European Commission

Industry 5.0

Towards a sustainable, human-centric and resilient European industry

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Industry 5.0

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Towards a sustainable, human-centric and resilient European industry

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Policy brief

2021 Directorate-General for Research and Innovation EN

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FOREWORD

"In the middle of difficulty lies opportunity." (Albert Einstein)

What drives innovation? On the one hand, it is driven by blue-sky research where discoveries often find applications that innovate our existing practices. On the other, it is driven by society's evolution itself; we adapt to emerging societal needs and realities by searching for and implementing new solutions. Industrial policy should provide the best conditions for innovation to flourish and to give it direction so that our society benefits, that no one is left behind and that we respect the boundaries of the planet.

Ever since the first industrial revolution, industry has been an engine for European prosperity. Industrial development has had a tremendous impact on European society, perhaps more so than any domain of human effort. Policy-makers and regulators have needed to channel and mitigate negative consequences, while ascertaining as many citizens as possible could share in its benefits.

Innovation shows no signs of slowing down. European industry continuously needs to innovate to stay competitive. Now more than ever, we need to invest in the future, to overcome the economic challenges posed by the coronavirus crisis, and to establish a "new normal" with a more competitive, more sustainable and greener European industry.

It is our role to steer this new wave of innovation. We need to make sure industry's evolution is in line with our priorities, including the European Green Deal, Europe Fit for the Digital Age and an Economy that Works for People. Becoming the world's first climate-neutral continent is both a challenge and an opportunity. It involves redesigning our economy, updating our industrial policy and investing in research and innovation. The twin green and digital transitions require new technologies, with investment and innovation to match.

We will have a variety of tools to make this happen, notably the Recovery and Resilience Facility of Next Generation EU and Horizon Europe, the next EU research and innovation programme. Policy initiatives such as the European Research Area are specifically aimed at accelerating the diffusion of new technologies, making sure they benefit the economy and wider society, across Member States, regions and cities.

However, more is needed. This concept paper puts forward a coherent vision for the future of European industry. We call it "Industry 5.0". This vision recognises the power of industry to achieve societal goals beyond jobs and growth, to become a resilient provider of prosperity, by making production respect the boundaries of our planet and placing the wellbeing of the industry worker at the centre of the production process. It complements the existing "Industry 4.0" paradigm by having research and innovation drive the transition to a sustainable, human-centric and

resilient European industry. It moves focus from solely shareholder value to stakeholder value, for all concerned.

We are at the beginning of this transition. Success depends on the widest possible engagement and action of all stakeholders. I therefore sincerely hope that this paper inspires you to engage within your community. I am looking forward to your feedback.

Mariya Gabriel
Commissioner for Innovation, Research, Culture, Education and Youth

1 Introduction

Industry[i] is the single biggest contributor to the European economy, providing jobs and prosperity across the continent. Between 2009 and 2019, industry constantly accounted for around 20% of EU GDP[ii], with manufacturing in particular adding around 14.5% of value to the EU economy[iii]. European industry is strong, but faces constant challenges. It is highly competitive, but operates in an increasingly complex globalised economy. It is a solid exporter, but is exposed to a fast-changing geopolitical landscape. It is efficient and cost-effective, but vulnerable to hick-ups in long value chains.

In order for industry to continue to bring prosperity to Europe, it needs to adapt itself continuously, to tackle these ever-changing challenges. This sustained adaptation is only possible through ongoing innovation. By innovating, European industry can improve its efficiency at different places in the value chain even further, increase the flexibility of its production systems to cater to the quickly changing demands of the global consumer, and continue to be a global reference for quality. In no small part, innovation will come from applying ever-more advanced digital technologies. Sensor technologies, big data and artificial intelligence (AI) are increasingly automating, interconnecting and optimising a wide range of industrial processes, and this innovation will continue to accelerate.

The highly transformative impact of a digital, data-driven and interconnected industry is bolstered in the concept of "Industry 4.0", likening this change to a fourth industrial revolution. Industry 4.0 represents a solid ambition and a sound guiding principle for the innovation and further technological development of European industry in the not-too-distant future. For all its merits, Industry 4.0 is primarily a techno-economic vision, indicating how more general technological advancements, often originated in non-industrial contexts, will be brought to bear on industrial value chains and how they will change industry's economic position. It describes how industry will use technology to cope better in a changing world and economy, and we believe it does this very well.

However, a wave of change in industry will have ripple effects that reach far beyond the technological change on the factory floor. A transformed industry will have a transformative impact on society as well. This is foremost true for industry workers, who may see their role changed or even threatened. Changing roles and increased reliance on complex technologies will require new skills. Will workers be empowered in their industrial work and attracted to work in new high-tech environments? More profound changes in how the workforce is organised will present themselves, challenging industry workers' traditional education life cycle of training, work and retirement. Increasing automation may undermine industry's societal role as an employer and engine of prosperity.

We believe the advent of these changes and questions closely linked to technological innovation will require industry to re-think its position and role in society. As European industry has vastly improved the lamentable situation of factory workers

depicted in Chaplin's "Modern Times" over the course of the last century, it should steer the ongoing and upcoming changes to mitigate, once again, fears of workers becoming enslaved by machines.

Conversely, changes and transitions on the wider societal stage will have a profound impact on industry as well. When looking at the current political priorities at European level, their impact on industry is not to be underestimated. The Green Deal will require a transition to a more circular economy, as well as increased reliance on sustainable resources including energy. "Europe Fit for the Digital Age" makes digital a priority for Europe and will offer great innovation potential. The re-invigorated European Research Area (ERA) will interconnect and boost research and innovation in Europe, while the new European Industrial Strategy and Skills Agenda seeks to address skills shortages.

The Covid-19 crisis has highlighted the need to re-think existing working methods and approaches. It has exacerbated the vulnerabilities of our industries, such as fragile strategic value chains, and super-charged the need to find flexible yet robust innovations to address these vulnerabilities. We find ourselves at a decisive moment, in which some of the "old normal" will crumble and a "new normal" will emerge. This transition could be a window of opportunity for us to actively shape and renew the role of industry in society. This will require a pro-active, purpose-oriented approach, rethinking the paradigms underlying our understanding of how societies, economies and industries function.

In this paper, we set out to explore what such a renewed European "Industry 5.0" may look like and how it could make our industries more future-proof, resilient, sustainable and human-centred. We look at some ways in which technological innovation can be deployed to support a better fit and "win-win" interaction between industry and society, shifting focus from shareholder to stakeholder value. We investigate how Industry 5.0 could benefit rather than threaten industry workers, while respecting planetary and social boundaries (like in the “Doughnut Economics” concept)[iv].

Our purpose is to kick-start a wider debate on the shaping of Industry 5.0, adapted to the European context. To do so, this concept paper explores emerging drivers for the industry of the future, with an emphasis on the perspective of the industry worker. We do not distinguish between "blue collar" and "white collar" workers; in Industry 5.0, the lines between different types of industry workers are blurred. European values and fundamental rights should be binding principles, including respect for privacy, autonomy, human dignity and general workers’ rights.

It is important to stress that Industry 5.0 should not be understood as a chronological continuation of, or an alternative to, the existing Industry 4.0 paradigm. It is the result of a forward-looking exercise, a way of framing how European industry and emerging societal trends and needs will co-exist. As such, Industry 5.0 complements and extends the hallmark features of Industry 4.0. It emphasises aspects that will be deciding factors in placing industry in future European society;

these factors are not just economic or technological in nature, but also have important environmental and social dimensions.

The concept of Industry 5.0 was discussed amongst participants from research and technology organisations as well as funding agencies across Europe in two virtual workshops organised by Directorate "Prosperity" of DG Research and Innovation, on 2 and 9 July 2020[v]. The focus was mainly on enabling technologies supporting Industry 5.0. There was a consensus on the need to better integrate social and environmental European priorities into technological innovation and to shift the focus from individual technologies to a systemic approach. Six categories have been identified, each of which is considered to unfold its potential combined with others, as a part of technological frameworks: (i) Individualised Human-machine-interaction; (ii) Bio-inspired technologies and smart materials; (iii) Digital twins and simulation; (iv) Data transmission, storage, and analysis technologies; (v) Artificial Intelligence; (vi) Technologies for energy efficiency, renewables, storage and autonomy.

2 Literature review

2.1 Industry 5.0 and Industry 4.0

Industry 5.0 has its roots in the concept of "Industry 4.0," which has been coined in Germany in 2011[vi], as a future project and part of the country's high-tech strategy to be commonly adopted by business, science and decision-makers. It was originally linked to how and to what extent the country had succeeded during the first decade of the 21st century and how it could be more effective in the coming decades in order to keep the number of employees in production largely stable. It was focused not only to better meet the economic but also the special ecological requirements of "green production" for a carbon-neutral, energy-efficient industry.

In 2013, Acatech (the German Academy of Engineering Sciences) presented a research agenda and implementation recommendations, which were developed at the instigation of the Federal Ministry of Research (BMBF) and based on the "National Roadmap Embedded Systems". It described the impact that the Internet of Things (IoT) was going to have on the organisation of production thanks to a new interplay between humans and machines and a new wave of digital application to manufacturing. Deutsche Bank (2014) suggested that adoption of Industry 4.0[vii] was to become the "factory outfitter of the world". Professor Klaus Schwab, founder and executive chair of the World Economic Forum, has published two books[viiiix] in which he describes how Industry 4.0 is fundamentally different from previous industrial concepts, which were characterized mainly by advances in technology.

The term has been influential internationally and already used in a number of alternative ways by think tanks, business leaders, international organisations and policy makers. Advanced and manufacturing-intensive economies such as China have identified how it would apply in their own context. The "Made in China 2025" governmental initiative draws direct inspiration from "Industry 4.0," focusing on revitalizing the Chinese manufacturing industry and achieving a smooth shift.

Over its ten years of life, Industry 4.0 has focused less on the original principles of social fairness and sustainability, and more on digitalisation and AI-driven technologies for increasing the efficiency and flexibility of production. The concept of Industry 5.0 provides a different focus and highlights the importance of research and innovation to support industry in its long-term service to humanity within planetary boundaries.

For an overview of early academic writing on the concept of Industry 5.0, see Annex II.

2.2 Relation with the concept of Society 5.0

The concepts of Society 5.0 and Industry 5.0 are related in the sense that both concepts refer to a fundamental shift of our society and economy towards a new paradigm.

The concept of Society 5.0 was presented by Keidanren, Japan's most important business federation, in 2016. It has subsequently been promoted by the Japanese government. Japan essentially takes the digitalisation and transformation dimensions, mainly situated on the level of individual organisations and parts of society, to a full national transformational strategy, policy and even philosophy.

