of the skill needs related to ICT from a specific perspective (European Committee for Standardization and European e-Competence Framework 2019).

We also benefited from several inter-sectorial strategic projects such as "Skills Alliance for Industrial Symbiosis—a Cross-sectoral Blueprint for a Sustainable Process Industry" (Spire-SAIS 2020), Machine Tool Alliance for Skills (METALS 2016), Digitalization of Small and Medium Enterprises, SMEs (SMeART 2018) and Procedures for Quality Apprenticeships in Educational Organizations (APPRENTICESHIPQ 2018). These projects provided us with a general point of view about the new skills needs in different sectors, related to energy efficiency, industrial symbiosis, digitalization and training.

During the development of the automated sectorial database for the occupation and skills of the steel industry, Visual Basic for Applications (VBA) was used as the programming language in Microsoft Excel Spreadsheet Software. Considering that ESCO database is updated regularly by the organization, our database needs to keep up with these update routines. Therefore, an Application Programming Interface was established in order to automate the updating process of the generated database.

Results and Discussion

The main objective of the methodology is to create an automated skills database for the steel sector job profiles. It includes the current competence needs as well as the near-future ones which are foreseen for the next 10 years.

While identifying the steel sector-associated professional profiles and detecting their current skills and competence needs, the main source of the data was ESCO. Firstly, we analysed the professional profiles connected with the steel sector in ESCO's database. Then, we picked them and integrated them into an excel datasheet. Once all the job profiles were present in the document, we executed the automation process through applying VBA on the datasheet. Therefore, the first edition of the automated database which incorporates solely the current skill and knowledge needs was generated. The following procedure was applied to detect the skill and competence needs for the future and incorporate them into the already-automated database.

ESCO provides us with a very convenient and systematic database used as a reliable reference to gather information related to professional profiles and skills in the EU labour market. However, it does not include satisfactory information related to natural evolution of occupations; its content needs to be updated about the new competence needs arising from the technological developments: namely digital, transversal and green competences. Therefore we used references other than ESCO to identify the future skills requirements of the steel sector. We carried out desk research about the general skill trends about the future of the steel sector (Sect. 2) and we combined it with the general elements of the methodology which we had developed in ESSA project. Therefore, the main reference used for defining the future competences (digital, personal, social, methodological, green) was the ESSA project. After that, we identified and picked the most relevant skills for the steel sector from the outputs of various EU-level databases and research projects: green competences from the SPIRE-SAIS project, ICT-related competences from the framework of European ICT Professional Role Profiles, and digital and personal, methodological competences from the METALS project.

The final list of future competences was generated through merging the results with the subject matter experts' opinions. This process enabled us to obtain detailed understanding about the additional competences demanded of the steel workforce in order to proceed a successful digital transformation and to achieve a sustainable and competitive steel sector. Tables 1, 2 and 3 show the ultimate list of the identified future competence requirements. They were classified into three groups to be practical: (1) digital competences (2) personal, methodological and social competences and (3) green competences.

Once having identified the future competences, the following step was to determine the profiles that would be transformed as a result of the ongoing digitalization of the steel industry. For this aim, we carried out an analysis on each selected profile present at the database. In order to identify the transformed profiles, we took ESSA project as a basis. At the same time, we also benefited from the above-mentioned (Sect. 2.2.1) European projects executed in a broad range of sectors to detect which occupational profiles were required to be updated through digitalization. Then, we analysed the steel sector occupations including the equivalent work tasks with those in other sectors which had gone through changes due to Industry 4.0 (such as process engineer, industrial manager, etc.). After, we added the future competence needs of these profiles into the database. Particularly, the framework of European ICT Professional Role Profiles provided us with the information of both the altered ICT-related job profiles and their future skills needs. For the rest of the steel sector job profiles, it was our research team who made the decision if their skills required an update or not. When an update was considered essential for a job profile, a detailed analysis based on the subject matter experts' opinion was carried out to select the future competence needs. Then, the identified competence requirements were incorporated manually to the database as "essential" or "optional".

Once we integrated all identified future competences in the database, the skill-updating process for each occupation was finalized. Subsequently, the automated occupation-skills database for the steel sector was generated successfully. Additionally, for the sake of being practical, all current skill and competence requirements demonstrated in ESCO´s database were assumed to be demanded also in the future. In the future, if they become outdated, these skills or competences will be removed both from our and ESCO database. Moreover, during our research, when we identified a competence requirement for the future and it was already present at the database of

Table 1 The list of the detected future digital competence requirements for the steel industry workforce

Future digital competences for the steel sector
Internet of things (IoT)
Machine learning
Big data
Cloud computing
Artificial intelligence (AI)
Business intelligence (BI)
Sensors technology
Collaborative and advanced robots
Customization and personalization of production
Augmented reality (AR)
Cyber-physical systems (CBS)
Human-machine interfaces (HMI)
Cybersecurity
Additive manufacturing
Predictive and proactive maintenance
Computerized maintenance management
Digital twin
Process simulation and integration in manufacturing
Communication among equipment (M2M) and environment
Online equipment and process monitoring systems
Traceability
Basic digital skills
Use of digital communication tools
Basic data input and processing
Advanced data analysis and modelization
Data management-safe storage
E-commerce
Enterprise resource planning (ERP)
Manufacturing execution system (MES)
Financial literacy
Quality procedures related to digital transformation
Project planning and management

ESCO, they were not referred as a ¨"future competence¨´ anymore. Solely, the new competences that we detected were categorized as ¨future competences¨.

Table 4 demonstrates an example data sheet of the created steel sector database. In this table, the "casting machine operator" is taken as an example. The initial four rows represent the hierarchical organization of the occupation groups: The "casting

Table 2 The list of the detected future personal, social and methodological competence requirements for the steel industry workforce

Future personal, social and methodological competences for the steel sector
Personal competences
Critical thinking and decision making
Strategic and systematic thinking
Interdisciplinary thinking and acting
Continuous learning
Adaptability and adapt to change
Work autonomously
Ethical skills
Personal experience
Appropriate linguistic skills
Methodological competences
Creativity
Cross-functional process know-how
Complex problem solving
Opportunity assessment
Risk management
Customer relationship management
Creativity
Cross-functional process know-how
Basic numeracy and communication
Quantitative and statistical skills
Complex information processing and interpretation
Advanced literacy
Social competences
Entrepreneurship and initiative taking
Interpersonal skills and empathy
Cultural empathy
Active listening
Effective communication and negotiation skills
Teamwork skills
Leadership and managing others
Conflict resolution
Networking
Teaching and training others

Table 3 The list of the detected future green competence requirements for the steel industry workforce

Future green competences for the steel sector
Environmental awareness
Understanding circular economy and industrial symbiosis concepts
Waste reduction and prevention
Waste management
Resource re-use and recycling
Sustainable resource management
Product life cycle thinking assessment
Eco-design of product, technology and processes
Understanding energy efficiency concept
Understanding energy use and costs
Energy management of equipment and plants
System optimization and process analysis
Energy data collection and analysis
Platforms for energy management of equipment and plants
Manufacturing principles to reduce energy consumption
Selection and use of monitoring equipment for energy consumption
General regulatory awareness (incl. legislation, compliance)
Legislation on waste management and CO_2 emissions

machine operator" professional profile is a part of the "metal processing plant operators" occupation group, which belongs to the broader group of "metal processing and finishing plant operators" and so on. The table incorporates a direct web link to the website of ESCO where all the presented data related to the profile is accessible. Moreover, the database demonstrates the ISCO number (the international occupation code) and the alternative labels for the presented professional profile. In addition, the table describes both the essential and optional skill, competence and knowledge requirements for the "casting machine operator" job profile. The current skill and knowledge requirements extracted from ESCO's database are shown in black font while the future competence needs that were identified in this research are demonstrated in red font.

The table is regarded as a "smart table" due to the automation process executed on the database. Therefore, when we alter "casting machine operator" professional profile with another one, all the data about the new profile comes into sight automatically on the spreadsheet replacing the information related to "casting machine operator". This capability enables us to display the competences of any professional profile instantly using the database. Hence, the database can be used as a very effective and convenient tool for the implementation of competencies.

