Conclusion: Recasting the Future of the European Steel Industry

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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.

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