In the “Societies” concept, the way in which people ensure their livelihood is directly related to the way they build their society. The numbering up to "5" results from a very different and much longer time scale than that of industrial revolutions. The first two "Societies" correspond to the pre-industrial periods (until the end of the 18th century) and are respectively related to the hunting/gathering and the agricultural economies. Society 3.0 is an industrial society and corresponds more or less to the period of the first, the second and part of the third industrial revolutions. Society 4.0 is characterized by the dominance of "information" and we can say that it evolved from a highly digitised version of the third industrial revolution, up until today.

Society 5.0 attempts to balance economic development with the resolution of societal and environmental problems. It is not restricted to the manufacturing sector but addresses larger social challenges based on the integration of physical and virtual spaces. Society 5.0 is a society in which advanced IT technologies, Internet of Things, robots, artificial intelligence and augmented reality are actively used in every day life, industry, healthcare and other spheres of activity, not primarily for economic advantage but for the benefit and convenience of each citizen.

3 R&I evidence base

In defining our concept of Industry 5.0, we build on the existing literature, but also develop our own vision based on a number of other elements. A first element is the analysis of the fast-paced societal evolutions taking place, in Europe and across the world. Advanced globalisation has raised global prosperity, but has also increased local inequality, which led to more fragile strategic value chains for critical supplies and infrastructure, and has worsened our overuse of natural resources and pollution of the environment. Technological advancement is an important driver behind these changes, which would simply be unimaginable without increased automation, digitalisation and connectivity. To illustrate the quick and sharp increase of the importance of digital technology: in 2009, only one tech company (Microsoft) made the top-10 of publicly traded companies (by market cap); in 2019, the entire top-5 consisted of only tech companies (Microsoft, Amazon, Apple, Alphabet and Facebook). The emergence of increasingly sophisticated artificial intelligence, attracting major investments worldwide, will only solidify and speed up this evolution. For all the good technological innovations have brought, society is now facing the downsides and risks they pose, including threats to our environment, to European values, including democracy itself, and to fundamental rights.

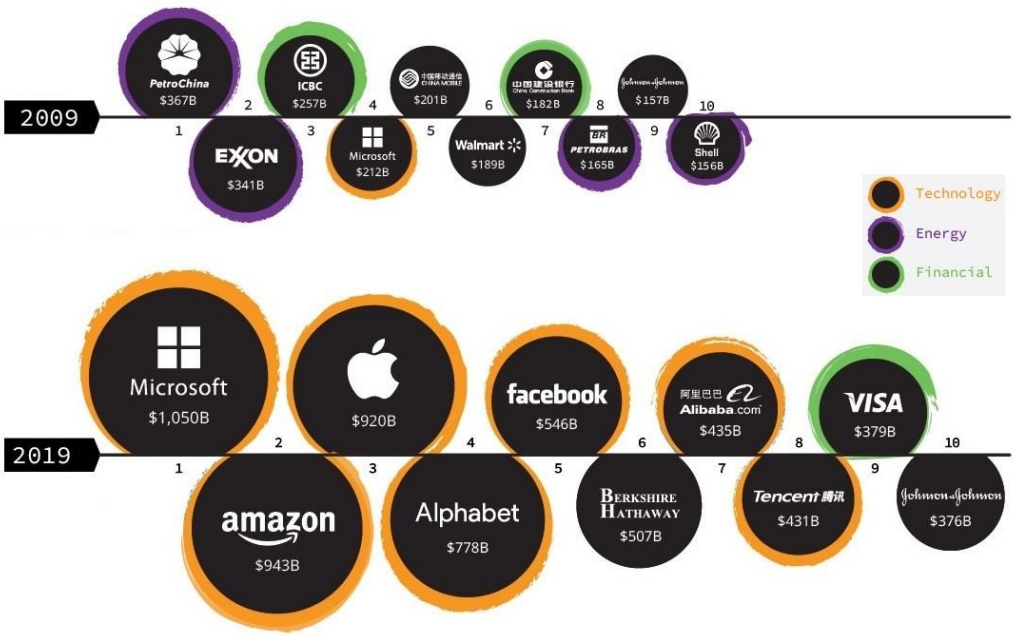

Figure 1. Largest companies by market cap (21/7/2019)
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A second element to be taken on board for the development of our vision is the current policy setting at European level, which aims to better frame and steer these

ongoing evolutions, in an effort to maximise their benefits for European society, while mitigating the emerging risks they pose. This is clearly reflected in two top priorities of the current European Commission: the "Green Deal," an encompassing strategy for making Europe climate-neutral by 2050, and a "Europe Fit for the Digital Age," targeting increased technological innovation in Europe, while introducing new and updated rules for technology and the digital economy. The recently published White Paper on a regulation of artificial intelligence, as well as the European Data Strategy, clearly illustrate the importance the European Commission attaches to the societal impact of digital technologies.

Thirdly, the real-world adoption rate of digital technologies in European industry has an important bearing on our concept. Despite claims of digital technology developing exponentially and becoming ever more disruptive in nature, the adoption of digitalisation in European industry seems to be of a more gradual nature. Although specific new technologies may allow for new, disruptive approaches, the large infrastructural investments required for some types of industry and the fragmentation into a multitude of smaller players (lacking digital skills or investment capacity) in other areas, result in the current uptake of digital technologies in European industry being linear rather than exponential, and gradual rather than disruptive. Overall, the technology picture in European industry is very diverse and ranges from state-of-the-art high-tech production lines to small businesses still keeping their client records in a paper-based rolodex.

On the one hand, this is cause for alarm, as insufficient investment in innovation may hamper the competitiveness of European industry sooner rather than later. This is why the European Commission puts emphasis on investment in new technologies as part of its priorities, such as Europe Fit for the Digital Age and the Green Deal. Policy initiatives such as the European Research Area, are specifically aimed at accelerating the diffusion of new technologies[x], making sure they are inclusively absorbed into the economy and wider society, across European Member States, regions and cities. On the other hand, the limited uptake of cutting-edge technologies such as AI may be a symptom of the use cases for such technologies not having fully crystallised, or continuing to be framed within a paradigm from the past.

In terms of technology, Industry 5.0 wants to come to grips with the promises of advanced digitalisation, big data and artificial intelligence, while emphasising the role these technologies can play to address new, emergent requirements in the industrial, societal and environmental landscape. This means using data and AI to increase production flexibility in times of disruption, and rendering value chains more robust; it means deploying technology that adapts to the worker, rather than the other way around; and, it means using technology for circularity and sustainability.

A fourth source for the development of our vision for Industry 5.0 has been the existing work done in and/or commissioned by the European Commission's Directorate-General for Research and Innovation. In particular the Radical Innovation Breakthrough Inquirer (RIBRI) report, which identified 100 potential innovation breakthroughs in fields such as artificial intelligence, robotics or biomedicine, and indicated how the EU can prepare for them, is of great value to anyone looking to

identify relevant technologies for the future. The high-level seminar "Research and Innovation as a compass for the future we want," organised in May 2019 with the Jacques Delors Institute, provided important insights in how research and innovation can be a driving force for the transition of European society to a sustainable future.

As a final yet important element, we have looked at the objectives and results of the research projects supported through the European Framework Programmes for Research and Innovation. Several Horizon 2020 funded projects have developed evidence and further guidance on the transformative elements pertinent to Industry 5.0., even if they do not explicitly refer to the term as such. In contrast to Industry 4.0, the focus of these projects goes beyond the gains that digitalisation and further automation could provide to companies in terms of efficiency and profit. They develop solutions that render the production more sustainable, resilient, and competitive on a long-term basis, and tackle challenges associated with beneficial human-machine interaction and skills matching.

Some projects aim at changing the business models that companies adopt, by fostering circular manufacturing (e.g. KYKLOS 4.0, DRALOD and PAPERCHAIN), considering servitisation (e.g. MAKERS), designing smart, autonomous and self-learning factories capable of increased mass personalisation production (e.g. SME 4.0), designing solutions to distributed (multi-site) industrial production (e.g. RICAIP) or improving the flexibility and adaptability of the production process (e.g. SYMBIO-TIC).

A growing number of projects is addressing the human and societal aspects of the digitalisation of our (industrial) workplaces, hence contributing to the human-centric perspective of Industry 5.0. A number of projects explore the interaction between humans and robots and cobots in the manufacturing context, looking into ways how to benefit from each of their strengths and how to valorise human capital (e.g. FACTS4WORKERS, EVRYON, HuMan Manufacturing, CoLLaboratE, Rossini). Another set of projects look into the implications of digitalisation for the future of work and welfare of individuals and society at large (e.g. BEYOND4.0, PLUS, SemI40). When analysing the preconditions for a successful transition to Industry 5.0, the required skillset of workers is an important aspect, which is addressed by several Horizon 2020 as well as ERASMUS+ projects, on emerging skills gaps and adapted training (e.g. BEYOND4.0, SAM, FIT4FoF, SAIS, FACTS4WORKERS, TECHNEQUALITY). Last but not least, projects look into the impact of digitalised work environment on workers' safety, working conditions, job satisfaction and physical and mental well-being (e.g. HuMan Manufacturing, SYMBIO-TIC, FIT4FoF, PLUS, MindBot, H-WORK, EMPOWER).

A detailed list of these projects can be found in Annex 1. It should not be considered as exhaustive, as several other Horizon 2020 projects address questions that are relevant for Industry 5.0, be it on innovative technology (AI, photonics, smart materials), greening of the economy and sustainability, or skills expertise and development.

4 Defining Industry 5.0

Even though Industry 5.0 is a relatively new concept, some early academic writing describing the main features of this notion exists. The analysis of the Industry 5.0 literature (see Annex II) shows a lot of uncertainty about what it will bring and how it will disrupt business in detail, as well as about its potential to break down barriers between the real world and the virtual one[xi].

Based on the literature review and our forward-looking analysis, we believe Industry 5.0 will be defined by a re-found and widened purposefulness, going beyond producing goods and services for profit. This wider purpose constitutes three core elements: human-centricity, sustainability and resilience.

A purely profit-driven approach has become increasingly untenable. In a globalised world, a narrow focus on profit fails to account correctly for environmental and societal costs and benefits. For industry to become the provider of true prosperity, the definition of its true purpose must include social, environmental and societal considerations. This includes responsible innovation, not only or primarily aimed at increasing cost-efficiency or maximising profit, but also at increasing prosperity for all involved: investors, workers, consumers, society, and the environment.