Table 4 An example sheet extracted from the automated occupation-skills database created for the steel sector

8—Plant and machine operators and assemblers
81—Stationary plant and machine operators
812—Metal processing and finishing plant operators
8121—Metal processing plant operators
Professional Job Profile: 8121.1 Casting Machine Operator
ESCO link: http://data.europa.eu/esco/occupation/25206eaa-04da-4fd6-bac7-173d7eb142dc
mold casting worker // metal molder // foundry operator // molding and casting worker // metal moulder // ladleman // metal caster // pourer and caster // foundryman // mould casting worker // ladleperson/
Casting machine operators operate casting machines to manipulate metal substances into shape. They set up and tend casting machines to process molten ferrous and non-ferrous metals to manufacture metal materials. They conduct the flow of molten metals into casts, taking care to create the exact right circumstances to obtain the highest quality metal. They observe the flow of metal to identify faults. In case of a fault, they notify the authorised personnel and participate in the removal of the fault
ISCO number: 8121
Essential
Knowledge
Casting processes
Manufacturing of metal assembly products
Metal joining technologies
Skill/competence
Admit basic metals to furnace
Assemble metal parts
Maintain mould parts
Use tools for castings repair
Optional
Knowledge
Precious metal processing
Types of metal
Skill/competence
Assess suitability of metal types for specific application
Cut metal products
Follow manufacturing work schedule
Future competences
Essential
Collaborative and advanced robots
Basic digital skills
Artificial intelligence (AI)

(continued)

Table 4 (continued)

8—Plant and machine operators and assemblers
Predictive and proactive maintenance
Augmented reality (AR)
Digital twin
Critical thinking and decision making
Strategic and systematic thinking
Effective communication skills
Teamwork skills
Advanced literacy
Understanding energy use and costs
Use of monitoring equipment for energy consumption
Waste reduction and prevention
Resource re-use and recycling
Optional
Cybersecurity
Quality procedures related to digital transformation
Creativity
Interpersonal skills and empathy
Cultural empathy
Complex information processing and interpretation

The main differences between our database and conventional ones, such as ESCO, are that (1) our database includes the anticipated skill requirements for each job profile and (2) ours is a steel sector-specific database. Our work aimed to fill the gap of a sectorial database including future skills emerging from sector-specific industrial changes, innovations and sustainability requirements. Therefore, the research findings aim to contribute to the continuous updating and development of ESCO, thus reaching more effectively to the end-users thanks to our interaction with ESCO experts. The findings are intended to be consistent with ESCO framework, which is a significant and common reference among the European labour market, training and education centres.

Moreover, the results of the research were validated by Sidenor Aceros Especiales SLU which is an international company and leader in the European steel industry for the production of special steel long products. Sidenor is also involved in the ESSA project as an industrial partner. They aim to implement the necessary skills on their workforce so that the workers can handle the current and upcoming technological developments and sustainability requirements properly. They are in the process of upskilling and reskilling of their workforce through identifying the skill gaps and looking for required training programmes. Therefore, they are using our automated and sector-specific database effectively. Our database provides Sidenor and other companies with easy access to information on foreseen skill requirements for each steel sector job profile. Through this information, they can analyze and identify suitable and well-developed training programmes for each job profile in the company. Therefore, after confirming the validity of the database, Sidenor is actively using it during the implementation of the new skills by the human resource department.

4 Conclusion

The steel sector faces constant and profound transformations of its manufacturing models because of Industry 4.0 and sustainability demands. The sector is already participating in the digitalization converting into a smart industry. The application of the smart technologies leads to more efficient and reliable manufacturing processes as well as higher quality products and services. Therefore, Industry 4.0 is recognized as a good opportunity for the sector. Furthermore, these flexible, complementary and complex smart processes are altering the organizational structure and competences of the steel industry. On the other hand, the steel industry is seeking solutions for an efficient use of resources and the reduction of CO_2 emission levels while maintaining their competitiveness. The industry is also working towards the implementation of solutions to ensure that they operate with respect to energy efficiency, workforce that can handle the implementation of new business models compatible with IS & EE and technological developments. Thus, it also creates a challenge for the sector. For this reason, the steel industry urgently needs to generate a multi-skilled labour force which is capable of managing the implementation of newly introduced business models compatible with smart technologies and environmental imperatives/sustainability requirements.

This competent workforce can only be created by up-skilling and re-skilling of the current one through the development of well-established training programs. Identifying the skill mismatch between the workforce and the industry's expectations is the key for the development of the high quality training and it is only possible through defining the current and anticipated skill needs for the steel industry. Our work responds to this need for addressing the current skill and competence requirements and foreseeing the future ones.

In this chapter, after evaluating the current skill requirements and defining the foreseen evolution of competences for the steel sector, we generated a structured and automated skills database for the steel industry professional profiles. We believe that the created sectorial database is an essential tool that could guide the steel industry through the implementation of new skills during digitalization. Indeed, the results of the research and the utility of the sectorial database for the skills implementation were validated by Sidenor Aceros Especiales SLU.

It is our belief that our research could be adopted as a guidance not only for companies but also for training centres, universities and policy makers throughout the development of well-designed training programs which are designed to minimize the skill gap between the workforce and job profiles. We strongly believe that in the lead of the ESSA project, the steel sector will be seeking more sectorial frameworks for the implementation of new skills in the steel industry. Our research would also serve them as a roadmap.

References

Agrawal M, Dutta S, Kelly R, Millán I (2021) COVID-19: an inflection point for industry 4.0. In: Our insights. McKinsey & Company. Available via McKinsey & Company. https://www.mckinsey.com/capabilities/operations/our-insights/covid-19-an-inflection-point-for-industry-40. Accessed on 10 October 2022

Akyazi T, del Val P, Goti A, Oyarbide A et al (2022) Identifying future skill requirements of the job profiles for a sustainable European manufacturing industry 4.0. Recycling 7(3):32

Akyazi T, Oyarbide-Zubillaga A, Goti A, Gaviria J, Bayon F et al (2020a) Roadmap for the future professional skills for the oil and gas industry facing industrial revolution 4.0. Hydrocarb. Process. November

Akyazi T, Goti A, Oyarbide A, Alberdi E, Bayon, F et al (2020b) A guide for the food industry to meet the future skills requirements emerging with industry 4.0. Foods 9(4):492

Akyazi T, Alvarez I, Alberdi E, Oyarbide-Zubillaga A, Goti A, Bayon F et al (2020c) Skills needs of the civil engineering sector in the European Union Countries: current situation and future trends. Appl Sci 10(2):7226

Akyazi T, Goti A, Oyarbide-Zubillaga A, Alberdi E, Carballedo R, Ibeas R, Garcia-Bringas P et al (2020d) Skills requirements for the European machine tool sector emerging from its digitalization. Metals 10(12):1665

APPRENTICESHIPQ Mainstreaming Procedures for Quality Apprenticeships in Educational Organisations and Enterprises Program (2018–2020) The European Commission's ERASMUS+ programme. Project Reference Number: 2017-1-DE02-KA202-004164. https://apprenticeshipq.eu/. Accessed 25 November 2021

Arcelay I, Goti A, Oyarbide-Zubillaga A, Akyazi T, Alberdi E, Garcia-Bringas P et al (2021) Definition of the future skills needs of job profiles in the renewable energy sector. Energies 14(9):2609

Bokrantz J, Skoogh A, Berlin C, Stahre J et al (2017) Maintenance in digitalised manufacturing: Delphi-based scenarios for 2030. Int J Prod Econ 191:54–169

Branca T, Fornai B, Colla V, Murri M, Streppa E, Schröder A et al (2020) The challenge of digitalization in the steel sector. Metals 10(2):288

CEPIS Council of European Professional Informatics Societies (2020). https://cepis.org/. Accessed on 10 November 2021

CEN European Committee for Standardization (2022). https://www.cencenelec.eu/. Accessed 10 November 2021

CEN and European e-Competence Framework (2019) European ICT Professional Role Profiles Version 2. In: CEN ICT Skills Workshop Agreement (CWA). CEN and European e-Competence Framework. Available via CEN and European e-Competence Framework. https://eufordigital.eu/wp-content/uploads/2019/10/EUROPEAN-ICT-PROF_ROLE-PROFILES-VERSION-2_PART-3_METHODOLOGY.pdf. Accessed on 10 December 2021

Colla V, Matino R, Schröder AJ, Schivalocchi M, Romaniello L et al (2021) Human-centered robotic development in the steel shop: improving health, safety and digital skills at the workplace. Metals 11(4):647

Deming DJ (2015) The growing importance of social skills in the labor market. In: Working Papers. National Bureau of Economic Research—NBER. Available via National Bureau of Economic Research. https://www.nber.org/papers/w21473. Accessed on 10 December 2022

Ellingrud K, Gupta R, Salguero J (2020) Building the vital skills for the future of work in operations. In: Our Insight. McKinsey Global Institute. Available via McKinsey Global Institute. Accessed on 15 September 2021

ESCO—European Commission ESCO European Skills/Competences Qualifications and Occupations (2022). https://esco.ec.europa.eu/en/. Accessed 30 November 2022

ESSA Blueprint "New Skills Agenda Steel": Industry driven sustainable European Steel Skills Agenda and Strategy (2019–2021) The European Commission's ERASMUS+ programme. Project Reference Number: 600886-EPP-1-2018-1-DE-EPPKA2-SSA-B. https://www.estep.eu/essa. Accessed 15 November 2021

European Centre for the Development of Vocational Training CEDEFOP (2009) Terminology of European education and training policy. In: Publication and Reports. Available via CEDEFOP. https://www.cedefop.europa.eu/node/11256. Accessed 15 November 2021

European Commission Executive Agency for Small and Medium-sized Enterprises (2019) Blueprint for sectoral cooperation on skills: towards an EU strategy addressing the skills needs of the steel sector. In: European vision on steel-related skills of today and tomorrow. Available via Publications Office of the European Union. https://data.europa.eu/doi/10.2826/458269. Accessed on 22 November 2022

Fragassa C, Babic M, Bergmann CP, Minak G et al (2019) Predicting the tensile behaviour of cast alloys by a pattern recognition analysis on experimental data. Metals 9(5):557