Figure 2. Industry 5.0.

Rather than taking emergent technology as a starting point and examining its potential for increasing efficiency, a **human-centric approach** in industry puts core human needs and interests at the heart of the production process. Rather than asking what we can do with new technology, we ask what the technology can do for us. Rather than asking the industry worker to adapt his or her skills to the needs of rapidly evolving technology, we want to use technology to adapt the production process to the needs of the worker, e.g. to guide and train him/her. It also means making sure the use of new technologies does not impinge on workers' fundamental rights, such as the right to privacy, autonomy and human dignity.

For industry to respect planetary boundaries, it needs to be **sustainable**. It needs to develop circular processes that re-use, re-purpose and recycle natural resources, reduce waste and environmental impact. Sustainability means reducing energy consumption and greenhouse emissions, to avoid depletion and degradation of natural resources, to ensure the needs of today's generations without jeopardising the needs of future generations. Technologies like AI and additive manufacturing can play a large role here, by optimising resource-efficiency and minimising waste.

Resilience refers to the need to develop a higher degree of robustness in industrial production, arming it better against disruptions and making sure it can provide and support critical infrastructure in times of crisis. Geopolitical shifts and natural crises, such as the Covid-19 pandemic, highlight the fragility of our current approach to globalised production. It should be balanced by developing sufficiently resilient strategic value chains, adaptable production capacity and flexible business processes, especially where value chains serve basic human needs, such as healthcare or security.

As indicated earlier, our concept of Industry 5.0 is an open and evolving concept, providing a basis for further development of a collaborative and co-creative vision of the European industry of the future. Nonetheless, we believe the core of Industry 5.0 can be defined as follows:

Industry 5.0 recognises the power of industry to achieve societal goals beyond jobs and growth to become a resilient provider of prosperity, by making production respect the boundaries of our planet and placing the wellbeing of the industry worker at the centre of the production process.

5 Benefits for the Worker: Human-centric approach

One of the most important paradigmatic transitions characterising Industry 5.0 is the shift of focus from technology-driven progress to a thoroughly human-centric approach. This means that industry needs to consider societal constraints, aiming not to leave anyone behind. This has a number of implications, pertaining to a safe and beneficial working environment, to the respect of human rights, and to the skills requirements for workers.

5.1 New role for the industry worker

In Industry 5.0, the role and the narrative around the industry worker change considerably. The worker is not to be considered as a 'cost', but rather as an 'investment' position for the company, allowing both the company and the worker to develop. This implies that the employer is interested in investing in skills, capabilities and the well-being of their employees, in order to attain their objectives. Such an approach is very different from merely balancing worker cost with financial revenue: human capital is more valorised and appreciated.

An important prerequisite for Industry 5.0 is that technology serves people, rather than the other way around. In an industrial context, it means that technology used in manufacturing is adapted to the needs, and diversity of industry workers, instead of having the worker continuously adapt to ever-evolving technology. The worker is more empowered and the working environment is more inclusive. To achieve this, workers are to be closely involved in the design and deployment of new industrial technologies, including robotics and AI.

Human – machine collaboration has been addressed in several Horizon 2020 funded projects (see Annex I). The Factory2Fit project, for example, aims at empowering and engaging workers in a more connected industrial environment. The workers are given more influence and hence greater responsibility in shaping the production process, through virtual means. As such, a virtual factory was built to test and further develop ideas in co-design sessions with workers and other work community members. A Worker Feedback Dashboard was developed to provide personal feedback on achievements and well-being. The first results of this project indicate a positive impact on both productivity and worker well-being. Initiatives like these allow linking ever-increasing automation with human expertise, thus strengthening the human-centric approach.

As another example, Romero, Stahre et al. (2016) have developed a typology for Operator 4.0, which aims at expanding the capabilities of the industry worker with innovative technological means, rather than replacing the worker with robots. This typology includes 8 future projections of extended operators: the Super-strength Operator (operator + exoskeleton), the Augmented Operator (operator + augmented reality), the Virtual Operator (operator + virtual reality), the Healthy Operator (operator + wearable tracker), the Smarter Operator (operator + intelligent personal

assistant), the Collaborative Operator (operator + collaborative robot), the Social Operator (operator + social networks), and the Analytical Operator (operator + Big Data analytics)[xii]. With this approach, humans remain at the centre of the production process, and technology maximises the benefits for both the company and the worker.

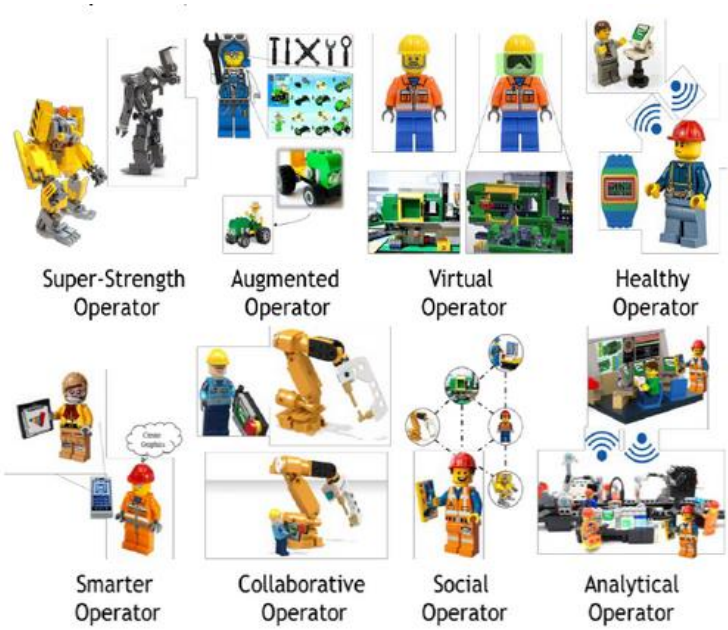

Figure 3. Operator 4.0 typology.
© Romero et al.

Building on the typology of Operator 4.0, the white paper on "Human-centred factories: From theory to industrial practice" proposes to cluster future types of operators in five categories: Augmented and virtual operator, Social and collaborative operator, Super-strong operator, Healthy and happy operator, and One-of-a-kind operator.[xiii] The One-of-a-kind operator has been added to the typology to embrace the characteristics and preferences of individual workers, to promote workplace inclusiveness. All of these initiatives illustrate efforts to identify new roles for empowered industry workers.

5.2 Safe and inclusive work environment

One of the fears associated with the uptake of new technologies is the loss of jobs. However, if applied correctly, new technologies have the potential to make workplaces more inclusive and safer for workers, as well as increase their job satisfaction and well-being.

Eurostat data on workplace accidents indicate that the top-3 sectors in which accidents happen are precisely the sectors in which dangerous and strenuous tasks of workers could be automated relatively easily, radically reducing the rate of

workplace accidents, including those with a fatal outcome. The current number of workplace accidents is considerable: in 2017, 3,3 million non-fatal accidents were reported (2/3 of the accident victims were men), as well as more than 3,500 fatal accident cases[xiv]. There are variations among Member States, both due to work culture, as well as accident reporting systems in place. The actual amount of workplace accidents, notably non-fatal, is therefore even higher, due to under-reporting.

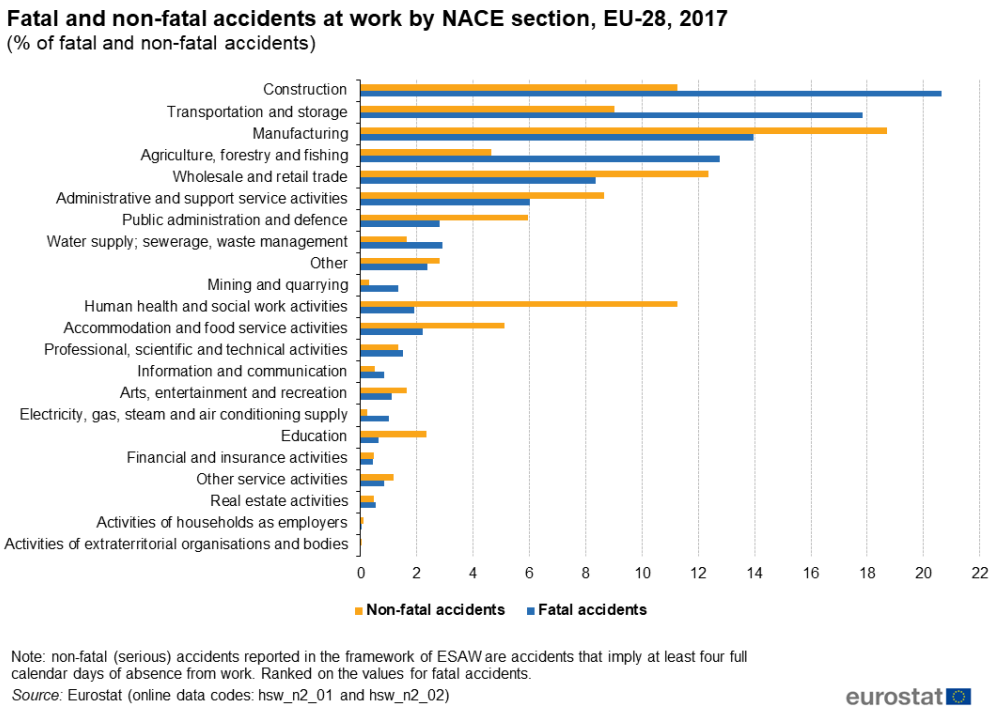

Figure 4. Fatal and non-fatal accidents at work, EU-28, 2017.
© Eurostat

Robots could take over a number of repetitive and simpler tasks, making workplaces safer for workers. The potential of robotics technology is far from being exhausted, especially when powered with artificial intelligence. AI-based technologies, as well as virtual and augmented reality tools, can be used for guiding the worker to fulfil more specialised tasks, otherwise requiring specific expertise and training. This could also open opportunities for introducing more people with reduced mental abilities in the working environment. Similarly, mobile robots and exoskeletons have the potential to make certain tasks less physically demanding. This may allow women to take on tasks that were previously reserved for men due to the required physical strength. A vast range of further opportunities will arise by further digitalisation of the workforce. Digitalising industrial processes enables remote work, allowing those living in distant regions to enter the labour market, and increasing the resilience of production itself. The recent Covid-19 crisis, during which the functioning of many enterprises has been put at risk due to physical distancing measures, has clearly illustrated the potential of digitalised remote operation.

The safety and well-being of workers is not just about ensuring and supporting their physical health in the workplace. Mental health and well-being have to be considered on an equal footing when designing digitalised workplaces. While there are new risks associated with digitised ways of working, such as the risk of burnout due to the always-online and always-available working culture, digital technologies could be used to support workers in better controlling and managing the risks and impact of the new working environment on their mental health and well-being. Digital solutions and wearables could open new channels for alerting workers and their general practitioners about critical health conditions, both physical and mental, as well as supporting workers in adopting healthy behaviours in the workplace[xv]. With the help of new technologies and digital solutions, companies and other organisations could foster mental health and a culture of well-being as an integral part of their corporate culture. This is moreover likely to bring economic benefits and savings due to productivity gains and avoidance of long-term illness and absences. For example, a Marie Skłodowska -Curie project INSTINCT developed the IT application Streblo, which helps construction workers cope with stress. According to the WHO, mental health issues such as depression and anxiety have an estimated cost to the global economy of $1 trillion per year in lost productivity. It is also estimated that each dollar invested in the treatment of common mental disorders would have a return of 4 dollars in improved health and productivity.[xvi]

The above-mentioned improvements in working conditions cannot, however, be done at the expense of workers' fundamental rights. Workers' autonomy, human dignity, privacy, physical and mental health cannot be put at risk at any stage when accommodating technological progress. Basic principles enshrined in the European Charter of Fundamental Rights have to serve as incontestable guidelines when designing the new work environment. An important element to consider when designing smart workplaces are the potential biases that need to be mitigated when developing AI-powered technologies used in production processes. When industry workers are closely collaborating with intelligent machines, it is crucial to ensure that the tools do not undermine, explicitly or implicitly, the dignity of the worker, regardless of their race, gender or age. A possibility to receive an explication of an algorithmic decision and to provide feedback in case this principle is breached must be ensured for every worker.

5.3 Skills, up-skilling and re-skilling

The skills dimension is another important set of considerations for Industry 5.0. Skills needs are evolving as fast as technologies. European industries are struggling with skills shortages and educational and training institutions are unable to respond to this demand. This applies to both expert level and general digital skills requirements. On the supply side, young people do not feel adequately equipped with the skills needed for the future labour market. A Deloitte study concluded that 70% of young people believe they only have some of the skills that will be required to succeed in the work of the future[xvii].

A possible way out of this skills mismatch would be a novel approach to technology development. Technology could be made more intuitive and user-friendly, so that workers would not require specific skills to use it. Furthermore, training could be developed simultaneously with this technology, thereby ensuring the available skillset better matches the skills requirements in industry. The Horizon 2020 projects SAM (Sector Skills Strategy in Additive Manufacturing) and SAIS (Skills Alliance for Industrial Symbiosis – a cross-sectoral Blueprint for a sustainable Process Industry)[xviii] are already adopting this approach.

It is important to note that it is impossible to ensure the up-skilling of every single industry worker. With increased automation, some skills will inevitably become obsolete and therefore difficult to develop further. As such, it is important to facilitate a shift in some workers' qualifications, i.e. to re-skill them. This often applies to digital skills, which may not have been on the curriculum at the time workers concluded their education and training. Regarding digital skills, it is essential to ensure a certain basic level of knowledge and understanding for everyone. This particularly applies to artificial intelligence. It is important that people have a basic understanding of how AI works, and know the potential benefits and limitations of this technology. For humans to remain in control of this powerful technology, this would be a first requirement.

Digital skills are not the only skills that will be pertinent for industry workers in the factories of the future. The World Manufacturing Forum has identified a top-10 of skills that will be needed in future manufacturing. Surprisingly, only four of them refer to digital skills: "digital literacy, AI and data analytics," "working with new technologies," "cybersecurity", and "data-mindfulness". The remaining skills are more transversal skills linked to creative, entrepreneurial, flexible and open-minded thinking[xix].

Figure 5. World Manufacturing Forum's op ten skills for the future of manufacturing
© World Manufacturing Forum

While research and innovation are key engines of productivity and competitiveness, economies and companies can also benefit by importing and adopting innovations produced elsewhere. The technology diffusion depends primarily on absorption capacity, which can be built via internal investment in skills and human capital. Companies could, and should, play a more important role in the education and training of the workforce as they have the expertise, knowledge and most direct link to technology. They know which skills are missing, and which will be required in the future. Workers should meanwhile be encouraged to participate in the design of trainings, to make sure trainings are relevant and adapted to their audience.

6 The Benefits for Industry

Industry 5.0 benefits workers as much as companies. The benefits for industry are wide-ranging, going from better talent attraction and retention, over energy savings, to increased general resilience. The overall benefit for European industry is long-term: continued competiveness and relevance by successfully adjusting to a changing world and new markets. In the shorter term, the investments required could expose European industries to the risk of temporarily losing competiveness to those not yet investing in Industry 5.0. It will be crucial to thoroughly time and coordinate investments, in order to mitigate this risk. We nonetheless believe the biggest risks for industry would materialise by not engaging with the larger societal transition to sustainability, human-centricity and resilience, and thereby losing competitiveness in the longer run.

6.1 Attracting and retaining talents

An increasing challenge for companies is attracting and retaining a qualified workforce. Filling positions that require digital and/or multi-disciplinary skills seem particularly challenging. The youngest part of the workforce is most likely to possess the required skillset: generations "Y" and "Z" have grown up in the digitalisation age, and are sometimes referred to as "digital natives". It is estimated that 75% of the workforce will consist of these so-called millennials —people born between 1985 and 1995— by 2025[xx].

In terms of ethnicity and race, millennials are the most diverse generation that has so far entered the labour market. There is solid evidence indicating that their preferences, orientations and motivations substantively differ from the previous generational cohorts. They are more often than previous generations driven by social values, rather than by more stable positions or higher salaries.

The Cone Communication survey (2016)[xxi] concluded that 75% of millennials would take a pay-cut to work for a socially responsible company, while 76% of millennials consider a company's social and environmental commitments before deciding (not) to work there. Sixty-four percent of millennials would not take a job if a potential employer does not have strong corporate responsibility practices. This was confirmed in the PricewaterhouseCoopers report, 'Millennials at work – Reshaping the workplace'[xxii], which claims that corporate social values become more important to millennials when choosing an employer once their basic needs, such as adequate pay and working conditions, are met. The report states: "millennials want their work to have a purpose, to contribute something to the world and they want to be proud of their employer."

Being a socially responsible and environmentally friendly company is not just about adapting production processes, but also about setting up initiatives outside of core working activities, such as employee volunteering schemes or organised activities for the local community[xxiii].

Another feature of the young generation of the workforce is that they are more committed to achieving Sustainable Development Goals, including equality, climate change, peace, justice, eradicating poverty, and prosperity.[xxiv] As such, millennials prefer to work in companies that are more environmentally friendly. In a Swytch survey of 1000 workers in the US, almost three-quarters said they would be more likely to work for a company with a green footprint, while about 40% of millennials surveyed said they have taken one job offer over another because of the company's sustainability. Seventy percent said it would affect their decision to stay with a company for the long haul.[xxv]

In order to remain competitive in the hiring market, companies need to accept and embrace the preferred values of potential employees. This is especially true for industries that are introducing digital solutions in their value chains; as such, there are in practice very few industries, if any, that will not be concerned.

6.2 Resource efficiency for sustainability and competitiveness

Capitalisation, market penetration, revenue, profit and all conventional economic indexes reflect neither the exact current state nor the overall outlook of "competitiveness" of an industry. For example, profitability might be built on the use of non-renewable resources, on a pre-existing strong brand name or on ephemeral conditions of the market. The concept of Industry 5.0 promotes the economic performance of industries while respecting workers' needs and interests as well as ensuring environmental sustainability. This makes it attractive not only to entrepreneurs but also to potential investors and to consumers who could benefit from the availability of more competitive, in the broadest sense, products.

Energy-Intensive Industries are embedded in many strategic value chains, which make up more than half of the energy consumption of EU industry[xxvi] and are responsible for about 8% of the EU's emissions. Therefore, the pursued climate-neutrality and the unavoidable fluctuations in energy prices disproportionately affect their costs. Energy technologies for resilience and cost reductions as well as a modern policy framework are needed in order to manage energy transition, while keeping energy intensive industries competitive at global level. EU-funded R&I projects like EMB3Rs, SO WHAT and INCUBIS turn waste heat into a valuable resource and help make better use of renewable energy sources. The OECD report on industrial transitions[xxvii] outlines the specific challenges at regional level in order to harness the opportunities arising from industrial modernisation, while at the same time limiting the costs for affected communities and workers.

ICT network operators use about 1% of global electricity (242 terawatt-hours in 2015) corresponding to 0.34% of overall global GHG emissions. Hence, the sector's share is non-trivial in terms of environmental sustainability and economic performance. During the last half decade, despite rising demand for data, ICT's electricity consumption is staying almost flat, as increased Internet traffic and data loads are countered by increased efficiency, like shutting older facilities in favour of new ultra-efficient ones. However, those wins could be limited in the near future and

many cited forecasts suggest that the electricity demand from data centres will increase in the 2020s. ICT's role in mitigating climate change is dual. Firstly, it can address sector emissions and reduce costs through energy efficiency and the uptake of renewable energy sources. Secondly, and more importantly, it has the potential to deliver emissions' reductions across the wider economy.

Resource efficiency is about doing "better with less", about optimising the relationship between product output and resource input. This means taking into account a life-cycle perspective and end-of-life considerations. The OECD RE-CIRCLE project[xxviii] provides policy guidance for resource efficiency and for the transition to a circular economy, which will not just be beneficial for material security, but will also improve environmental and economic outcomes. The adoption of innovative resource efficiency is the blueprint for a new economy, closely related to the UN's Agenda 2030[xxix] and mainly its 9th and 12th Sustainable Development Goals (SDGs) for "Industry, Innovation and Infrastructure" and "Responsible Consumption and Production". The OECD regular report "Measuring Distance to the SDG Targets"[xxx] provides an overview of strengths and weaknesses in performance across all the SDGs, helping its members to identify priorities within the broad 2030 Agenda. At EU level, the European Commission –through Eurostat– has developed a reference indicator framework to monitor progress towards the 17 SDGs. Eurostat recently published the 4th edition of its monitoring report[xxxi], based on a list of 99 unique and 41 multi-purpose indicators. The statistical overview of the five-year period since the adoption of the 2030 Agenda, shows that the EU has significantly progressed in delivering on the SDGs and continues to reinforce its efforts.