Gajdzik B, Grabowska S, Saniuk S, Wieczorek T et al (2020) Sustainable development and industry 4.0: a bibliometric analysis identifying key scientific problems of the sustainable industry 4.0. Energies 13:4254

Gajdzik B, Wolniak R (2021) Digitalisation and innovation in the steel industry in Poland—selected tools of ICT in an analysis of statistical data and a case study. Energies 14(11):3034

German National Academy of Science and Engineering—ACATECH (2016) Skills for industrie 4.0: training requirements and solutions. In: Acatech position paper, Executive Summary and Recommendation. ACATECH. Available via ACATECH. https://www.acatech.de/publikation/kompetenzen-fuer-industrie-4-0-qualifizierungsbedarfe-und-loesungsansaetze. Accessed on 27 November 2021

Hanoglu U, Šarler B (2019) Hot rolling simulation system for steel based on advanced meshless solution. Metals 9(7):788

Insight- Fostering Industrial Symbiosis through the development of a novel and innovative training approach (2020) Industrial Symbiosis Facilitator Key study based on current knowledge, skills and qualifications regarding IS. Available via Erasmus+ Programme. https://www.insight-erasmus.eu/library/reports/. Accessed 15 November 2022

Jagannathan S, Ra S, Maclean R et al (2019) Dominant recent trends impacting on jobs and labor markets—an overview. Int J Train Res 17(1):325–329

Madl I (2021) Employment impact of digitalisation. In: The digital age: Automation, digitisation and platforms. European Foundation for the Improvement of Living and Working Conditions, EUROFOUND. Available via EUROFOUND. https://www.eurofound.europa.eu/data/digitalisation/research-digests/employment-impact-of-digitalisation. Accessed on 14 November 2022

METALS Machine Tool Alliance for Skills (2016–2019) The European Commission's ERASMUS+ programme. Project Reference Number: 562464-EPP-1-2015-1-BE-EPPKA2-SSA. http://www.metalsalliance.eu/. Accessed 30 November 2021

Naselli J (2020) The role of industrial digitalisation in post-Covid-19 manufacturing recovery, diversification and resilience. In: Cambridge Industrial Innovation Policy. University of Cambridge. Available via University of Cambridge. https://www.ciip.group.cam.ac.uk/reports-and-articles/role-industrial-digitalisation-post-covid-19-manuf/. Accessed on 15 November 20

Neef C, Hirzel S, Arens M (2018) Industry 4.0 in the European Iron and Steel Industry: Towards an Overview of Implementations and Perspectives. Fraunhofer Institute for Systems and Innovation Research ISI. Available via Fraunhofer ISI. https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cce/2018/Industry-4-0-Implementation-and-Perspectives_Steel-Industry_Working%20document.pdf. Accessed on 20 November 2022

Romero D, Bernus P, Noran O, Stahre J, Berglund ÅF (2016) The operator 4.0: human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems. In: Rannenberg K (ed) IFIP advances in information and communication technology, vol 488. Springer, New York, NY, USA, pp 677–686

Schlegel P, Briele, K, Schmitt RH (2018) Autonomous data-driven quality control in self-learning production systems. In: Proceedings of the 8th Congress of the German Academic Association for Production Technology (WGP), Aachen, Germany, 19–20 November 2018

SMeART Making Europe's SMEs smart, Knowledge alliance for upskilling europe's SMEs to meet the challenges of smart engineering (2018–2020) The European Commission's ERASMUS+ programme. Project reference number: 575932-EPP-2016-DE-EPPKA2-KA. http://www.smeart.eu/en/about/. Accessed 10 November 2021

Spire-SAIS Skills Alliance for Industrial Symbiosis—A Cross-sectoral Blueprint for a Sustainable Process Industry SPIRE (2020–2024) The European Commission's ERASMUS+ programme. Project Reference number: 612429-EPP-1-2019-1-DE-EPPKA2-SSA-B Available online: https://www.spire2050.eu/sais. Accessed 25 November 2021

Ten REA, St S (2015) Digitaliseringens Betydelse för Industrins Förnyelse. En Rapport fr´ ln Teknikföretagen. Available via YUMPU. https://www.yumpu.com/en/document/read/54879334/digitaliseringens-betydelse-for-industrins-fornyelse. Accessed 15 November 2021

The Organisation for Economic Co-operation and Development, OECD (2014) Greener Skills and Jobs. In: OECD Green Growth Studies Greener Skills and Jobs. Available via OECD and CEDEFOP. https://www.oecd.org/greengrowth/greener-skills-and-jobs-9789264208704-en.htm. Accessed 10 November 2021

Tihinen M, Kääriäinen J, Teppola S, Parviainen P et al (2017) Tackling the digitization challenge: how to benefit from digitization in practice. Int J Inf Syst Proj Manag 5:63–77

Wang J, Ma Y, Zhang L, Gao RX, Wu D et al (2018) Deep learning for smart manufacturing: methods and applications. J Manuf Syst 48:144–156

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Identifying Future Skills for the Digital Transformation in the Steel Industry: An Ecosystem Analysis in the German Rhein/Ruhr Area

Adrian Götting, Clara Behrend, and Michael Kohlgrüber

1 Introduction

The impact of the increased use of digital technology on the world of work has become an important and controversial topic in public and political debate. Although a variety of factors, such as globalisation, demographic change or climate change, have an impact on work and human capital, much attention is paid in academic discourse to digitalisation in particular as a driver of change. It is expected that the digital transformation has and will have far-reaching consequences for employment and will lead to traditional job profiles changing, also affecting skills, with new demands for workers emerging (Gonzalez Vazquez et al. 2019: 10; Kirchherr et al. 2019: 2).

Thus, this chapter aims at examining the question of how digitalisation affects the skill demands of employees and managers. Especially with regard to the skills required of employees in the future, there is a great deal of need for discussion and a lack of clarity. This chapter thereby aims to make well-founded analyses of skill requirements. The topic of future skill demands is explored in the steel sector of the Rhein/Ruhr region, with a focus on the Düsseldorf administrative district in Germany. In order to categorise future skills, the skill classification of the BEYOND 4.0 project[1] will be used. This chapter thereby focuses on the categorised transversal skills, i.e. digital, personal, social and methodological skills needed for the digital transformation. Accordingly, it is expected that not only digital skills, but also non-digital skills will gain in importance in connection with a changed organisational structure, the increasingly fast pace of the working world and a related change in

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work culture. In the context of this chapter, skills shall be understood as “the stock of human capabilities that allow human beings to perform tasks” (Fernández-Macías et al. 2016: 30) and underpin the execution of tasks.

This chapter will show the results of a qualitative study conducted within the BEYOND 4.0 project with various company representatives and other stakeholders of the steel industry in the Düsseldorf administrative district. It approaches the question of which skills employees and managers need for digital transformation. Despite supra-regional corporate strategies, the administrative district level is a suitable unit of analysis when focusing on skill needs and skill supply. We thereby refer to the concept of entrepreneurial ecosystems, assuming that not only companies and start-ups but also other actors, processes and institutions such as universities and research institutions, the public sector in the form of business development and political actors, as well as educational institutions, banks and associations play a crucial role in the development of a sector within a region (Brown and Mason 2017: 15; Stam 2015).

Such close links between actors from different sectors of society (e.g. economy, public, research, civil society) could indeed be identified in the steel sector of the Düsseldorf administrative district. Following an ecosystem approach, steel-related stakeholders in the region, including company representatives, experts from the federal employment agency and regional employment agencies, business development agencies, chambers of industry and commerce as well as various research and educational institutions, were interviewed to share their expert knowledge on which skill demands for employees will arise as a result of digitalisation in the steel ecosystem. In total, 8 interviews were conducted and evaluated. In this way, concrete assessments of the questions were obtained from different perspectives in order to be able to qualitatively describe the effects of digitalisation on skill demands from a regional perspective.

2 BEYOND 4.0’s Categorisation of Future Skills

The determination of skill demands is fundamental in order to design skills supply appropriately and to teach the right skills, avoiding skill mismatches and operating on a common understanding of skill requirements among different stakeholder groups. The BEYOND 4.0 research project[2] offers an orientation in that matter. Within the framework of the project, a systematic literature research on future skills was carried out, on the basis of which a skill categorisation was developed. The literature reviewed did not necessarily refer to individual sectors, as the skill categorisation aims to present skills that apply to all sectors, and thus to the digital world of work in general. This categorisation serves as the basis for the empirical results of this chapter and structures the findings.

[2] The project BEYOND 4.0 has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 822296.

One finding with regard to the categorisation of future skills of the digital transformation was that not only digital, but also non-digital skills, in the form of personal (e.g. required personal traits, e.g. adaptability to technological changes), social (e.g. communication/collaboration) and methodological skills (e.g. problem-solving) gain importance in the course of the digital transformation while job-specific skills (including work experience) remain important (see explanations of the categories below; Kohlgrüber et al. 2021: 2). Within BEYOND 4.0's skills framework, primarily those non-digital skills were considered that tend to gain in importance across different professions in all sectors due to the influence of digitalisation (Kohlgrüber et al. 2021: 20).

The central role of ***digital skills*** is recognised in all the studies examined (e.g. Gonzalez Vazquez et al. 2019; Bughin et al. 2018; Kohlgrüber et al. 2021: 35). In this analysis, a distinction will be made between basic, moderate and advanced digital skills. It is a common result of different broader studies that basic digital skills are already important in most occupations and at all skill levels and will become even more important in the coming years (Kohlgrüber et al. 2021: 35; see also Cedefop 2020; Gonzalez Vazquez et al. 2019). Basic digital skills thereby mean basic computer skills like handling a mouse or scrolling up and down on screens and creating and reading digital documents. While moderate digital skills are mainly important in medium-skilled jobs and especially in jobs with administrative tasks, literature shows that advanced digital skills are particularly required for jobs of higher-skilled workers and are closely linked to job-specific skill demands. Moderate digital skills thereby refer to word-processing or creating documents and/or spreadsheets, while advanced digital skills refer to rather sophisticated tasks like programming (cf. Kohlgrüber et al. 2021: 35). Digital skills also include, among others, the use of digital devices, cybersecurity, the secure handling of data, including their analysis and interpretation, as well as the use of complex digital communication tools (Kohlgrüber et al. 2021: 33).

In the context of BEYOND 4.0, ***personal skills*** are understood as skills or rather personal traits that people need in order to fulfil their working tasks and to succeed in the modern world of work (Kohlgrüber et al. 2021: 35). Such personal skills include self-reflection, integrity, sense of responsibility, motivation, willingness to take risks and personal attitude, for example in the form of openness or values (cf. Abel 2018: 28). In close connection with openness, adapt to change is one of the most important personal skills in the context of the digital transformation, as is the ability to learn new skills. The basic assumption here is that further education and lifelong learning are becoming enormously important in the course of digitalisation (Janis and Alias 2018).

Social skills include all skills related to interpersonal interaction. They include basic communication skills such as the exchange of information as well as more complex social interaction skills such as skills for teamwork or other types of cooperation, intercultural skills, the coordination of social networks, conflict resolution strategies, teaching, mediating, negotiating and persuading as well as the knowledge of how to appear polite and friendly (Kohlgrüber et al. 2021: 36). Social skills are gaining in importance in the course of digitalisation, also due to a change in the organisation of work. At the same time, it is assumed that the demand for social skills will increase in the future, as these are skills that are difficult to automate from a technological point of view (Cedefop 2019 and Eurofound 2018). It is also expected that especially skills related to leadership and management, negotiation skills as well as interpersonal skills and empathy will gain in importance in the coming years (Bughin et al. 2018; DRIVES 2020).

Advanced ***methodological skills*** are needed to find strategic solutions to achieve a defined goal (Kohlgrüber et al. 2021, p. 36). For such a systematic approach, problems need to be analysed and understood before creative solutions can be found and prioritised. Problem-solving skills as well as creative and analytical thinking are required in this context (Abel 2018; OECD 2019). In addition, basic methodological skills such as literacy and numeracy are seen as important prerequisites for the acquisition of digital skills and form another category of methodological skills. Such basic methodological skills include also basic language skills and cognitive skills. They form the basis for lifelong learning (OECD 2019). In addition, basic methodological skills are crucial for individuals to benefit from the digital transformation. This is not least because these skills are essential for employability and make an important contribution to the inclusion of people in digitalised work processes (Kohlgrüber et al. 2021: 36).

Job-specific skills form another category with regard to future skills and are also part of the BEYOND 4.0 skills classification, even though they are not in the focus of this chapter. Such job-specific skills relate to the specific field of work, domain or occupation in question. In this way, job-specific skills form a counterpart to general or transversal skills, as they refer to the use of specific knowledge. However, the exact consideration of so-called job-specific skills, which are assigned to individual fields of activity, is difficult in the empirical analysis. Since there are myriads of different jobs and occupations, it seems difficult to gain an overview of the skills required for them. For this reason, in this chapter, job-specific skills are not considered in the empirical analysis.

3 Focusing on Steel in the Rhein/Ruhr Area

The Ruhr region and Düsseldorf administrative district are of particular importance as a steel location for various reasons: Even though the steel sector is now heading in a climate neutral direction with the aim of replacing coal with hydrogen, in the past (and to this day), coal played a significant role for steel production. The Ruhr region and the city of Duisburg have thereby always benefited from rich coal deposits in the region. Furthermore, Duisburg's location directly at the river Rhein makes it an ideal location for the production of steel (Röhl 2019: 49) and the import of more coal from other regions and countries. After all, the river can be used to transport bulk goods such as iron ore, which are also needed for steel production—the city's steelworks still obtain ores from Rotterdam via the Rhein.[3] The Ruhr region itself, which today is one of the most densely populated, largest conurbations in Europe, grew "around industry", so to speak (Hahn 2011: 43). Thus, the expansion of the transport infrastructure in the form of a rail and road network connecting the various locations preceded the population growth and urbanisation in the region.[4] The Ruhr area has developed over the decades into the largest steel region in Europe and the Ruhr region has established itself strongly in the metal industry.

Over the years, steel production in the Ruhr region and in general has changed drastically, even before digitalisation and decarbonisation. German steel companies are producing more and more efficiently. Labour productivity, measured in terms of crude steel production per employee, has almost tripled in the last 30 years (Küster-Simic et al. 2017: 19). Also, employment figures of the steel ecosystem show that there have been enormous staff cuts in recent decades: while the Duisburg coal and steel industry of the 1960s employed around 160,000 people, today this figure is around 21,000 (Berger 2007: 5). Despite this enormous decline in employment, the steel sector is still by far the largest employer in the city of Duisburg (Bundesagentur für Arbeit 2020). In addition to the depth of added value of the steel product, the high indirect employment of the sector, which is not included in the statistics, should be emphasised. If suppliers and other service providers are included, experts assume that a total of around 40,000 people are employed in the steel sector in the city of Duisburg.[5]

The city of Duisburg generally occupies a special position in the analysis of the ecosystem. However, the capital of North Rhine-Westphalia and eponym for the administrative district of Düsseldorf also plays an important role in the ecosystem. After all, for a long time, the administrative headquarters of numerous iron and steel producing companies as well as steel associations were located in the state capital Düsseldorf.

4 Empirical Findings on Skill Demands in the Steel Ecosystem

In the following, the empirical results on skill demands and changes in skill demands due to digitalisation from the qualitative interviews are summarised. The thematic focus is on skill demands in the steel ecosystem, the structuring element being the transversal skill categories defined in the BEYOND 4.0 project, which gain importance across different jobs and occupations. The results are divided into digital, personal, social and methodological skills.

[3] Expert intermediary, 08_12_2020.

[4] Expert intermediary, 08_12_2020.

[5] Expert intermediary, 08_12_2020.

Digital Skills

Overall, new tasks appear to be emerging at all skill levels in the steel industry as part of the digital transformation, which are accompanied by changed skill demands.[6] The focus should now first lie on those skill demands that relate directly to the use of digital technologies or technologies in general.

Based on the expectation of the experts surveyed, it appears that medium-skilled workers in various occupations and fields are confronted with new software and digital systems. The intensity and the question of whether basic, moderate or advanced digital skills are needed, varies depending on the occupational field. Changes affect office workers as well as skilled workers in production.[7] Digital skills will particularly be demanded at the level of production management and quality assurance, as complex tools are already being used in this area.[8] Skilled workers, accordingly, need an understanding of the function, operation and use of such technologies: "You cannot always use such technologies if you do not fulfil certain prerequisites. For this, of course, you have to understand how these technologies work and what you have to pay attention to. The demands on the employees on site then also increase".[9]

The steel experts interviewed expect high-skilled workers to have the highest requirements compared to other skill levels, while some interview partners assume that the demands for low-skilled jobs will not change dramatically in the near future.[10] One reason for this is that, from a companies' point of view, digital systems ought to be easy to use, especially for the low-skilled. As it can be deduced from statements of the expert of one of the research institutes of the ecosystem, which has specialised in the development of digital solutions for steel companies,[11] in many cases companies place high demands on the user-friendliness of digital technologies: "if [...] we come up with really great modern solutions, then the [steel plants] say, yes, that's all great, but then the simple man at the plant (...) must also be able to understand and operate them. That is why we (...) try to design the solutions in such a way that they are as simple as necessary and possible for the end user".[12] The aim is thereby to reduce the need for complex training courses on digital knowledge at the low-skilled level.[13]

One example for a digitalisation process that kept digital skill demand rather low are control terminals in steel plants and in the logistics halls of steel producers and steel processors that function similarly to smartphones, so that only basic digital skills are needed to use these devices by the operators.[14] For example, mobile terminals,

[6] Expert employee representative, 01_09_2020.

[7] Expert research, 27_04_2020.

[8] Expert research, 27_04_2020.

[9] Expert research, 27_04_2020, item 82a.

[10] Expert research, 27_04_2020; expert intermediary, 10_12_2020; expert company, 15_12_2020.

[11] Expert research, 27_04_2020.

[12] Expert research, 27_04_2020, item 82b.

[13] Expert employee representative, 01_09_2020.