6.3 Increased resilience

Resilience refers to the ability to cope flexibly with change. Globalised value chains and markets are increasingly prone to disruptive changes, such as those caused by (geo-)political shifts (Brexit, trade wars, protectionism, etc.) and natural emergencies (pandemics, impact of climate change, etc.). The industry of the future needs to be equipped to adapt quickly to changing circumstances for key value chains, in order to secure its role as a sustainable engine for prosperity. A resilient industry can deal with vulnerabilities that can occur on many levels, including the factory floor, supply network and industrial system levels.

Under stable societal and environmental circumstances, innovation in industry tends to focus on increasing the efficiency of production lines and supply chains. Such increases in efficiency, however, often come at the cost of lowered resilience. A low-cost value chain may be a fragile one and could have single points of failure; the most efficient factories may be rigid in their setup so that they need to cease or significantly decrease production in case of unforeseen circumstances.

Research into industrial resilience can help to understand the global, local and technical risks industry increasingly faces. It can develop and implement mitigation strategies that can be the cornerstones of an optimal and resilient functioning of industry in the future. Innovative techniques, including more modular production

lines, remotely operated factories, use of new materials, and real-time risk monitoring and management can help industry attain the resilience it needs.

A special role will be played by digital technologies. While digital interconnection will enable a host of resilient technologies (including data gathering, automated risk analysis and automated mitigation measures), an increased dependence on digital technologies exposes industry to technical disruptions, due to malfunctions as well as cyberattacks. Research and innovation will play a key role in developing the cybersecurity required for the resilient industry of the future.

7 Making It Happen

Sustainability, human-centricity and resilience are the hallmark features of Industry 5.0. We do not consider these features as just desirable, but believe they are necessary for European industry to remain relevant, competitive and fit for the future. Therefore, when asking how we can make Industry 5.0 happen, we are asking how European policy can provide the enabling conditions for industry to prepare and innovate for the future.

That future may be closer than is often assumed; in some respects, it may already be here. The digital revolution is in full swing and shows no signs of slowing down. Climate change is a reality that is increasingly manifesting itself. The Covid-19 pandemic already had a strong impact on production in a variety of industrial sectors. Changes in the political climate, such as the increased popularity of protectionist ideologies, are putting established global value chains in question. Difficulties in finding new staff with the correct skills, as well as keeping in-house skills up-to-date, have been an enduring problem in many industrial sectors.

A robust European policy response tackling many of these issues has already been put on the rails: the European Commission is moving forward with supporting as well as regulating emergent digital technologies, including AI. Its ambitious Green Deal is endorsed by all Member States. A new European Industrial Strategy and Skills Agenda have been proposed. The Recovery Package contains solid provisions to ensure the recovery after the Covid-19 pandemic will be strong, future-proof and resilient.

These impactful changes, and their matching policy responses, are precisely what drives our concept of Industry 5.0 forward. Where the paradigm of Industry 4.0 has been primarily driven by the potential of emerging technologies to improve efficiency and productivity, Industry 5.0 is propelled by emerging societal changes and realities. Industry 5.0 focusses on technology and innovation as necessary components for the transition to a new industrial paradigm, in which European industry is increasingly resilient and adapts itself to a new societal reality, in which production is required to respect the boundaries of our planet, and industry worker well-being is placed at the centre of the production process.

Our specific role as the European Commission's Directorate-General for Research and Innovation is to support the development of new and emerging technologies that underpin this transition for European industry.

7.1 Human-centricity

The European Union has already adopted a human-centric and socio-centric approach in several of its key policies. To name just a few, General Data Protection Regulation (GDPR) protects the rights of individuals to their personal data protection in using both corporate and governmental services; the White Paper on Artificial Intelligence sets out the principles for eventual AI regulation that provides

safeguards for the users of certain categories of AI technologies. While both of these policy initiatives received some criticism from the corporate world, they once more affirmed the European commitment towards the protection of human and fundamental rights as a priority. Europe is indeed leading by example on the global stage when it comes to such value-based policies.

In the industrial context, there is still place for progress regarding the human-centric approach. In order to ensure that both companies and workers benefit from the digital transition, rethinking and redesigning business models is necessary. Workers should be involved in every step of this transition process.

In order to benefit from the relative strengths of technologies and workers, companies need to invest in both. A stronger cooperation is needed between enterprises on the one hand, and education and training institutions on the other, as companies are well placed to determine the skills gaps and forecast the skills needs for the near future. Research should accompany this process by providing skills expertise, based on broader trends in society and labour markets.

Education, training, re-skilling and up-skilling are certainly among the most pressing issues to address when accommodating the digital transition in industries, as qualified human capital is of the utmost importance to make it a reality. Unfortunately, we must admit that not everyone will be eligible for re-training. Some workers might lack even the most basic digital skills required for further education and training.

There is already a number of policy initiatives envisaged in the EU Skills Agenda. Namely, the updated Digital Education Action Plan (2021-2027) outlines the European Commission's vision for high-quality, inclusive and accessible education and training systems fit for the digital age. Its two priorities address the need to foster the development a high performing digital education ecosystem and boost digital skills and competences for the digital transformation. Nevertheless, some further work might be needed in labour policies regarding the appropriate recognition of work in the digital economy (e.g. data labelling), platform work, or the revision of standard working hours.

This might need to be accompanied by substantive reforms in social policies such as welfare and health protection systems. Re-thinking of the links between paid work and social benefits, as well as revising existing taxation systems, may be required. Given that not all workers will be able to find their new place in transformed industries, it is a societal responsibility to help them remain relevant and protected members of society.

7.2 Sustainability

Sustainable development has been at the heart of European policy for a long time, firmly anchored in the European Treaties. The EU has fully committed to deliver on the 2030 Agenda for the 17 Sustainable Development Goals (SDGs), adopted by the

UN General Assembly in 2015, as outlined in the reflection paper: 'Towards a Sustainable Europe by 2030'[xxxii]. The Green Deal announced in December 2019 clearly sets out what Europe must do to transition to a sustainable economy. Several powerful instruments helping the EU reach its carbon-neutral ambitions have been identified. Innovations in green technology, combined with EU initiatives aimed at Digitising European Industry (including better use of big data and artificial intelligence) are a reality and are increasingly embraced by industry. In the face of mounting public environmental and societal concerns, companies are incorporating sustainability into their business models. When fully realising the advantages of an improved corporate image and of savings on energy and material costs, industry will embrace resource efficiency as a natural choice. Research should pay more attention to how companies can renew their business model and better account for environmental sustainability at the organizational level in their business ecosystems.

Increase in industrial production normally requires more energy and increases carbon emissions. Innovation can reverse this trend by smarter production planning and the use of more energy-efficient technologies. Between 1990 and 2016, the energy efficiency of end-use sectors in the EU improved by 30% at an annual average rate of 1.4%/year[xxxiii]. All sectors contributed to this improvement, with the largest gains registered in the industry by overall 38% or 1.8%/year. However, since 2005, there has been a net slowdown in industries' energy efficiency improvement (1.2%/year against the previous 2.2%/year). There were improvements in all industrial branches? but they have been considerably lower in the most energy-intensive ones. It is of paramount importance to consider the link between energy consumption and economic growth at sectoral level, especially for energy-intensive industries. Such sectoral analysis can help us identify industry-specific issues that could lead to more targeted research and innovation efforts for energy efficiency, as well as to a sharply focused energy policy.

The current percentage of secondary raw materials and resources being brought back into the economy (around 12%) can clearly be improved.[xxxiv] The concept of the circular economy is a blueprint for a new economy, complies with the 12th UN's SDG for "sustainable consumption and production patterns", generates rapid and lasting economic benefits, and receives broad public support. It provides a positive, coherent innovation challenge, through which young people see the relevance and opportunities in terms of re-thinking and redesigning their future. The optimisation of existing techno-economic solutions is certainly not enough. Industry has to pursue new game-changing solutions, put them into practice and understand the implications of reworking its business models. Some materials fit quite easily into the circular economy concept while others (like composite materials, fibre-reinforce plastics, metallurgical wastes, etc.) present a much tougher challenge and require further research. Such research should continue to be supported by Horizon Europe, building on the work done under previous research framework programmes. Many European firms already recognise that industrial ecology and more particularly industrial symbiosis (sharing and repurposing secondary resources and by-products) is good, not only for the environment, but in helping industries compete in global markets and retaining their long-term competitiveness.

7.3 Resilience

The outbreak of the coronavirus pandemic has challenged the resilience of our society and economy. By being resilient in its own right, industry can greatly contribute to societal resilience, making sure production is upheld and workers can continue to work. Rather than returning to the established but fragile "old normal" as soon as possible, the re-building of a much more resilient and future-proof European economy and industry will allow us to overcome the Covid-19 crisis.

This conviction is mirrored in the very substantial European-level response to the economic crisis brought about by the pandemic, propelling some of the key features of Industry 5.0 to the forefront, as requirements for a successful transition to the "new normal." With the Recovery and Resilience Facility, the European Commission wants to support EU countries in reform efforts that ensure sustainable recovery. Carrying out reforms and investing in the green, digital and social resilience priorities will help create jobs and sustainable growth, and allow recovery in a balanced, forward-looking and sustained manner. The Recovery and Resilience Facility will be funded through an emergency European Recovery Instrument, Next Generation EU, amounting to €750 billion. To access the facility, Member States are required to prepare recovery and resilience plans, setting out their reform and investment agendas.

In the context of the Recovery and Resilience Facility, the European Commission is also taking steps to enhance the Union's strategic autonomy in a number of specific areas, including in strategic value chains. It also proposes to create a new Strategic Investment Facility to invest in key value chains crucial for Europe’s future resilience and strategic autonomy in the context of the green and digital transitions.

It is clear that industry will play a key role in this transition to a more resilient, sustainable and human-centric society. As we have stressed throughout the paper, for industry to fulfil and continue to fulfil its role as the engine of prosperity for our societies, it needs to innovate and adapt to be able to transition to a new societal and environmental paradigm. Close coordination and cooperation between industry and Member States at European level will be required to emerge successfully from the Covid-19 crisis. Although there are challenging times ahead, they present industry with a unique opportunity to invest in the transition to the "new normal" of Industry 5.0.

7.4 Next steps

As we have shown, the transition towards Industry 5.0 has already started. A number of on-going projects in Horizon 2020 are already contributing to the development of this concept. The following major actions, foreseen as next steps, are part of our growing toolbox for making Industry 5.0 happen:

- Increasing awareness in industry, but also with European social partners. This will allow for consolidation and promotion of the concept of Industry 5.0. For this purpose, we are preparing an infographic and a dedicated webpage pitching the main elements of the concept.