[14] Expert company, 02_11_2020.

which are partly used in manufacturing by steel processors in the ecosystem, have Android interfaces. These types of interfaces are familiar to a large proportion of workers from everyday smartphone use. Yet, applications important in the work context differ from those on private smartphones, so their operation is still trained in the companies, but in a quick and easy way. Nevertheless, the focus here is on a user-friendly application and the attempt to reduce errors in dealing with new systems.[15]

Accordingly, low-skilled employees are primarily required to have basic digital skills. However, such basic skills are not only a prerequisite for low-skilled workers, but for all skill levels for working with digital technologies. Basic digital skills include the use of end devices such as tablets, smartphones, laptops and computers or basic knowledge of Microsoft Office.[16] The training of these basic skills is one of the most important tasks of various actors in the ecosystem, such as the employment agency, who has a mediating role between companies and training providers. Our respondents mentioned some challenges of providing basic digital skills as they are closely related to other basic skills. For example, methodological skills such as literacy and numeracy are essential for the acquisition of digital skills. In particular, language skills play a decisive role, so that teaching basic digital skills to migrants who do not have a certain level of German language skills is sometimes difficult: "We also have a large group of applicants with a migration background. We notice that digital skills would be important. But there is a step before that, namely the language component, which is also an issue for us […]. We would have potential and the means to qualify people, but oftentimes this is not possible due to the lack of language skills. Because of the language barrier, skilled people sometimes end up in unskilled jobs".[17] Here, the clear demand for language courses becomes obvious. Local employment agencies have increased the number of offered paid German courses for unemployed as a result.

Although digital systems are playing an increasingly important role in almost all areas, advanced digital skills are a prerequisite especially for highly qualified jobs. Thus, not only IT specialists, but also other occupational groups such as engineers are increasingly required to set up and to have an in-depth understanding of digital programmes, according to some experts.[18] Highly qualified as well as medium-skilled workers in the steel ecosystem are also increasingly confronted with new technologies in work systems, which leads to new skill demands, for example with regard to programming and the secure handling of data and data protection. Consequently, the share of jobs with a stronger focus on IT systems and programming is increasing in general.[19]

[15] Expert company, 02_11_2020.

[16] Expert intermediary, 10_12_2020.

[17] Expert intermediary, 10_12_2020, item 30.

[18] Employee representative, 01_09_2020; expert intermediary, 10_12_2020.

[19] Expert employee representative, 01_09_2020.

Personal Skills

Changes are taking place at a rapid pace in the digital transformation. According to the interviewed experts, employees are regularly confronted with new software, so that further education and ongoing training on new technologies are of great importance, especially at middle and higher skill levels. Lifelong learning is therefore becoming indispensable in the context of digitalisation, as programmes and digital systems are constantly being further developed and new digital elements are being integrated into companies at regular intervals. However, this statement does not only refer to the steel ecosystem, as this impression also seems to arise in other sectors: “We notice in the entire labour market that changes that used to take place within 15 years now happen within months”.[20]

As a prerequisite for the development of the necessary learning skills, employees are required to be open towards new technologies and willing to learn and to change.[21] At the same time, this also requires determination, courage and trust on the part of employees as well as managers. The more these qualities are present in organisations in the steel ecosystem, the better digitisation can be implemented as a major transformation topic, according to the experience of one of the company experts interviewed.[22] Accordingly, employees are required more than ever to recognise their own skill gaps and training needs. On the part of the employees, this requires a high degree of honesty and self-reflection in addition to proactivity and independence. This assessment of the interviewed experts was also confirmed by an in-house survey at one of the leading steel manufacturers in the ecosystem.[23] Overall, the experts share the assessment that further qualification and training, respectively lifelong learning along all skill levels of the steel ecosystem are gaining in importance due to the influence of digitalisation. Accordingly, personal skills, which enable lifelong learning, are becoming fundamentally important for all employees.[24]

At the same time, the leading companies in the steel ecosystem are characterised by low staff turnover. As a result, employees, even in the low-skilled spectrum, normally have a high retention rate in steel-producing and steel-processing companies, which in turn has a positive effect on the willingness of companies to provide further training.[25] The fact that employees stay longer in the company makes the investment in their further qualification “worthwhile” from the company’s point of view. In many cases, regional steel companies consequently rely on in-house further education and training, so that the requirements for potential applicants are manageable. An interviewee from a local steel SME states that a completed apprenticeship on low and partly also lower medium job profiles is therefore not necessarily a prerequisite for a worker in the company. However, certain basic characteristics are required in

[20] Expert intermediary, 10_12_2020, pos. 40.

[21] Expert company, 15_12_2020.

[22] Expert company, 15_12_2020.

[23] Expert network, 01_10_2020, expert intermediary, 10_12_2020.

[24] Expert intermediary, 10_12_2020.

[25] Expert company, 15_12_2020.

this context, which can also be described as personal skills, or rather, personal traits, including punctuality, diligence and reliability: "[T]he people we need have to be punctual, hard-working and reliable, and we teach them the rest",[26] as the company expert puts it. These prerequisites may sound self-evident, but various statements show how essential these qualities are and how difficult it seems to be, especially for smaller companies in the ecosystem, to recruit appropriate workers[27].

Accordingly, personal skills such as the ability and willingness to adapt to change can be seen as a prerequisite to acquire digital skills related to the operation of technologies, programmes and systems. It is precisely these personal skills that play a decisive role not only in high- and medium-skilled jobs, but also in the low-skilled end. Although basic digital skills are currently mostly sufficient for low-skilled jobs, employees at this skills level may also be expected to constantly familiarise themselves with new digital tools, so that further training and education is likely to become an issue for low-skilled workers in the future[28].

Social Skills

Social skills have not only been important since the emergence of the terms Industry 4.0, Industry 5.0 and digitalisation. Nevertheless, the digital transformation means that social skills are gaining in importance. Reasons for this include the changed organisation of work, which certainly does not affect all areas equally, but is nevertheless noticeable in many companies and departments. For example, topics related to digitalisation are often dealt with in interdisciplinary teams. The focus is thereby on project work, so that employees from different departments come together for a certain period of time to solve specific, internal company problems as is the case of one of the companies of our study[29]. This exchange between different professional groups has increased the demands on interdisciplinary teamwork. After all, the working methods and communication cultures of different professions are not always compatible, even within the company—employees from marketing, for example, have different thematic focuses, work content and technical jargon than engineers or IT specialists. Accordingly, interdisciplinary cooperation comes with various challenges. At the same time, digitalisation is also shaping contact with national and international customers. Through communication tools, web conferences can be held across national and continental borders. As a result, especially more highly qualified employees increasingly have contact with people from different cultural backgrounds.[30] Other drivers also play a role, such as globalisation. In the steel ecosystem and in the steel industry in general, company takeovers and mergers are

[26] Expert company, 02_11_2020, item 18.

[27] Expert company, 02_11_2020.

[28] Expert intermediary, 10_12_2020.

[29] Expert company, 15_12_2020.

[30] Expert intermediary, 01_09_2020.

not uncommon, with the strongest competitors in the industry coming from China, so that employees are also confronted with other cultures and ways of working.[31]

In addition, the importance of intensive customer contact is increasing in various sectors, including mechanical engineering. This is a development that has been ongoing for years and is accelerated by the use and possibilities of digital technologies, ultimately enabling the customer in the steel industry to intervene more and more in the design processes. As a result, the work pressure for employees increases, but also the communication requirements, as more and more people are involved in processes.[32] The interviewed company experts confirm that the end customer plays an increasingly important role in development processes and is optimally integrated into production and design processes. Communication and cooperation are thus becoming more important aspects of the modern working world for more workers than before.[33]

Social skills also include management skills. This point is also related to a changed organisation of work. Ultimately, forms of agile work are currently increasingly required, in which flat hierarchies are of great importance. According to the experts, the trend in companies with a high level of digital technologies is moving away from hierarchical structures towards cross-functional, cross-hierarchical work: "For many managers, it is a challenge how they should lead their team. Namely, via a technology that they sometimes have much less knowledge of than their team members. And if you are now in a culture where the boss always does everything best and if everyone believes that, then of course it is a problem. But our managers should also see their role more in coaching their team to success instead of being the one who brings solutions".[34] In this context, interviewed company experts emphasise that digitalisation should always be understood as a joint project, as various areas are important in the digital transformation. Accordingly, experts in technologies, for business aspects and for work organisation are also found in project teams. Ultimately, managers have the primary task of bringing these different roles together and promoting successful cooperation.[35] A high degree of empathy and sensitivity is thereby required on the side of managers. Nowadays, managers also have more and more the task of supporting the development of their employees, recognising needs and, if necessary, pointing out appropriate further training opportunities. Such a non-authoritarian leadership style seems to have already been implemented at least in the large steel plants of the Rhein/Ruhr ecosystem in the areas where digitalisation plays a role.[36]

[31] Expert intermediary, 10_12_2020.

[32] Expert employee representative, 01_09_2020.

[33] Expert company, 15_12_2020.

[34] Expert company, 15_12_2020, item 43.

[35] Expert company, 15_12_2020.

[36] Expert company, 15_12_2020; expert employee representative, 01_09_2020.

Methodological Skills

Methodological skills include basic skills such as logical thinking, numeracy and literacy as well as advanced methodological skills such as complex thinking, problem solving skills and creativity. Interviewed experts confirm that these skills are indispensable for the acquisition of digital skills and the handling of digital technologies.[37] These skills also play a role independently of digital skills, as they contain the prerequisites for the acquisition of further knowledge. Finally, as already mentioned, the in-house training of unskilled workers plays an important role in many cases, especially in the regional steel industry.[38] So-called lifelong learning is of great importance, which in turn requires methodical learning skills. If these prerequisites are met, even unskilled workers in steel companies have the opportunity to undergo training and further their professional development.[39] This impression is not only created by statements of interviewed experts from two companies, but also by assessments of other, company-external actors in the ecosystem. One of the company experts formulates it as follows: "We are a company that has almost no fluctuation. This is [...] good, because we have an infinite amount of time to develop our people. That means that when we hire people, it's partly not a question of what they can do, but what they are capable of learning. We can train the people, so there are hardly any bad investments. It's different when the average length of stay of the employees is 3 years, of course you have to ask yourself whether it's worth investing".[40]

The methodological learning skills that are essential for lifelong learning are becoming more important in the course of the digital transformation. Work content is changing at a rapid pace due to the influence of digitalisation. As it is difficult under such pressure of change to impart concrete digital knowledge on the long term, for example related to the function of a particular system, employees are more than ever required to develop methods that enable lifelong learning.[41] In this context, experts observe that learning skills are more likely to be present in employees who have completed a degree or training and that it is therefore easier for them to familiarise themselves with new systems and structures at these levels: "The higher my skills are, and also my human capital, the higher the possibilities are to prepare myself for other things and to be retrained".[42] This also has an impact on recruitment processes in the steel ecosystem, as it is assumed in this context that disadvantaged labour market groups such as unemployed and unqualified workers lack learning skills and that the acquisition of digital skills as well as dealing with change will therefore be all the more difficult for them.[43] The increasing demand for skilled workers in the steel ecosystem therefore can also be explained by the fact that completed training has

[37] Expert intermediary, 10_12_2020.

[38] Expert company, 02_11_2020.

[39] Expert company, 15_12_2020.

[40] Expert company, 15_12_2020, item 17.

[41] Expert intermediary, 10_12_2020.

[42] Expert intermediary, 10_12_2020, item 11.

[43] Expert intermediary, 10_12_2020.

become more important against the backdrop of these developments, as it is expected "that someone with a completed training is also able to acquire company-specific knowledge more easily".[44]

Learning skills are closely related to flexibility and the ability to adapt to new circumstances and respond to change. In this context, analytical skills are also important, which are required in various areas, especially at higher skill levels.[45] For low-skilled employees, the pressure for education and further training is lower in comparison. However, it is evident that influences such as digitalisation, globalisation and internationalisation of markets lead to changes in forms of work and the labour market, so that skills will also require regular updates in the low-skilled end, at least with regard to future prospects, and therefore, methodological skills as well as lifelong learning play a role at all skill levels.[46]

As digitalisation is accompanied in many places by changed processes and a changed organisation of work, the demands on the self-organisation of employees are increasing. Ultimately, digitalisation is also associated with new autonomy and more flexibility on the part of employees, which in turn leads to new demands on employees' skills to organise themselves. Employees are required to recognise training and further education needs as well as weaknesses and deficits on their own. "Thinking outside the box" and developing an understanding for one's own work are thereby demanded.[47]

The use of digital technologies in various areas can reduce complexity and lead to simpler work processes; however, paradoxically, it becomes particularly complicated when problems arise in situations that do not correspond to routine work processes. In these cases, methodological skills such as problem-solving skills, understanding of systems, expertise and experience are particularly in demand.[48]

5 Conclusion

The empirical material of BEYOND 4.0 project, in which steel industry experts of the Rhein/Ruhr area were interviewed, illustrates the importance of non-digital skills in connection with digital skills. Digital skills, at least in basic form, are playing an increasingly important role at all qualification and skill levels. However, it is above all the requirements for the continuous learning of new skills in dealing with digital systems and software that play a special role. Personal skills, such as willingness to change and adaptability, as well as intrinsic motivation to increase one's own level of digital skills are particularly important. In this respect, different skill categories are interacting with each other. Many of the non-digital skills can be seen as a

[44] Expert intermediary, 10_12_2020, item 15.
[45] Expert intermediary, 10_12_2020.
[46] Expert intermediary, 10_12_2020.
[47] Expert employee representative, 01_09_2020.
[48] Expert employee representative, 01_09_2020.

prerequisite for the learning of digital skills. This becomes particularly clear with the methodological skills numeracy and literacy, without which it is difficult to learn digital skills.

A central finding with regard to the skill demands in the steel ecosystem are the challenges that arise from the fast pace of digitisation. This fast-moving nature means that it is difficult to impart specific knowledge, especially in dealing with digital technologies, because the software and tools used change at regular intervals.[49] As a result, non-digital skills are particularly in demand. The fast pace of digitisation has an effect above all on methodological and personal skill demands. Here, in addition to openness, the motivation and willingness to learn seems to be important for employees at all skill levels. At the same time, requirements for skills that enable lifelong learning, such as personal skills, are also increasing.[50] Some of the experts interviewed emphasise that skilled workers and highly qualified people in particular are more likely to be trusted with these personal and methodological skills. In this context, the training or university degree is seen as evidence that the respective persons have the necessary learning skills and the necessary adaptability to better cope with change.[51] This could indicate that formal educational qualifications will become even more important against the backdrop of digitalisation and increase the disadvantage of the low-skilled on the labour market or that some form of certification of being an apt learner might be needed.

The degree to which digital skills are needed varies greatly depending on the skill level of the employee. For example, more digital skills are needed for higher skilled employees, while the challenges are less at lower skill levels. Experts in the steel ecosystem report that especially in the low-skilled sector a lot of value is placed on a high level of user-friendliness of digital solutions.[52] It is questionable to what extent this development is also evident at other skill levels. Ultimately, in some cases this could lead to a loss of importance of skilled work, especially in the medium-skilled sector, not necessarily with regard to formal educational qualifications, but with regard to the actual work tasks. In a second step, this could of course also have an impact on job advertisements and thus ultimately on formal qualification requirements. The described user-friendliness speaks rather against an "upgrading" of low-skilled jobs caused by digitalisation at this moment in time, but rather for the fact that employees at this level are not confronted with demands for advanced or even moderate digital skills despite the increasing use of digital technologies. In contrast, according to the experts, the demands for advanced digital skills are increasing for highly qualified employees.[53] With the next waves of digitalisation this situation might change, as still more aspects of the production process get digitalised and ask for appropriate digital skills, also on the shop floor.

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[49] E.g. expert intermediary, 10_12_2020.

[50] Expert intermediary, 10_12_2020.

[51] Expert intermediary, 10_12_2020.

[52] E.g. expert research, 27_04_2020.

[53] E.g. expert employee representative 01_09_2020.

References

Abel J (2018) Kompetenzentwicklungsbedarf für die digitalisierte Arbeitswelt. Forschungsinstitut für gesellschaftliche Weiterentwicklung (FGW), Düsseldorf

Berger F (2007) Regionen, Staaten und Europäische Gemeinschaft angesichts der industriellen Krisen: der französische und deutsche Stahlsektor im Vergleich. Institut für politische Wissenschaft

Brown R, Mason C (2017) Looking inside the spiky bits: a critical review and conceptualisation of entrepreneurial ecosystems. Small Bus Econ 49:11–30

Bughin J, Hazan E, Lund S, Dahlström P, Wiesinger A, Subramaniam A (2018) Skill shift. Automation and the future of the workforce. McKinsey Global Institute. https://www.mckinsey.com/featured-insights/future-of-work/skill-shift-automation-and-the-future-of-the-workforce

Bundesagentur für Arbeit (2020) Brancheneinschätzung Herbst 2020. Faktencheck zum Arbeitsmarkt. https://arbeitsmarktmonitor.arbeitsagentur.de/faktencheck/branchen/tabelle/552/866/?r=&c=2%2C3%2C5%2C14%2C16%2C8%2C10

Cedefop (2019) Skills panorama: most requested skills in job vacancies in the EU. https://skillspanorama.cedefop.europa.eu/en/indicators/skills-online-vacancies?&utm_content=dashboard&utm_source=sendinblue&utm_campaign=OJV&utm_medium=email

Cedefop (2020) Vocational education and training in Europe, 1995–2035. Publications Office of the European Union. Luxembourg (Cedefop Reference Series, 114)

Cedefop and Eurofound (2018) Skills forecast: trends and challenges to 2030 (Cedefop Reference Series No. 108). Luxemburg. http://data.europa.eu/doi/10.2801/4492

DRIVES (Ed) (2020) Skill Needs and Gaps: Deliverable 2.8. https://www.project-drives.eu/Media/Publications/19/Publications_19_20200323_215437.pdf

European e-Competence Framework 3.0 (2014) Building the e-CF–a combination of sound methodology and expert contribution. Methodology documentation of the European e-Competence Framework. CEN