- Implementation of the technologies necessary for Industry 5.0. We have organised two (virtual) workshops on emerging technologies for Industry 5.0. Its main outcomes are being taken into account in the preparation of the first Horizon Europe programme, in particular within Cluster 4.

- Identify existing actions and opportunities for the development of Industry 5.0 across Europe, including actions for encouraging inclusive technology diffusion across Europe.

- Following the Innovation Principle, checking regulatory barriers to innovation relevant for Industry 5.0. Where appropriate, propose Innovation Deals/regulatory sandboxes to help overcome such obstacles.

- Exploring open innovation and testing new forms of sharing research and innovation results (for example, see the European Commission's Manifesto for EU Covid-19 Research[xxxv]).

- Promoting the hallmark features of Industry 5.0 as guiding principles for the development of common technology roadmaps under the Strategic Innovation Agendas, as mentioned in the new European Research Area Communication[xxxvi].

- Outreach to other policy areas. The transition into Industry 5.0 will require a number of policy actions in areas such as social policy, education, taxation, energy, industrial policy, etc. These areas are outside the remit of the Directorate-General for Research and Innovation. Bilateral contacts with the responsible DGs will be initiated to discuss possible actions in these policy areas.

ANNEX I
MAPPING OF PAST AND ON-GOING PROJECTS

ACTPHAST 4.0

ACceleraTing PHotonics innovAtion for SME's: a one STop-shop-incubator

1 November 2017 - 31 October 2021

ACTPHAST 4.0 is a unique European one-stop-shop innovation incubator in photonics, which is being funded by the European Commission under the Horizon2020 Framework , and which combines the state-of-the-art expertise and technologies of 24 leading research institutes in photonics from across 13 European countries, to make them available to any European company – with a particular emphasis on SMEs – for the purposes of solving critical innovation challenges in the companies' new product development activities through innovation projects. The costs of the photonics innovation projects are subsidized by ACTPHAST 4.0 on the basis that they will have a substantial impact on the business growth of the supported companies, and the overall digitization of European industry.

https://www.actphast.eu/en

BEYOND4.0

Technological inequality – understanding the relation between recent technological innovations and social inequalities

1 January 2019 - 31 December 2022

BEYOND4.0 focuses on the key developments and the concepts needed to deliver an inclusive Europe by examining the impact of new technologies on the future of jobs, business models and welfare in the EU. The main premise is that technology is not deterministic but socially negotiated by key social actors at various levels: firms, industry, regional, national and EU. The project's ambition is to generate new scientific evidence and policy development around these issues and contribute to the EC's Europe 2020 strategy promoting smart, sustainable and inclusive growth by responding to the challenges and maximising the opportunities of digitalisation in Europe for the next decade and beyond. In meeting the need for integrative research, the main objectives of BEYOND4.0 are about to: 1) Provide systematic insight into technological transformation and its disruptiveness; 2) Provide insight into relevant company strategies as well as the role of social dialogue with key actors; 3) Examine the impact of this technological transformation using new, innovative approaches to analyse and predict its impact; 4) Identify the range of policy options to deal with the consequences of technological transformation; and, 5) Identify the range of social investment and tools towards an inclusive technological transformation.

https://beyond4-0.eu/

BOOST 4.0

Big Data Value Spaces for COmpetitiveness of European COnnected Smart FacTories 4.0

1 January 2018 - 31 December 2020

EFFRA recommendations on Factories 4.0 and Beyond (Sept 2016) clearly stated the need for development of large scale experimentation and demonstration of data-driven "connected smart" Factories 4.0, to retain European manufacturing competitiveness. BOOST 4.0 will address this need, by demonstrating in a measurable and replicable way, an open standardised and transformative shared data-driven Factory 4.0 model through 10 lighthouse factories. BOOST 4.0 will also demonstrate how European industry can build unique strategies and competitive advantages through big data across all phases of product and process lifecycle (engineering, planning, operation, production and after-market services) building upon the connected smart Factory 4.0 model to meet the Industry 4.0 challenges (lot size one distributed manufacturing, operation of zero defect processes & products, zero break down

sustainable operations, agile customer-driven manufacturing value network management and human centred manufacturing).

https://boost40.eu/

CoLLaboratE

Co-production Cell performing Human-Robot Collaborative Assembly

1 October 2018- 30 September 2021

CoLLaboratE will revolutionize the way industrial robots learn to cooperate with human workers for performing new manufacturing tasks, with a special focus on the challenging area of assembly operations. The envisioned system for collaborative assembly will be capable of allocating human and robotic resources for executing the production plan sharing the tasks according to the capabilities of the available actors. The CoLLaboratE project will build upon state-of-the-art methods for teaching the robot assembly tasks using human demonstration, extending them to facilitate genuine human-robot collaboration. To this end, a framework for equipping the robots and AGV mobile platforms with basic collaboration skills, such as load sharing, human touch recognition and human intention detection, will also be developed, coupled with deep reinforcement learning algorithms for increasing adaptability. Special attention will be paid to providing effective safety strategies allowing the use of a fenceless approach within the production cell. As a result, closer collaboration will be achievable and efficient production plans making optimal use of the available resources will be designed and executed.

https://collaborate-project.eu/

DISCE

Developing Inclusive & Sustainable Creative Economies

1 January 2019 - 31 December 2021

The DISCE project is set to improve and enhance the growth, inclusivity and sustainability of the Cultural and Creative Industries (CCIs) in the EU. Overall, the ambitious objectives of DISCE are: i) to support the development patterns of CCIs within the EU through research on new business models and inclusive growth; and ii) to re-shape understanding of what 'inclusive and sustainable growth' consists of in this context, shifting the CCIs (and CCIs policy) towards strategic goals of 'cultural development' that encompass both GDP and human flourishing. DISCE is an interdisciplinary, mixed-methods project that builds on three pillars: 1) Robust statistical analyses, mapping and development of new statistical indices for a better understanding of the inclusive and sustainable development of CCIs in Europe; 2) In-depth case studies developing rich findings and nuanced understanding of the Creative Economies and their ecologies; and, 3) Active co-creation and interaction with stakeholders to validate the policy relevance of the project, as well as the policy outcomes and achieve long-term impact and sustainability. DISCE serves all the beneficiaries relevant research results, which will help and support stakeholders to fill existing information gaps in daily policy and decision-making processes. The project will bring out recommendations for actors how to react, function and decide in specific situations to promote inclusive growth and progress on the sustainable development in the field of CCIs.

https://disce.eu/

DRALOD

Renewables-based drying technology for cost-effective valorisation of waste from the food processing industry

1 August 2018 - 31 December 2020

DRALOD is addressed to waste management enterprises serving the food-processing sector since most enterprises in the food sector outsource their waste management operations to specialized subcontractors. It is also addressed to the Food Manufacturing and processing sector, for valorisation as functional food additives perfectly aligned with the food enterprises core business. DRALOD uses

renewables only, to allow valorisation of plant-origin waste into highly valuable functional ingredients as demanded by the nutraceutical and pharmaceutical industry.

https://dralod.com/

EMB3Rs

User-driven Energy-Matching & Business prospection tool for industrial Excess heat/cold Reduction, Recovery and Redistribution

1 September 2019 - 31 August 2022

The EU-funded EMB3Rs project develops an open-source platform to support a bottom-up characterisation of energy supply and demand. It simulates the cost benefits of alternative options for the recovery and use of excess heat for a wide range of industries. By translating industrial excess heat into savings and increased overall system efficiency, EMB3Rs allows the energy-intensive industries to improve their competitiveness and contribute to the EU climate change goals.

Users, like industries that produce waste heat, will provide the essential parameters, such as their location and the available excess thermal energy. The EMB3Rs platform will then autonomously and intuitively assess the feasibility of new business scenarios and identify the technical solutions. End users such as energy communities will be able to determine the costs and benefits of industrial excess heat and cold utilisation routes and define the requirements for implementing the most promising solutions. Matching excess heat providers with end-users will enable win-win partnerships and reduce CO2 emissions. Seven case-studies will deliver data to create and validate the platform including the re-use of excess heat from a cement producer and a metal casting company, an industrial park and local supermarkets in district heating networks.

https://www.emb3rs.eu/

EMPOWER

European platforM to PromOte Wellbeing and HEalth in the workplace

1 January 2020 - 31 December 2023

EMPOWER is a multidisciplinary research and innovation effort aiming to developing, implementing, evaluating and disseminating the effectiveness and cost-effectiveness of a modular eHealth intervention platform to promote health and well-being, reduce psychological distress, prevent common mental health problems and reduce their impact in the workplace. In collaboration with stakeholders, we will adapt existing effective interventions focused on different components (awareness and stigma, workplace conditions and psychosocial factors, stress, common mental health symptoms, early detection, comorbidity, lifestyle, and return to work) to create a combined online modular platform feasible in various workplace settings by culturally and contextually adapting it.

Through scaling-up pre-existing effective and cost-effective interventions, EMPOWER is aimed at addressing the overarching challenges from different perspectives, including individual level (e.g., addressing stigma, mental health, well-being and lifestyles, taking into account legal, cultural and gender issues) and organizational level. The main outcomes effort will help employees, employers and policymakers in decision processes of new legal and contractual framework at EU and national level covering the new economy landscape.

https://empower-project.eu/

EVRYON

Evolving Morphologies for Human Robot Symbiotic Interaction

1 February 2009 - 31 May 2012

The goal of the EVRYON project was to develop a novel approach for the design of Wearable Robots (WRs), e.g. exoskeletons, prostheses and other wearable mechatronic devices that can be used for a variety of applications, such as rehabilitation, personal assistance, human augmentation and more.

Ideal solutions for such systems should aim at the optimal trade-off between performance, i.e. the level of assistance to be provided to the end-user, and some critical requirements, such as minimal weight and dimensions, low energy consumption and several other factors that can significantly affect the effectiveness and efficiency of WRs.

https://www.biorobotics.it/

FACTS4WORKERS

FACTorieS for WORKERS

1 December 2014- 30 November 2018

Human workforce in factories on all levels from shop floor to management should be strengthened in their flexibility. The project aims to increase problem-solving and innovation skills, cognitive job satisfaction and worker productivity, finally attracting more young talents to factory work. The human resource is the most skilled, flexible and productive asset of any production system.

https://facts4workers.eu/

FIT4FoF

Making our Workforce Fit for the Factory of the Future

1 October 2018 - 30 September 2021

The project aims at addressing workers' needs, analysing technology trends across 6 industrial areas of robotics, additive manufacturing, mechatronics/machine automation, data analytics, cybersecurity and human machine interaction, to define new job profiles, which will inform education and training requirements.

https://www.fit4fof.eu/

FourByThree

Highly customizable robotic solutions for effective and safe human robot collaboration in manufacturing applications

1 December 2014 - 30 November 2017

The project proposes the development of a new generation of modular industrial robotic solutions that are suitable for efficient task execution in collaboration with humans in a safe way and are easy to use and program by the factory workers.

http://fourbythree.eu/

GROWINPRO

Growth Welfare Innovation Productivity

1 January 2019 - 31 December 2021

GROWINPRO aims to provide a detailed analysis of the causes of the anaemic growth performance observed in Europe during the last decades and, in particular, after the Great Recession. On the grounds of such analysis, GROWINPRO delivers a set of policy solutions aimed at restoring sustained and inclusive economic growth with particular attention both on the demand and on the supply-side. GROWINPRO brings together researchers from eleven international academic institutions and three national statistical offices. The project has two main ambitions. From a diagnostic perspective, it proposes to link three levels of analysis – macro, meso and micro – empirically dissecting the sources of productivity slowdown and the relations between productivity, demand and growth. From a normative perspective, it aims at providing a novel, integrated set of policies to push Europe towards a balanced, innovation-fuelled and inclusive trajectory of development, also addressing major societal challenges, such as climate change, ageing population, and robotisation.

http://www.growinpro.eu/

HR-Recycler

Hybrid Human-Robot RECYcling plant for electriCal and eLEctRonic equipment

1 December 2018 - 30 November 2022

The technological advances that have been achieved over the past decades have led to a tremendous increase of both the types and the total amount of electrical and electronic equipment that is manufactured. Despite the importance of Waste Electrical and Electronic Equipment (WEEE) management, the issue of the WEEE recycling has not received that increased industrial attention.

https://www.hr-recycler.eu/

HUMAN

HUman MANufacturing

1 October 2016 - 30 September 2019

The project aimed to define and demonstrate workplaces where automation and human workers operate in harmony to improve the productivity, quality, performance of the factory as well as the worker satisfaction and safety.

http://humanmanufacturing.eu/

H-WORK

Multilevel Interventions to Promote Mental Health in SMEs and Public Workplaces

1 January 2020 - 30 June 2023

The general aim of the H-WORK project is to design, implement and validate effective multi-level assessment and intervention toolkits providing new products and services to promote mental health in public organisations and SMEs, evaluate individual and organisational outcomes of the adopted measures, and provide recommendations for employers, occupational health professionals and policymakers. The project aims to design, implement and exploit an integrated toolkit (H-TOOLS) which will provide managers and CEOs to effectively assess organisational psychosocial risk (HAT), implement the most appropriate interventions (HIT), and evaluate individual and organisational outcomes of the adopted measures (HET).

https://h-work.eu/

INCUBIS

An Industrial Symbiosis Incubator for Maximizing Waste Heat/Cold Efficiency in Industrial Parks and Districts

1 May 2020 – 30 April 2023

INCUBIS delivers an ambitious Incubator programme to help stakeholders overcome these challenges and implement Energy Symbiosis projects at the local and regional level. Energy Symbiosis (the selling and buying of excess energy) can lead to energy efficiency improvements, CO2 and cost reductions, new revenue, jobs and local investments. Five Energy Symbiosis Incubators will be launched, supporting existing or novel exchanges of waste heat & cold within industrial areas in Spain (Barcelona Province), France (Dunkirk), Norway (Agder Region), United Kingdom (Humber Region), and Germany (Brunsbuttel). These Incubators will provide to local actors all the tools, expertise and training required to secure seed funding for the projects, find solutions to problems, intermediate in negotiations, and see the energy symbiosis projects through to implementation. The Incubator´s tools and services will become available across European territories through the Virtual Platform, while the methods followed could be integrated in existing reference documents and standards like the EU´s Energy Efficiency BAT and EMAS.

http://www.incub-is.eu/

INSTINCT

Inhibiting Stress in the Construction Industry

3 January 2017 - 5 July 2019

An intervention to curb the advent of stress is proposed: 'Stress-Blocker' (Streblo). Cognitive psychology identifies five main personalities (Big-5): extraversion, agreeableness, conscientiousness, neuroticism and openness. How these Big-5 differ in the dynamics of stress are unexplored, particularly in the field of construction where stress is also prevalent. Behavioural science explains differences in the coping abilities of people. Thus Part A of the study is an empirical investigation of the impacts of stressors on the Big-5 and their different coping behaviours. Data from at least 1500 UK construction personnel was collected using a questionnaire, and analysed using multiple inferential statistical techniques: hierarchical regression, factor analysis and sequential equation modelling. The findings informed Part B: the development of Streblo, a cloud-based IT tool for the effective recognition and deterrence of stress. Streblo is a simple, quick-to-use and free IT app which will be accessible on mobile devices, PCs and laptops. Streblo exploits advanced technologies to prevent stress in different construction job profiles as well as other sectors of the economy.

http://www.instincproject.eu

KYKLOS 4.0

An Advanced Circular and Agile Manufacturing Ecosystem based on rapid reconfigurable manufacturing process and individualized consumer preferences

1 January 2020 - 31 December 2023

In circular manufacturing, manufacturers find ways to eliminate waste by reusing and recycling materials and goods. The EU-funded KYKLOS 4.0 project aims to show how cyber-physical systems, product life-cycle management, life-cycle assessment, augmented reality, and artificial intelligence technologies and methods are able to transform circular manufacturing. It will achieve this through seven large-scale pilot projects that will demonstrate improvements in operational efficiency and deliver solutions for resource reuse. It will further ensure the scalability of novel circular manufacturing technologies, engage over 100 European industry actors, transfer know-how and mobilise additional sector investments. The project's advanced ecosystem can reshape factory processes and services so as to benefit manufacturing throughout Europe.

https://kyklos40project.eu/

MAKERS

Smart Manufacturing for EU Growth and Prosperity

1 January 2016 - 31 December 2018

The project's objectives are to study the opportunities and barriers for the EU to lead a manufacturing renaissance that upgrades existing manufacturing competences and develops new technological capabilities across EU regions to support regional industrial resilience for more distributed and sustainable socio-economic growth and prosperity. The novelties of the project are:

1. A conceptualization of Industry 4.0+

2. define firms' and industries' new business model with servitisation

3. definition of reshoring more clearly and in an interdisciplinary way.

4. understand how small firms and clusters of firms can upgrade to take on I4.0 model

5. understanding the relocalisation of supply chains and that continental based value chains are likely to emerge."

http://www.makers-rise.org/

MindBot

Mental Health promotion of cobot Workers in Industry 4.0

1 January 2020 - 31 December 2022

MindBot aims at identifying methods and implementing solutions for promoting good mental health in the emerging industry 4.0 within the specific context of manufacturing small and medium-sized enterprises (SMEs) that adopt collaborative robots (cobots) in their production lines. MindBot idea is to design workplaces where level of challenge and difficulty of job tasks are matched with the workers' abilities and skills, in order to support motivation and engagement of workers interacting with cobots in a flexible and personalized way. This will facilitate an active and positive attitude of the worker that promotes good mental health and prevents negative experiences of anxiety or boredom and apathy that eventually lead to mental illnesses.

http://www.mindbot.eu

PAPERCHAIN

New market niches for the Pulp and Paper Industry waste based on circular economy approaches

1 June 2017 - 31 May 2021

PAPERCHAIN project brings in an industrial symbiosis model cantered in the use of different waste streams generated by the European Pulp and Paper Industry, as valuable feedstock for three resource hungry industrial sectors: construction sector, mining sector and the chemical industry. Different waste streams are produced, as a result of the manufacturing processes of the Pulp and Paper industry to produce paper, board and other cellulose-based products. PAPERCHAIN aims to unlock the potential of a resource efficient model based on industrial symbiosis, which will demonstrate the potential of the major non-hazardous waste streams generated by the PPI (i.e. green liquor dregs, grits, lime mud, paper sludge fly ash, deinking paper and fibre sludge) as valuable secondary raw materials.

https://www.paperchain.eu/

PHABLABS 4.0

PHotonics enhanced fAB LABS supporting the next revolution in digitalization

1 December 2016 - 31 May 2019

PHABLABS 4.0 aims to integrate photonics in a durable way into the rapidly expanding ecosystem of European Fab Labs and Makerslabs, resulting in a larger and better skilled photonics workforce with superior innovation capacity to achieve a lasting, positive impact on the next revolution in digitization. Combining the forces of top experts from 13 European photonics institutes and STEM-oriented organizations with the Fab Lab stakeholders, PHABLABS 4.0 will devise and deliver a comprehensive suite of 33 Photonics Workshops, 11 Photonics Challenger projects and Photonics Toolkits to enhance Fab Labs and Makerslab with photonics activities aimed at 3 specific target groups: young minds (age 10-14), students (age 15-18) and young professionals and technicians (age 18+). These activities will be extensively tested in 14 existing Fab Labs with the purpose of rolling them out to the entire growing network of European Fab Labs as a proven model at the end of the project. They will stimulate hands-on design, fabrication, experiments, and the building of innovative systems with photonics, and in this way nurture the 21st Century skills of the participants.

The ultimate impact of PHABLABS 4.0 will be seen in the emergence of a much larger and better trained workforce with 21st Century skills capable of translating the potential of photonics as a key enabling technology into tangible products for the benefit of society.

http://phablabs.eu/

PLUS

Platform Labour in Urban Spaces: Fairness, Welfare, Development

1 January 2019 - 31 December 2021

PLUS aims to address the main features of the platform economy's impact on work, welfare and social protection through a ground-breaking trans-urban approach. The project focuses on this specific and meaningful segment of the so-called Industry 4.0 revolution because it summarizes all main opportunities and challenges for the future of work, social innovation and a fair growth. The project's main goal is to sketch a picture of such transformations proposing an innovative approach that identifies urban dimension as fundamental stage for measuring and evaluating social and economic impact of these innovations and for building policies that are more inclusive. In this way, PLUS attempts to fill a gap both in understanding and tackling challenges posed by digitization of labour. The project valorises the role that different stakeholders could play in promoting and balancing such transformations. A bottom-up approach and techniques of co-creation will be adopted to produce outputs directly affecting policy-making, market and welfare: innovative typologies of contracts, a Chart for digital workers' rights, taxation and regulation guidelines, social enterprise pilots and educational patterns for new skills.

https://project-plus.eu/

Productive4.0

Electronics and ICT as enabler for digital industry and optimized supply chain management covering the entire product lifecycle

1 May 2017 - 30 June 2020

The main objective of Productive4.0 is to achieve improvement of digitising the European industry by electronics and ICT. Ultimately, the project aims at suitability for everyday application across all industrial sectors – up to TRL8. It addresses various industrial domains with one single approach of digitalisation.