Fernández-Macías E, Hurley J, Bisello M (2016) What do Europeans do at work? A task-based analysis: European Jobs Monitor 2016. https://www.eurofound.europa.eu/sites/default/files/ef_publication/field_ef_document/ef1617en.pdf

Gonzalez Vazquez I, Milasi S, Carretero Gomez S, Napierala J, Robledo Bottcher N, Jonkers K, Goenaga X (Hrsg) (2019) The changing nature of work and skills in the digital age. EUR 29823 EN, Publications Office of the European Union, Luxembourg

Hahn H-W (2011) Die Industrielle revolution in Deutschland, 3rd ed, vol 49. Oldenbourg Verlag, Müchen

Janis I, Alias M (2018) A systematic literature review: human roles, competencies and skills in industry 4.0. In: 2017 Asia International Multidisciplinary Conference (ed) The European proceedings of social & behavioural sciences. Future Academy, pp 1052–1072. https://doi.org/10.15405/epsbs.2018.05.84

Kirchherr J, Klier J, Lehmann-Brauns C, Winde M (2019) Future skills: Welche Kompetenzen in Deutschland fehlen. Diskussionspapier 1. Essen

Kohlgrüber M, Behrend C, Cuypers M, Götting A (2021) Understanding future skills and enriching the skills debate. BEYOND 4.0, Horizon 2020, GA-No. 8222293

Küster Simic A, Gül O, Lauenstein P (2017) Branchenanalyse Stahlindustrie. Entwicklungstrends und Zukunftschancen. Hans Böckler Stiftung

OECD (2019) OECD skills outlook 2019: thriving in a digital world. OECD Publishing, Paris. Source https://doi.org/10.1787/df80bc12-en

Pfeiffer S, Lee H, Zirnig C, Suphan A (2016) Industrie 4.0 - qualifizierung 2025. Frankfurt am Main. https://www.sabine-pfeiffer.de/files/downloads/2016-Pfeiffer-Industrie40-Qualifizierung2025.pdf

Röhl K-H (2019) Das Ruhrgebiet: der anhaltende industrielle Strukturwandel im Spiegel der Regionalpolitik. Wirtschaftsdienst, pp 49–55

Stam E (2015) Entrepreneurial ecosystems and regional policy: a sympathetic critique. Eur Plan Stud 23(9):1759–1769

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Conclusion: Recasting the Future of the European Steel Industry

Tugce Akyazi, Aitor Goti, Elisabete Alberdi, Clara Behrend, Antonius Johannes Schröder, Valentina Colla, Dean Stroud, Luca Antonazzo, and Martin Weinel

When the European Coal and Steel Community (ECSC) was established in 1952 to unite European countries economically and politically to secure long-lasting peace, steel production was one of the two main strategic industries in which a common European project was first launched. Today, the steel industry still represents a critical asset for the European economy and contributes to the development of a huge number of transforming industries, in particular the automotive, construction and infrastructure, robotics, advanced machinery and tools, and household appliances sectors. During the period till the end of the ECSC in 2002 and then beyond into the new millennium, the steel industry in Europe more broadly and within the EU has gone through significant waves of expansion, consolidation, modernisation, rationalisation and shrinkage, and it is currently facing tremendous pressures and challenges (see Chap. 2).

The EU steel industry has been dealing with urgent issues, such as overproduction, dumping from non-EU competitors, protectionist measures, high energy prices and serious environmental concerns:

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- The mid-to-long-term goal of achieving carbon neutrality presents one source of pressure for EU steel companies. Having already halved energy usage and CO_2 emissions since the 1960s, the self-conception and mission of the industry is to help the EU to reach its Paris Agreement climate change commitments.
- The last decade was characterised by increasing worldwide steel production capacities that led to growing imports in the EU, which in turn led to overcapacities in the EU steel market.
- Pressure also results out of the need to respond to the demands of the key customers of the steel industry e.g. the EU automotive industry as they transform their products and/or business models.
- Digitalisation presents the steel sector with incredible opportunities in the long term, but the implementation and integration of the smart technologies is nevertheless a big challenge for the industry. Not least, the international response to the COVID-19 pandemic has been to accelerate industrial digitalisation across the entire manufacturing sector through existing or new horizontal measures, which has created further pressure on the steel sector.
- Imported raw materials prices for steelmaking have become more volatile in recent years.
- The EU steelmakers have also been affected tremendously by the consequences of the ongoing war in Ukraine since the war has increased energy prices and accelerated inflation and raised interest rates the central banks.
- An aging workforce and scarcity of skilled labour are further challenges faced by the EU steel sector.

This volume (and conclusion section) explores some of these challenges aiming to offer reflections and recommendations to the various stakeholders involved in the industry, as well as insights to researchers interested in the transformation of the sector.

Despite all the challenges, the ambition of the European steel sector is to become the most advanced steel industry in the world. The European Steel Technology Platform (ESTEP) describes the vision for the EU steel industry up to 2030 anticipating major changes, many of which will be driven by new scientific and technological developments, evolving customer and stakeholder demands, and the ambitious European climate goals. Resilience has progressively (and rightfully) become a major concern in national and international debates and policies. To achieve industry resilience for the EU steel sector, current and future research needs to be focused on innovative techniques, such as more modular production lines, remotely operated factories, use of new materials, and real-time risk monitoring and management. In this context, digital technologies will enable resilience-enhancing approaches, such as data gathering, automated risk analysis and automated mitigation measures.

To date, the sector has taken significant steps towards Industry 4.0 and evolving into a smart industry, even though the steel industry has been recognised as a mature sector with relatively minor technological updates, compared to, say, automotive for example. Steel companies are digitising their manufacturing processes by integrating 4.0 technologies into the melting, casting, rolling and finishing sub-processes. The manufacturing models are changing with the adoption of smart technologies such as Internet of things (IoT), Artificial Intelligence (AI), robotics, predictive maintenance and so on. The use of digital technologies is resulting in a new stage of automation, which enables more efficient and creative processes, products and services. In addition, the adoption of new technologies aims at improving energy efficiency and at monitoring and controlling environmental impacts (see Naujok and Stamm 2017).

The digital transformation of the steel industry together with strong demands to put the sector on a more environmentally sustainable footing and to align with European climate objectives represent the main drivers for increasing energy and resource efficiency and contributing to keeping materials in use for a longer time. The European steel sector has been undergoing continuous and considerable changes due to these key factors in the last years. The sector's digital transformation and its move towards a circular economy can further be supported by exploiting synergies between the different EU initiatives. Moreover, as the European steel industry continues to face substantial challenges, it is imperative that a coordinated effort of unions and employers is directed towards achieving net zero emissions (Antonazzo et al. 2021a). It is more essential than ever that unions work together with employers as the industry takes on, perhaps, the greatest challenge it has ever faced.

A new relationship between environmental sustainability and competitiveness is emerging. The simple externalisation of costs associated with pollution and nature depletion is no longer an option. Changing consumer demands and societal values, together with a regulatory environment that makes unsustainable steel production more and more costly, offer an opportunity for the European steel industry to increase its competitiveness by embracing sustainable production regimes. Costs related to energy transition and the EU environmental legislation represent, on the one hand, two pressure factors for the EU steel industry as they constitute a significant share of fixed costs compared to global competitors. On the other hand, in the last few decades, these policies and legislation have represented drivers for companies to adopt measures and solutions for facilitating innovation to stay competitive. New relationships between environment and industrial competitiveness have recently been mainly based on innovative solutions to achieve both environmental protection and industrial competitiveness (Eurofer 2023). And these new relationships are backed up with policies and legislation.

Of course, not all regulations are beneficial to the industry. Some specific regulations and policies, although encouraging the implementation of innovative measures in the steel sector, can limit the industry. The key to overcome these potential disadvantages for EU steel companies is to have clear, consistent, and less bureaucratic legislation and policies as well as economic incentives. Increasingly stringent environmental legislation represents a push factor for the steel sector to implement digital technologies for coping with energy demands, improving energy efficiency and adopting low-carbon energy systems (Antonazzo et al 2021a; Eurofer 2023). The transformation of processes through digital technologies (e.g. through the adoption of high-performance components, machines and robots to optimise the materials and energy consumptions) can help to significantly reduce emissions and improve resource efficiency, by optimising materials and energy consumption.

As argued in various chapters of this volume, the ongoing transformation of the steel industry does not involve only a technological dimension but needs to be accompanied by a complementary process of social innovation that recognises that technical fixes need to be run within an adequate and supportive social framework. As it has been noted in this volume, the technological transformation will entail a social one too and the need, for example, to recruit, retain and develop a highly skilled workforce (by means of, for instance, addressing the industry's poor image to attract new talent, develop iterative upskilling and shift the focus of training from solely technical to include more in the way of transversal skills at all levels, etc.). It is noted, moreover, that the industry's social transformation is not only determined by technological innovations and questions of sustainability alone, but is part of interrelated processes of globalisation, internationalisation, privatisation, rationalisation and restructuring, among other pressures (e.g. Fairbrother et al 2004; Eurofer 2022. See Chaps. 2 and 3 of this volume, for example).