What makes the project unique is the holistic system approach of consistently focusing on the three main pillars: digital automation, supply chain networks and product lifecycle management, all of which interact and influence each other.

This is part of the new concept of introducing seamless automation and network solutions as well as enhancing the transparency of data, their consistence and overall efficiency.

https://productive40.eu/

RICAIP

Research and Innovation Centre on Advanced Industrial Production

1 September 2017 - 31 August 2018

The project's ambition is to establish the RICAIP Centre as the independent international hub for Industry 4.0 which will bring new, smart, safe, and sophisticated solutions to distributed (multi-site) industrial production of the future. The four founding partners of the RICAIP Centre will jointly build up a unique, virtually connected, experimental facility (the RICAIP Testbed) that would enable excellent research and cooperation of academia and industry in the field of cyber-physical systems, artificial intelligence, production systems, and other relevant topics of Industry 4.0 Initiatives. The RICAIP Testbed will be based on the current experimental facilities of the partnering organizations in Prague, Brno and Saarbrücken, that need to be upgraded to enable their interconnection and joint operation. The long-term objectives of the RICAIP Centre will be implemented by a virtual "joint venture" of the RICAIP Project partners, at the Czech side benefiting from established infrastructure and organizational set up of interdisciplinary university research institutes (both CVUT-CIIRC and BUT-CEITEC).

http://ricaip.eu/

ROSSINI

Robot enhanced Sensing, Intelligence and actuation to improve job quality in manufacturing

1 October 2018 - 31 March 2022

The project aims to design, develop and demonstrate a modular and scalable platform for the integration of human-centred robotic technologies in industrial production environments. This will be achieved both by developing innovative technological components and methodologies in all fields related to collaborative robotics (sensing, control, actuation, human aspects, risk assessment methodology), and by integrating all such components in an open platform ensuring quick ramp-up and easy integration.

https://www.rossini-project.com

SAFETY 4.0

Launching working environment safety systems based on UWB connectivity aimed at the 4.0 INDUSTRY

1 August 2017 - 30 November 2017

The 4.0 Industry is an environment where there are more and more vehicles without drivers, robots and machines it is necessary that people can share the place in a safe and healthy way. Therefore, the 4.0 Industry needs more security, which can be provided by our innovative approach.

Today, the main technological challenge our customers face is to design a protection and positioning system that is precise, reliable, adaptable, low-cost and low intrusive. CLAITEC is driven to answer these needs, overcoming technical limitations that RFID systems has After 3 years of development, we characterised our own IR-Ultra-Wide Band technology including distance calculation algorithms to use as the basis of the products in development.

At CLAITEC we have identified process constraints for the prototype industrialisation. The feasibility study carried addressed a financial plan, foreseeing the all costs and investments associated with commercialising the product and its expected revenues forecasted at 5-years. The study included the assessment of legal aspects such as i) product certification according to European/Foreign legislation, and ii) patenting strategy consolidation. All these activities converged into a detailed business plan that first, confirmed our hypotheses about business potential, and that most importantly paved the way towards the commercialization of SAFETY 4.0.

https://claitec.com/en/

SAM

Sector Skills Strategy in Additive Manufacturing

The project aims to tackle the current European need for developing an effective system to identify and anticipate the right skills for the Additive Manufacturing (AM) sector demands in response to the increasing labour market needs, thus, contributing for the smart, sustainable and inclusive growth of the AM sector.

www.skills4am.eu

SPIRE-SAIS

Skills Alliance for Industrial Symbiosis (SAIS) – A Cross-sectoral Blueprint for a Sustainable Process Industry (SPIRE)

1 January 2020 - 31 December 2023

The project 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.

https://www.spire2030.eu/sais

SO WHAT

Supporting new Opportunities for Waste Heat And cold valorisation Towards EU decarbonisation

1 June 2019 - 31 May 2022

SO WHAT develops and demonstrates an integrated software which will support industries and energy utilities in selecting, simulating and comparing alternative Waste Heat and Waste Cold (WH/C) exploitation technologies that could cost-effectively balance the local forecasted H&C demand also via renewable energy sources (RES) integration. The SO WHAT integrated tool will be designed to support industries, and energy utilities in: 1) Auditing the industrial process to understand where WH/WC could be valorised; 2) mapping the potential of locally available RES sources to be integrated with WH/WC potential; 3) mapping the local forecasted demand for heating and cooling; 4) define and simulate alternative cost-effective scenarios based on WH/WC technologies also leveraging RES introduction; 5) evaluate the impacts (in terms of energetic, economic and environmental KPIs) that the adoption of the new scenarios will generate against the current situation (i.e., baseline) both at industrial and local level; 6) promoting innovative contractual arrangements and financing models to guarantee economically viable solutions and less risky investments. To do so, SO WHAT will capitalize already existing tool and knowledge from previous research experiences (REEMAIN, PLANHEAT, REUSEHEAT, CELSIUS…) and the expertise of 11 industrial validation sites from different REII/ non-REII sectors (petrochemical, chemical, metallurgic, food etc.) that will be involved in the project to validate the tool and provide relevant insights for its development.

https://sowhatproject.eu/

SYMBIO-TIC

Symbiotic Human-Robot Collaborative Assembly: Technologies, Innovations and Competitiveness

1 April 2015 - 31 March 2019

The project addresses these important issues towards a safe, dynamic, intuitive and cost-effective working environment: immersive and symbiotic collaboration between human workers and robots can improve this situation and bring significant benefits to robot-reluctant industries where current tasks and processes are perceived to be too complex to be automated. The benefits include lower costs, increased safety, better working conditions and higher profitability through improved adaptability, flexibility, performance and seamless integration.

www.symbio-tic.eu/

SYMPLEXITY

Symbiotic Human-Robot Solutions for Complex Surface Finishing Operations

1 January 2015 - 31 December 2018

SYMPLEXITY is closing the gap between the highly automated production processes and the manual polishing of complex geometries by creating a safe environment of collaboration between the robot and the human worker.

https://www.symplexity.eu/

TECHNEQUALITY

Inclusive Futures for Europe BEYOND the impacts of Industry 4.0 and Digital Disruption

1 January 2019 - 31 December 2021

The main goal of the project is to improve the understanding of the relation between current technological innovations and social inequalities, by:

- Providing better predictions of the consequences of technological innovations for the European labour markets; Understanding which skills are crucial for productive growth and how skill differences can lead to (technology-driven) inequalities in income, education, wellbeing and health;
- Researching how education (lower, higher and vocational) can prepare today's children and workers for tomorrow's labour market;
- Assessing how governments can avoid large-scale poverty caused by technological unemployment;
- Investigating what the consequences of automation (and unemployment) are for income tax and public finances;
- Comparing the current technological boom with earlier technological revolutions to draw lessons learned.

https://technequality-project.eu/

ANNEX II
EARLY ACADEMIC WRITING ON INDUSTRY 5.0

Industry 5.0 is often proposed as the solution we will need to pursue prosperity, as a sustainable manner to increase productivity while not removing human workers[xxxvii] from the realm of manufacturing industry. We could say that fits into the overall framework of various revisionist proposals for a "new capitalism" correcting its excesses, which could continue to thrive only if fair, inclusive, and sustainable. Similar ideas have been around for decades. Neo-capitalism was a social and economic ideology that arose already in the second half of the 20th century and in which the capitalist doctrine became deeper, based on the technological revolution and internationalisation of markets. Recently, several business leaders have been expressing concerns[xxxviii] about the state of capitalism and agree that a major overhaul is needed in order to serve society better. They also believe that capitalism "would eventually benefit from some tweaking to better serve society".

Several analyses of Industry 5.0 focus on increased collaboration between humans and smart systems. According to Atwell[xxxix], marrying the two will merge the high-speed accuracy of industrial automation with the cognitive, critical thinking skills of humans. More particularly, he proposes to leave the monotonous, repetitive tasks to the mechanical and open up the creative side to the biological. This would allow staff to take on more responsibility, and increased supervision of systems to elevate the quality of production across the board. Already in 2016, the consulting firm Accenture conducted a survey[xl] with 512 manufacturing executives from all over the globe, revealing that some of them envisaged an advanced collaborative production line between humans and robots in their plants in order to increase the productivity, the customization, the sustainability, as well as the operational efficiency. In February 2020, DG Research and Innovation published a report[xli] on the potential of collaborative robots for economy and society while embracing European values. This report offers a vision on collaborative industrial robotics based on ten assessment criteria, with seven particular recommendations as a contribution to the preparation of the strategic plan of Horizon Europe.

A complementary vision describes Industry 5.0 as faster, more scalable and more people-centred, through the use of new technologies[xlii]. This is proposed to happen by advanced human-machine interfaces, by improved integration, better automation through robots, paired with the power and creativity of human brains[xliii].

Ostergaard (Universal Robots' Chief Technology Officer) points out that the next Industrial Revolution will be necessary to meet consumers' high-demand for individualized products[xliv]. He is inspired by the car industry and underpins his statement with an article from Bloomberg, describing how a German car manufacturer is already giving more space to humans in its production facilities to increase customization, bringing important value for modern consumers.

Another complementary view on Industry 5.0 emphasises its potential economic, societal and ecologic effects, and its potential for sustainability as a systematic

prevention of pollution and waste, focused on industrial upcycling[xlv]. Environmental awareness and responsibility are seen as giving a competitive edge, due to support from governments and international organizations, as well as a growing customer base supporting environmentally friendly business models.

Paschek, Mocan and Draghici recently presented a paper[xlvi] analysing and evaluating the business impact of the next Industrial Revolution (using the term Industry 5.0). They claim that success will come to industries that are more innovative and responsive to market changes and that Industry 5.0 accentuates a clear change from mass automation to the process of enhancing the capabilities of human workers. This raises future questions, such as: Which skills need to be developed? What kind of rules have to be defined? Which impact may AI have? Which conflicts may arise between humans and AI?

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Industry 5.0 complements the existing Industry 4.0 paradigm by highlighting research and innovation as drivers for a transition to a sustainable, human-centric and resilient European industry. It moves focus from shareholder to stakeholder value, with benefits for all concerned. Industry 5.0 attempts to capture the value of new technologies, providing prosperity beyond jobs and growth, while respecting planetary boundaries, and placing the wellbeing of the industry worker at the centre of the production process.

Research and Innovation policy

Publications Office
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