The recently proposed EU Industry 5.0 approach envisions a way to overcome some of the challenges addressed in this volume, along with the social innovation that the EU steel industry is confronted with. While in Industry 4.0 technologies are deemed to have an inherently transformative potential, the Industry 5.0 concept flips the perspective and provides a holistic framework that emphasises the importance of environmental and social elements when it comes to implementing Industry 4.0 technologies. It highlights not only a sustainable and resilient industry but also the human-centric orientation, developing technology for people and at the same time addressing societal challenges. As Chap. 3 notes, what is needed is an overview of the state of the art and the preconditions for integrating the Industry 5.0 perspective (human-centric, resilient, sustainable) and a framework for engaging stakeholders, raising awareness, increasing acceptance, gathering and exchanging good practices, enabling policy and regulations, developing indicators and so on.

What emerges is the need for an evidence-based and long-term management of the European industry workforce and skill needs, which accounts for an inclusive working environment and empowered workforce strategy to build a human-centric European industry. Multi-level and multi-stakeholder governance that engages the relevant societal domains (industry, policy, research and education, civil society) is the necessary ground for setting the foundations for a comprehensive social innovation process and an Industry 5.0 roadmap. As such, the transformation of the European steel industry might well be led in many ways by 'science' and technological innovation, but its people must be part of the journey too–it requires a social consensus on the direction it takes.

Furthermore, what many of the chapters in this volume have focused on is that to realise a healthy, digital, green and social transformation, the industry requires the right people and the right skills. To meet the industry's future challenges it must be cognisant of, and active on, demographic changes occurring in the sector, and focus on recruiting and developing a multi-skilled and competent workforce (White Research et al. 2020). The workforce needs to be skilled and qualified to handle the implementation of smart technologies, contemporary business models and organisational structures. This is only possible through: (1) upgrading the skills, knowledge and credentials of the current workforce and (2) recruiting new talents.

A workforce with updated skills is key for the steel sector to keep up with growing digitalisation, and to adapt to green transformation and novel working systems. The initial step of this continuous re-skilling and up-skilling of the workforce is addressing the current skills needs and trends, as well as foreseeing future ones. Once the anticipated evolution of skills needs is identified, a long-term methodology may be established for reducing the skills gap between the industry expectations and the current workforce. Such a methodical approach would ideally provide tools for the recruitment of new talents, as well as introduce well-designed education and training infrastructure developed by society-wide effort, and redesign work processes (see Chap. 12).

The steel industry has already invested considerable sums in innovation and in research and development. At the same time, it is (and will continue to be) necessary to invest in the current and future workforce. Considering that it will be a relevant investment, it will be necessary to involve in future educational activities not only steel companies, but also national public education authorities, training and education providers, so that these correspond to the current requirements for an educated workforce of steel and metallurgical companies. At the same time, it will be critical to introduce concepts of lifelong learning on the part of employees, who will have to continuously respond to new concepts and production changes that are constantly coming.

Research from ESSA and other projects presented within this volume, as well as the reflections offered by industry professionals, has pointed out how many workers in the industry still lack adequate digital skills despite the increasing digitalisation of workplaces. One of the perhaps more interesting arguments presented in this volume is the importance of (non-digital) transversal skills in connection with digital (Anotonazzo et al., 2021c). Digital skills, at least in their basic form, are playing an increasingly important role at all qualification and skill levels. When it comes to higher digital skills (e.g., programming), however, the degree to which these are needed varies greatly depending on the skill level of the employee. For example, stronger digital skills are needed for higher skilled employees, while the challenges are less demanding at lower skill levels.

The research presented in this collection demonstrates, however, that the acquisition of digital skills depends on the prior acquisition of transversal or soft skills such as the willingness to change, autonomous learning and adaptability, as well as intrinsic motivation to continuously improve and adapt one's competence and skill levels are particularly important in this respect. As many different types and forms of skills interact with each other, many of the non-digital soft skills can be seen as a prerequisite for the learning of digital skills. This becomes particularly clear with the methodological skills numeracy and literacy, without which it is difficult to acquire digital skills. Another central finding with regard to the skill demands in the steel ecosystem are the challenges that arise from the fast pace of digitisation. This fast-moving nature means that it is difficult to impart specific knowledge, especially in dealing with digital technologies, because the software and tools used change at regular intervals. This, once again, puts emphasis on the importance of soft skills (Antonazzo et al. 2021c).

Continuous learning and the reskilling and upskilling of the workforce rely in part on robust company programmes (e.g. on-the-job training). But the foundations rest on the development of well-designed Vocational Education and Training (VET) programmes devised to minimise the skill gap between the workforce and job profiles. VET programmes are required to provide theoretical knowledge, specialised technical skills, basic and advanced digital skills, and a wide range of soft skills (social, methodological, personal, etc.), along with on-the-job training to consolidate learnings. The 'human capital 4.0' approach proposed by Flores and colleagues is intended accordingly as a 'holistic shift in terms of competence, well-being, education and innovation' (Flores et al. 2020). In line with this, Chap. 11 calls for a holistic shift in vocational education and training to enhance workers' adaptivity, as well as businesses innovation and resilience (see Antonazzo et al. 2021b).

The Covid-19 pandemic has also permanently changed the training approach of the steel companies. Fortunately, accelerated digitalisation in recent years has provided companies with the opportunity to improve their asynchronous training programs and provide new training opportunities for greater numbers of attendees through remotely delivered content by using software tools such as Teams or Zoom.[1]

Recruiting new talents is another key to build a highly capable steel workforce, in addition to upgrading the skills of the current employees. The age structure in most European steel-producing companies is such that more than 25% of the workforce will leave the industry in the period 2020–2030. Therefore, to ensure competitiveness, attracting top talents to the EU steel industry is vital. However, it is first of all essential to pro-actively respond to talents' needs and expectations (on both professional and personal aspects) by developing suitable work-life balance models. In addition, with a negative public image and an uncertain economic future, the steel industry in the EU does not look like a prospering and attractive place to work to potential future employees even if they have a personal affinity to steelmaking as a secure job and a good economic outlook are important criteria when choosing an employer (White Research et al. 2020).

With these obstacles in mind, it is important to highlight the positive opportunities and chances for a career in the European steel industry, to counter-balance negative public perceptions. Therefore, the industry needs to step up its efforts in communication with the public and with potential candidates and to send a clear message: the European steel industry is a high-tech employer with state-of-the-art production facilities, strong research and development departments and develops sustainable solutions for its customers. It has a great opportunity to create exciting and innovative jobs and to communicate the upcoming innovative technological developments.

For better and more sustainable products in our future world, steel, due to complete recyclability and versatile properties, is and will remain indispensable. However,

[1] One example of this comes directly from the ESSA project and the *steelHub* developed in cooperation with Worldsteel (Steel University), which provides a repository of technical and transversal training programmes for many different roles within the industry.

the European steel industry will still have to deal with unequal conditions on the global market, unfair competition, overcapacity, protectionism, problems with the supply of raw materials. But an educated workforce and investments in research and development will support the transition to a greener and more sustainable steel production, and increase the potential for a competitive position on world markets. It becomes clear that the transformation of the steel industry needs to go in the direction of environmental and social sustainability, jobs and production stability, enhanced resilience and a skilled workforce.

References

Antonazzo L, Stroud D, Weinel M, Dearden K, Mowbray A (2021a) Preparing for a just transition: meeting green skills needs for a sustainable steel industry. Community/Cardiff University

Antonazzo L, Stroud D, Weinel M (2021b) Institutional complementarities and technological transformation: IVET responsiveness to industry 4.0-meeting emerging skill needs in the European steel industry economic and industrial democracy. https://doi.org/10.1177/0143831X211059227

Antonazzo L, Weinel M, Stroud D, Szulc W, Paduch J (2021c). Identification of national (sector) VET qualification and skills (regulatory) frameworks for stee (ESSA Deliverable No. 4.1). https://www.estep.eu/assets/Uploads/ESSA-D4.1-Identification-of-National-Sector-VET-Qualification-and-Skills-Regulatory-Frameworks-for-Steel-Version-2-final.pdf

Eurofer, (2022) Press release: upcoming decisions crucial to test EU determination to keep industry in Europe. European Steel Association (Eurofer), Brussels

Eurofer (2023) Position paper: an EU industrial policy providing a strong business case for green investment in Europe. European Steel Association (Eurofer), Brussels

Fairbrother P, Stroud D, Coffey A (2004) The European union steel industry: from a national to a regional industry. Working paper. Cardiff University, Cardiff

Flores E, Xun X, Yuqain L (2020) Human capital 4.0: a workforce competence typology for industry 4.0. J Manuf Technol Manag 31(4):687–703

Naujok N, Stamm H (2017) Industry 4.0 in steel: status, strategy, roadmap and capabilities. In: Keynote Presentation Future Steel Forum. Warsaw

White Research, Intrasoft International, Rina Consulting, Valeu Consulting, with Gibellieri E, Schröder A, Stroud D (2020) Blueprint for sectoral cooperation on skills: towards an EU strategy addressing the skills needs of the steel sector. Publications Office of the European Union

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Index

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